

# Proceedings of 16th Students' Science Conference "Science is our universe"

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**Students'  
Science  
Conference**



Prace Studentów  
Politechniki Wrocławskiej

**24**

Seria:  
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**24**

## **Proceedings of 16<sup>th</sup> Students' Science Conference „Science is Our Universe”**

**Edited by Wojciech Wodo and Adam Sulich**

Boguszów-Gorce, 19–22 September 2018



Oficyna Wydawnicza Politechniki Wrocławskiej · Wrocław 2018

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## FOREWORD

Ladies and gentlemen, dear readers,

It is a great honor to have the opportunity to address you at the 16th Students' Science Conference 2018 (SSC 2018) held and organized annually by the Wrocław University of Science and Technology. Each year the conference is unique due to its participants – young scientists who have just begun their adventure in science and want to popularize their research and discoveries. The conference creates a platform to support young scientists and to give them an opportunity to boost their research careers and gain scientific excellence. This statement is not only a great vision but it has also been implemented because of the double-blind review and proofreading of papers selected to be presented during the conference. These are the criteria to publish scientific articles in the hereby proceedings.

The 16th Students' Science Conference 2018, just like the previous editions, was a place for exchange of international knowledge and experiences between participants from five countries who actively took part in the event. The idea stays always the same and is a result of the assumption that the young generation is certainly one of the resources on which the strategy of building a modern society can rely. It is almost certain that hard-working students and young scientists are a group on whom in the future the development of the country and its regions will depend. This idea is accompanied by an intuition that the young generation of scientists is undergoing a special period, experiencing numerous civilization changes.

The Students' Science Conference 2018 proceedings entitled "Science is Our Universe" is divided into chapters which correspond to the division of the SSC 2018 participants in their sessions and thematic groups as follow:

1. Architecture and Civil Engineering, Management and Law,
2. Biotechnology and Bioengineering,
3. Computer Science, Electronics and Telecommunications,
4. Mechanics and Materials Engineering.

That is why I would like to thank everyone involved for organizing and participating in this event which will surely help young people gain a good start position for future scientists and Ph.D. candidates and contribute to the science. Popularization of science is urgently needed not only outside the academia, to inform society about scientific progress and to invite a new generation of students to start higher education, but also inside the universities to build a strong community and multidisciplinary teams. So that we could truly say that science is our universe!

Adam Sulich  
*Member of Scientific Committee and Editor*



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**Students'  
Science  
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**I**

**ARCHITECTURE, CONSTRUCTION,  
MANAGEMENT AND LAW**

*Key words:*  
*architecture, paper, building elements, experimental building*

Agata JASIOŁEK<sup>1</sup>

## **EXPERIMENTAL USE OF PAPER AS A BUILDING MATERIAL: THE EXAMPLE OF THE ZBIGNIEW HERBERT EXHIBITION PAVILION\***

The topic of this article is experimental use of paper as a building material as exemplified by the Zbigniew Herbert Exhibition Pavilion, which has been designed and built by a group of 18 students at the course ProtoLAB at the Faculty of Architecture at Wrocław University of Science and Technology. The project focused on constructing pavilion components out of paper tubes and corrugated cardboard, which have been proven to be a promising building material. Wood-based materials also have been used to strengthen the construction. The design of the Pavilion aims to use the geometry of the components to minimize the amount of metal used to connect elements. The article focuses on the problems of paper's strength, stability, connections, impregnation, and the way they have been solved during the building process.

### 1. INTRODUCTION

In spite of being an inherent part of everyday life, paper is not usually considered a valid building material because it is believed to be unstable, fragile and not resistant to weather conditions. Cardboard could nonetheless be successfully used in architecture, especially in temporary structures such as pavilions or emergency shelters. Paper is natural, ecological, affordable, light, and easy to operate without the need of using any heavy equipment. As paper architecture is still a very new and developing area, every new structure is an experiment that requires testing, prototyping and searching for better solutions.

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\* Paper awarded in the Best Paper Contest.

## 2. DESIGN GUIDELINES AND IDEAS

### 2.1. PROTOLAB PROJECT GUIDELINES

The Pavilion was designed and built during the ProtoLAB course at the Faculty of Architecture at Wrocław University of Science and Technology (WUST) by a group of 18 graduate students tutored by prof. Romuald Tarczewski and dr Jerzy Łątka. The aim of the project was to create an experimental ecological mobile exhibition pavilion made mostly of paper elements which can be easily built using simple methods and tools.

### 2.2. INITIAL IDEAS

The organic form of the Pavilion measuring 3 by 5 by 3 m was inspired by woodlands and divided into three sections: two bases on a plan of a curved triangle, slanted columns growing out of them resembling tree trunks, and the roof symbolizing tree crowns with fluttering paper strips as leaves. Geometrically the Pavilion was a cuboid with dimensions of 3 by 5 by 0.8 m and construction grid with a 0.5 m spacing cut into parts by a parametric surface and expanded to create the bases and roofing of the Pavilion (see Figure 1).

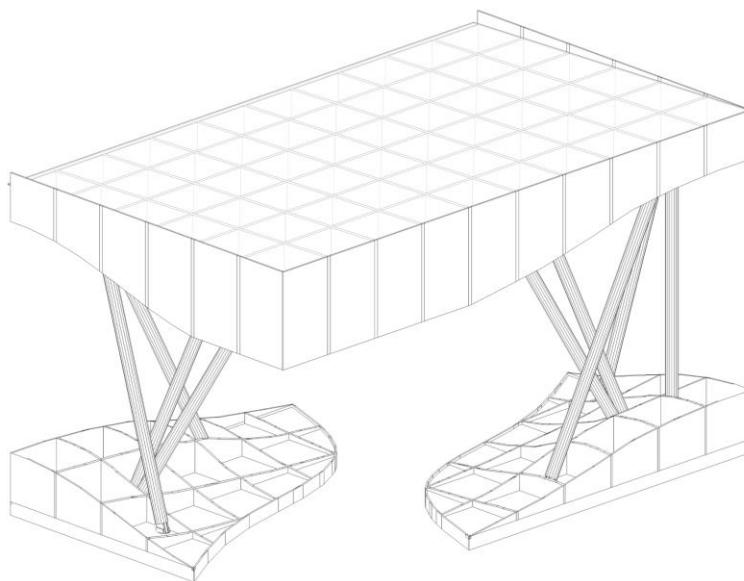


Figure 1. Axonometry of the structure drawn by Konrad Niedźwiedziński

Paper is generally an affordable and light material with limited strength and for this reason it is usually used to create massive constructions that provide better stability. The Pavilion was an attempt to create an openwork framing form that requires the minimum amount of building materials Bases and roofing were thus designed to be composed of flat perpendicular ribs with a 0.5 m spacing.

### 3. RESEARCH AND PROJECT DEVELOPMENT

#### 3.1. CHANGES IN THE FORM OF THE PAVILION

During the development of the project it became clear that 6 columns would not guarantee the stability of the structure, so their number has been increased to 10: 4 vertical and 6 slanted. To prevent the Pavilion from rain a polycarbonate roof was added. To emphasize the organic character of the structure a decision was made to plant grass and flowers in the empty boxes of the bases.

#### 3.2. CHOOSING AND TESTING MATERIALS

The most common types of paper materials used as building elements are paper tubes, corrugated cardboard and honeycomb panels which were all considered for the purposes of the project. After strength tests that had been carried out in the laboratory at the Faculty of Civil Engineering at WUST it became clear that the corrugated cardboard, in spite of being heavier than honeycomb panels, has a significantly higher compressive strength and will allow to design thinner ribs (see Table 1). As a result, a decision was made to construct the ribs out of 4 layers of 7 mm thick corrugated cardboard glued together with polyvinyl acetate glue. To strengthen the ends of the ribs and allow to fix the cover boards of the Pavilion roof elements of OSB were added, locally replacing two layers of the corrugated cardboard (see Figure 2).

Table 1. Selected results of compressive strength tests, dimensions of samples: 5x15x30 cm, squeezed length: 15 cm

Type of material	Force [N/cm <sup>2</sup> ]	Weight [g]
honeycomb 5 cm thick	12	60
honeycomb 2 x 2.5 cm thick	17	70
corrugated cardboard 7 x 0.7 cm thick	71	125

The floor and ribs of the base part of the pavilion were made of 18 mm thick OSB and impregnated plywood boards and set on wooden beams because they were meant to be a permanent element which can later serve as a detached flowerbed. It was also

crucial for the bases to have a substantial weight as the Pavilion has no foundations. Paper tubes with an external diameter of 12 cm and 1 cm thick walls were used to create columns. They were connected with the other parts of the pavilion by plywood tenons. The single vertical column structure was proven to withstand a compressive force of nearly 20,000 N.

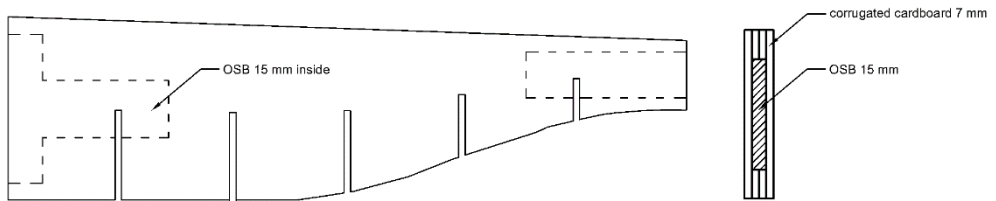


Figure 2. Ribs structure drawn by Agata Jasiołek

### 3.3. WORKING ON THE CONNECTIONS

The Pavilion aims to use the geometry of the specific components to minimize the amount of used metal connecting elements and consequently reduce weight and cost of the whole structure. All ribs were prepared to be easily assembled thanks to the cuts on their edges and as a result only small wooden blocks and screws were needed to stiffen the structure (see Figure 3). The bases of the columns were fixed to the wooden frame with 10 mm bolts working as hinges with metal plates. The roofing was attached to the columns by the means of plywood platforms.

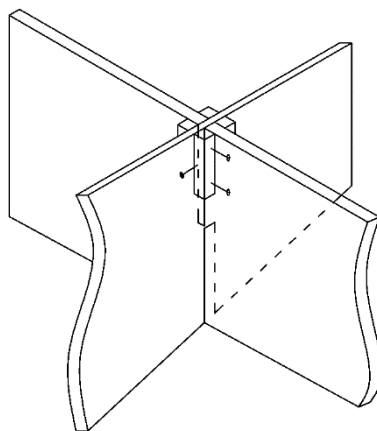


Figure 3. Connection of the ribs, drawn by Agata Jasiołek

### 3.4. IMPREGNATION OF PAPER COMPONENTS

Water and humidity are the biggest threat to paper based structures, but impregnated paper is usually not suitable for recycling. Having this fact in mind, a decision was made to impregnate only the columns, using the enamel based on polyurethane resins, silicone, and adhesive tape. The cardboard ribs were protected from water by polycarbonate roof at the top and the side casings made of impregnated thin plywood. Its edges were also covered with adhesive tape. A small gutter was installed to move water away from the pavilion.

## 4. CONSTRUCTION

### 4.1. TECHNOLOGY AND SCHEDULE OF WORKS

The construction works lasted for 22 days with approximately 10 people working every day. Only basic equipment and materials were used and all the components were prepared in a workshop out of cardboard, OSB and plywood panels.

The works began with preparation of the cardboard ribs, the most complicated and fragile parts of the whole structure. All the layers needed to be glued together with the OSB elements before the shape could be cut out. Later other elements were made and all the prefabricated components were transported from the workshop to the construction site.

The construction began with placing the two bases in the right positions, secondly the columns were mounted and the four main roofing ribs were attached to them. The remaining ribs and the polycarbonate and plywood casings were put into place afterwards. Finally the whole structure was stiffened and the finishing and the exhibition elements were mounted.

### 4.2. PROBLEMS AND CHANGES DURING THE CONSTRUCTION PROCESS

When the Pavilion was under construction, a heavy rain got the part of the ribs wet and broken even though they were covered with a waterproof tarp. The construction process had to be lengthened because of the accident and new ribs needed to be made. Due to the weakening of the ribs by putting the structure together and taking it back to pieces the decision was made to change the four main ribs from paper to 15 mm thick OSB covered with corrugated cardboard on both sides. Immediately after completion of the work it was raining continuously for 4 days and this time the Pavilion remained intact by water.



## 5. CONCLUSION

The Zbigniew Herbert Exhibition Pavilion, which was exposed in the courtyard of the WUST A-1 building, is another proof that paper elements can be successfully used as a building material, especially in temporary structures. The construction was simple enough to be assembled by unqualified people using only basic equipment. It is light, ecological, stable, and waterproof. The whole building process required considerable commitment and hard work. It was nonetheless a unique opportunity for students to acquire skills such as group working, project management, creativity in designing and use of materials.



Figure 4. Roof assembling, photo by J. Łątka



Figure 5. Under construction, photo by J. Łątka



Figure 6. The completed Pavilion in the courtyard of the WUST A-1 building, photo by J. Łątka

## ACKNOWLEDGEMENTS

The Pavilion was designed and build thanks to the efforts of tutors: Prof. Romuald Tarczewski and Dr Jerzy Łątka; and students: Szymon Ciupiński, Joanna Gronostajska, Eżbieta Kłeczek, Konrad Niedźwiedziński, Paweł Balcer, Agata Witczak, Patrycja Jędra, Damian Kuna, Wojciech Wiśniewski, Małgorzata Zielonka, Maciej Marszał, Malgorzata Denysiuk, Monika Smorağ, Yuri Zabuzhko, Agnieszka Owczarek, Justyna Kaźmierczak, Jolita Tamošiūnaitė and Agata Jasiołek. The realization of the whole project was possible thanks to the permission and cooperation with Wrocław University of Science and Technology, WUST Faculty of Architecture, students' organization Humanization of the Urban Environment, archi-tektura.eu, Czasoprzestrzeń, Centrum Przedsiębiorczości i Biznesu Dąbie, Wolne Meble, Accredited laboratories at the Faculty of Civil Engineering and the financial support of Schumacher Packaging, BART Packaging, Dekoral Professional and Grunwald24 printing shop.

## REFERENCES

- [1] CORREA C. *Designing with Paper Tubes*. Structural Engineering International, 2004
- [2] GOULD L.A., LUNA I., MIYAKE R., *Shigeru Ban: Paper in architecture*, Rizzoli International Publications, 2009
- [3] LATKA J. F. *Paper in architecture. Research by design, engineering and prototyping*, 2017
- [4] SCHONWALDER J., ROTS J. G., *Cardboard: An innovative construction material*. Sustainable Construction Materials and Technologies, 2007

*Key words:*  
*tribology, concrete wear, compression, superplasticizer*

Janis BEKERS<sup>1</sup>

## **TRIBOLOGICAL PROPERTIES OF CONCRETE DEPENDING ON CHEMICAL ADDITIVES**

Exposed concrete surfaces both as a constructive and as design elements are widely used in designed buildings. Concrete surface quality is one of the topical issues, both economically, and in terms of aesthetics and practicality. However, it has been observed that the technical documentation rarely indicates the quality of the concrete surface, but it should be assumed that it determines the longevity of the product. To determine the quality of a concrete surface, it is advisable to use not only the compression strength test, but also tribological tests. The study has practically conducted tribology and compression tests for two concrete mixtures - without and with a super-plasticizer to find out how concrete additives affect the tribological properties of the concrete material (wear depth and volume) using tribological equipment, or in this case pin-on-disk tribometer. However, the results obtained in this practical field should consider the fact that the preparation of concrete under laboratory conditions without chemical additives differs from its obtaining on the construction site.

### **1. INTRODUCTION**

#### **TRIBOLOGICAL PROPERTIES OF CONCRETE**

The physical and mechanical properties of concrete depend on the composition of the mixture, the type of binders and fillers, the application of concrete mortar, the conditions of hardening, and the age of concrete. [2] However, the tribological properties of concrete are not widely available. In one literature source, the concrete friction coefficient is set to be  $\mu = 0.4$  [3], another specifies that the concrete (concrete carriage) has a coefficient of friction of 0.1, but with a filler (worker), the concrete is

---

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0.5 [4-6]. Concrete wear depends on the size of the aggregates, shape, composition, hardness and moisture, as well as the microstructure of the concrete.

Considering the availability of many types of equipment and models, suitable devices for the testing of concrete wear should be considered when assessing suitability. Concrete is a fragile material, therefore, in order not to encounter problems with strengthening and testing samples, after reviewing the literature, studying and consulting with scientists, it should be concluded that the most appropriate would be a pin-on-disk test. The Swiss-made tribometer CSM Instruments SA, the TRB model (Fig. 1 a), is also available in RTU.

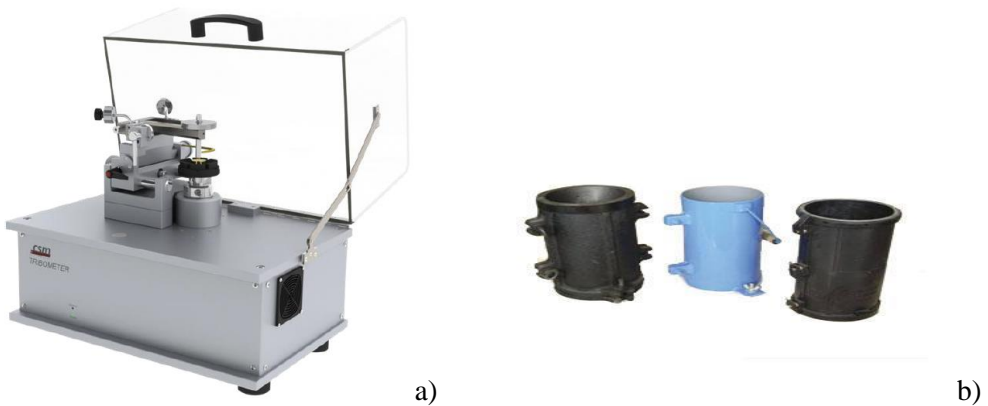


Fig. 1. Swiss tribometer, CSM Instruments SA, model TRB (a) and molds of concrete sample (b)

Due to the molds, the size of concrete samples needs to be known and determined before the concrete mix is made. The shape of standard concrete molds is the shape of a cylinder and a cube. Also, the tribological parameters of the inner part of the concrete will differ markedly from its upper and lower or used surface contact properties. From this, it can be concluded that the cured concrete surface abrasion tests are not objective, but a significant result would be achievable only from the top of the test samples, the untapped plane.

Since the hardness of the concrete is tested after 28 days, the abrasion test must also be carried out after a 28-day hardening of the concrete sample. A tribology test should use at least two types of material mixture, from each of five samples, a total of 10 pieces in order to obtain reliable test results.

The volume of wear is calculated using the formula [1]

$$V_{disk} = 2\pi R \left[ r^2 \sin^{-1} \left( \frac{d}{2r} \right) - \left( \frac{d}{4} \right) (4r^2 - d^2)^{\frac{1}{2}} \right] \quad (1)$$

where

R – radius of friction path;

d – depth of friction road;

r – pen end radius.

## 2. EXPERIMENTAL PART

For the preparation of concrete samples, concrete composition was determined. The aggregate uses 0/4 sand with the largest grain diameter of 0.4 mm. The water / cement ratio is 0.583 and 0.50. A 10 liter mixture is prepared which is arranged in appropriate molds. After hardening the samples for 28 days, their compressive strength is 33.2 MPa and 42.5 MPa. The proportions of the relevant samples are shown in Tables 1 and 2. The concrete friction coefficient  $\mu_{\text{mean}} = 0.65$  was determined with the computer program.

Table 1. Concrete composition for 1 m<sup>3</sup> and 10 liters

No	Composition	Unit	Quantity 1 m <sup>3</sup>	Quantity 10 liters
1	Cement CEM 42.5 I	kg	600	6.0
2	Sand 0/4	kg	1450	14.5
3	Water	l	350	3.5

The compression strength 33.2 MPa (M400).

Table 2. Concrete composition with superplasticizer for 1 m<sup>3</sup> and 10 liters

No	Composition	Unit	Quantity 1 m <sup>3</sup>	Quantity 10 liters
1	Cement CEM 42.5 I	kg	600	6.0
2	Sand 0/4	kg	1500	15.0
3	Superplasticizer VINMIX 1.8%	ml	7200	72.0
4	Water	l	300	3.0

The compression strength 42.5 MPa (M500).

To test the concrete sample on the pin-on-disk device, the dimensions of the sample must be of the following diameter: 20 mm or 30 mm; max thickness: 10 mm. From one concrete test cylinder, up to six samples of Ø30 mm tribology testing can be created, but only 5 samples are required. After unmolding, the bottom edge of the concrete cube must be cut with a concrete cutting equipment (for example, with a diamond drilling machine) to form a Ø30x100 mm (d \* h) cylinder. A tribometric test should use at least two cylinders, from each of three pairs, a total of 10 pieces to have reliable test results. Dimensions are selected based on the model limiting dimensions

and construction of the most popular templates currently available on construction sites so that no new formwork is needed.

### 3. RESULTS AND DISCUSSION

After tribological tests, the results are summarized in Tables 3 and 4. The first sample consisted of concrete without additional chemical additives, the second - with concrete chemical additives which reduce wear. Five tests were performed using 5 samples. The friction path radius and the point radius of the pin are of constant values depending on the devices used. For each sample, the depth of the friction road and the friction volume was measured in cubic millimeters determined by the formula (1).

Table 3. Concrete without the chemical additives test results and calculation of the depth of wear road and volume of the friction

Object	Symbol	test 1	test 2	test 3	test 4	test 5	Average
Wear road radius	R, mm	25	25	25	25	25	
Pin point radius	r, mm	0.5	0.5	0.5	0.5	0.5	
Wear depth	d, mm	0.73	0.77	0.71	0.69	0.72	0.724
Wear volume	V, mm <sup>3</sup>	12,537	15,211	11,363	10,286	11,938	12,267

Table 4. Concrete with the chemical additives test results and calculation of the depth of wear road and volume of the friction

Object	Symbol	test 1	test 2	test 3	test 4	test 5	Average
Wear road radius	R, mm	25	25	25	25	25	
Pin point radius	r, mm	0.5	0.5	0.5	0.5	0.5	
Wear depth	d, mm	0,64	0,61	0,62	0,63	0,60	0,620
Wear volume	V, mm <sup>3</sup>	7,957	6,778	7,155	7,548	6,417	7,171

In Figs. 2 and 3 graphically, the depth and volume of friction wear of these two samples can be compared. The depth of the friction wear road for the concrete sample ranged from 0.69–0.77 mm, but for concrete with chemical additives 0.60–0.64 mm the volumes are: 10,286–15,211 and 6,417–7,957 mm<sup>3</sup> respectively. From this we can conclude that chemical additives help to reduce the wear of concrete material.

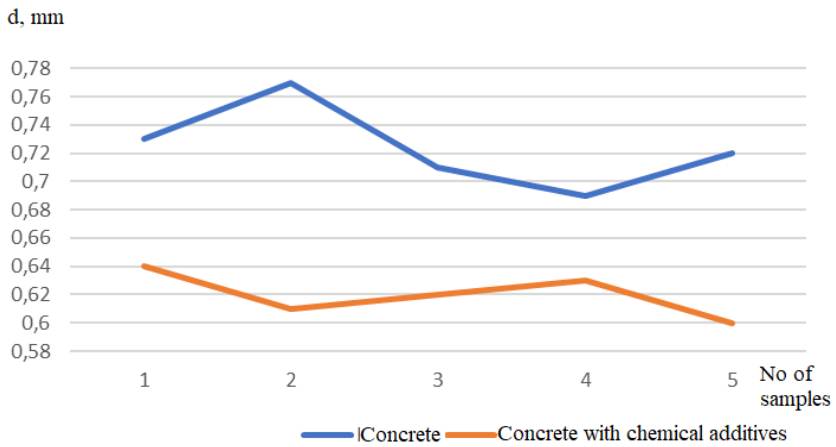


Fig. 2. Comparison of friction wear depth between 2 sample groups

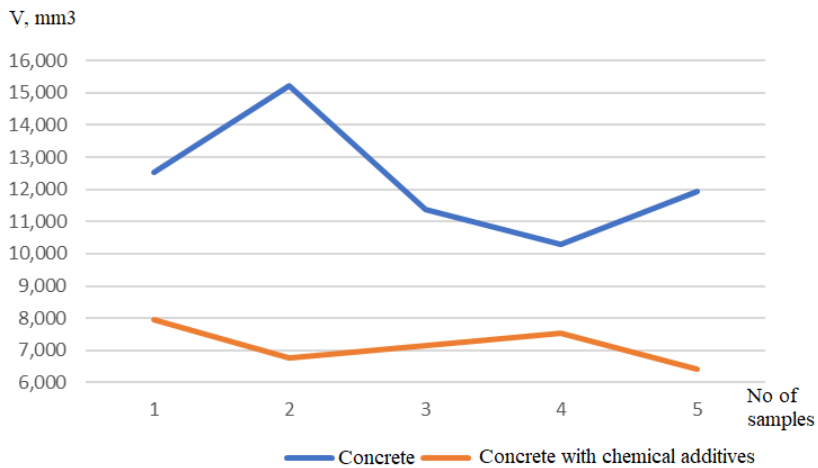


Fig. 3. Comparison of friction wear volume between 2 sample groups

Depending on the concrete composition (1.8% superplasticizer admixture), the depth of friction wear decreases by 14.4% and the friction wear volume decreases by 41.5%.

#### 4. CONCLUSION

The pin-on-disk test is one of the most relevant ways of determining the tribological properties of concrete material.

The wear resistance of a concrete material was explored experimentally. The mean value of the friction wear depth measured was 0.724 mm for concrete and 0.620 mm for superplasticizer concrete and the mean value for friction wear was 12.267 mm<sup>3</sup> and 7.171 mm<sup>3</sup> respectively.

Depending on the concrete composition (1.8% superplasticizer admixture), the depth of friction wear decreases by 14.4% and the friction wear volume decreases by 41.5%.

Preparation of concrete under laboratory conditions without chemical additives is different from obtaining it at a construction site. The concrete without chemical additives is dry, therefore it is difficult to be integrated into the concrete with the addition of a superplasticizer. Concrete with additives is significantly more resistant to wear. While constructing a building (floor) with an open concrete coating, it is imperative to connect the superplasticifier to the concrete, thus reducing the exploitation of resources.

#### REFERENCES

- [1] CSM Instruments SA. *Tribometer user manual R0.1.3a*
- [2] CHATTOPADHYAY R., *Surface Wear: Analysis, Treatment, and Prevention*, Pages 318, ASM International, Materials Park, OH USA, 06/2001
- [3] XIANGCHENG LUO, D. D. L. Chung, *Tribology of Graphite and Concrete, Studied by Contact Electrical Resistance Measurement During Cyclic Compression*, J. Tribol 123(4), 682-685 (Dec 06, 2000) (4 pages) doi:10.1115/1.1353588
- [4] SIDDIQUE R. *Wear Resistance of High-Volume Fly Ash Concrete*. Department of Civil Engineering Thapar University, Patiala (Punjab) - 147 004, India. 30 December 2010: [http://ijs.academicdirect.org/A17/021\\_036.htm](http://ijs.academicdirect.org/A17/021_036.htm)
- [5] DIN 50 324; *Testing of Friction and Wear*. I.2
- [6] ASTM G 99 - 95c; *Standard test method for wear testing with a Pin-on Disk apparatus*.



*Key words:*  
*privacy, right to privacy, personal data,*  
*information technologies, Internet, Social networks.*

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## **ENFORCEMENT OF THE RIGHT TO PRIVACY IN THE AGE OF DIGITALIZATION**

In the conditions of modern development of civilization and ubiquitous use of information technologies, access to information is expanding, objectively ensuring the exercise of the human right to freedom of information. Automated databases on information storage and accessibility capabilities surpass the functionality of conventional archives and libraries (computer disk drives are capable of storing volumes of information equivalent to large university libraries). Software procedures for comparing data from different files (procedures like data matching) enable the creation of "biographical portraits" of individuals using information collected from various databases (for example, the social network Facebook and the Google search system). Thus, access to databases of personal data of individuals increases the risk of intrusion into the privacy sphere and violation of the right to inviolability. IT greatly exacerbated legal problems related to the dilemma of disclosure of information or to protect privacy and the lack of traditional legal means to ensure privacy. Thus, in the era of IT, automated processing of personal data is the main source of threats to the inviolability of the privacy sphere.

### 1. INTRODUCTION

The privacy immunity principle formulated in the 19th century is acknowledged by the international privacy unity and is included in the Universal Declaration of Human Rights. Nowadays, the right to privacy is one of the fundamental human rights, important not only for self-assertion, but also for individual safety.

The right to privacy is the right to keep a domain around us, which includes all those things that are part of us, such as our body, home, thoughts, feelings, secrets and identity. The right to privacy enables us to choose which parts of this domain can be

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accessed by others, and to control the extent, manner and timing of the use of those parts we choose to disclose [1].

Modern discussions on the issue of the right to privacy have become more active with the development of information technologies. Therefore, it is important to take into account the rapid “evolution” of computers, mobile appliances, the Internet and their applications when considering the enforcement of the right to privacy.

The disclosure by Edward Snowden in June 2013 of the facts of personal data storage which was conducted by the National Security Agency in the USA [2] and publication by the international organization WikiLeaks in March 2017 of documents about the possible reception of information by the Central Intelligence Agency through the cameras and microphones of mobile appliances using IOS and Android systems, computers using Microsoft and Linux operating systems, as well as Samsung Smart TVs [3] demonstrates that the searching, collection and storage of data about telephone conversations, Internet-searches, electronic payments, etc. are introduced and used on a regular basis by these governmental institutions. Personal information about customers and potential customers is an important asset also for business companies.

Thus, the access to databases of individuals’ personal data increases the risk of intrusion into the privacy sphere and violation of the right to inviolability. IT has greatly exacerbated legal problems related to the dilemma of disclosure of information, protection of privacy and the lack of traditional legal means to ensure privacy. Thus, in the era of IT, automated processing of personal data is the main source of threats to the inviolability of the privacy sphere.

We believe that modern achievements in the sphere of information technologies threatens human privacy and causes negative consequences in the issue of access to personal data. This will now be considered in more detail using the specific examples : Internet and Social networks.

## 2. THE INTERNET

The Internet was invented in the 1980s as a scholarly network for information exchange. The inventor of the Global Internet Network, Timothy Berners-Lee, states in the book “Web Invention”: “The Web is rather more a social than a technical phenomenon”: It was aimed at result achievement i.e. to help people work together, but not as a technical toy. The most general Web objective is the support and improvement of our life in the world which is web-based in many things” [4].

The Internet developers understood that “for existing of any group the issue of its integrity is a key one, which presupposes the privacy and confidentiality”. [4]

However, they considered that “nothing hinders the privacy maintenance, as everything may be conducted automatically – the information entrance and verification, as well as taking the privacy insurance steps” [4]

It was supposed that the common use of personal information when communicating with other Web members would not do any harm, and the issue of confidentiality and data safety appeared when the Internet became global. Understanding that the agreement with regard to the privacy is “the most important precondition of any web-type community” – confidence, for the confidence insurance, the Global Web developers introduced cryptography with the public key (public key cryptography – PCI), a mechanism of information coding, due to which it is impossible to read it without the key [4].

However, on 12 March 2017 Timothy Berners-Lee determined that the loss of control over personal data was one of the key modern Internet problems. The inventor of the Web stated that “an essential amount of web-sites offer free content in exchange for personal data. Many of us agree to this - although often accepting long and sophisticated documents with the conditions but in principle, we do not object against collection of such information in exchange for the free services”[5]. In order to preserve personal data of a person person, companies do not provide the possibility of direct control over this information and do not allow tracking the information on the personal data transferred to the third persons.

One more problem of privacy insurance on the Internet is connected with the use of “cookie” files. Most browsers support cookie files. Some of these files may be used for tracking users on several web-sites (tracking cookie files) which allows, for example, to advertise a product (service) which the user searched for on other site(s). Thus, the web-site of the company “Shell Ukraine” contains the Cookie Files Policy [6], which states that “although we do not use the cookie files for the creation of the portfolio of the behavior of your browsers on the other web-sites, we use the third-party consolidated data to show you the appropriate and interesting information”. This site contains the list of all used cookie files: “Adobe Analytics”, “DoubleClick Floodlight”, “Facebook”, “Google Adwords Conversion”, “Google Analytics”, “Google”, “Lucid”, “Specific Media”, “Twitter”, “Tube Mogul”, “Xaxis”, “YouTube”. However, the users may adjust their browsers for rejection of certain or specific cookie files and may delete cookie files at any time.

Cloud Technologies are used for remote processing and storage of data. Using the “clouds”, the service suppliers transfer the data from server to server in different corners of the world and do not store them in one place. This provides the efficiency of the demands satisfaction of the data users and allows “balancing” the loading of the networks used by the providers. However, when data is stored in different places, it is not always possible to determine the legal norms which may be applied for the protection of information and subjects who may demand the data access. This dubiousness is a critical disadvantage which will need settlement, as the amount of

“clouds” in the Internet will grow. In order to create the privacy insurance condition in the Cloud Technologies, the service provider shall take the corresponding technological and organizational steps to guarantee the information security when rendering the services as to the functioning of the network the user (applies). He shall also notify the consumers of the services on the existing risks of the personal data protection infringement and possible ways of protection [7].

### 3. SOCIAL NETWORKS

A social network is an Internet service designed for the simultaneous communication of users and for their information posting and sharing [8].

As of January 2017, according to Alexa & SimilarWeb [9] the most popular social networks are as follows: Facebook, Twitter, LinkedIn, Instagram, Vkontakte, Odnoklassniki ra QZone.

The users and resource owners are mostly interested in the personal data protection in the social networks. Some want to keep their life private and others want to get as many users as possible. Despite the confidentiality policy in the social networks, these are the users who are responsible for the content filling with personal information. On the social networks servers the central storages are created of the personal data, the amounts of which grow each day depending on its filling by the users.

The analysis of [10] Facebook’s “Data use policy” testifies to the fact that, depending upon the services used by a person, the present social network received different types of information from the person or about the person, as follows: sex, date of birth, place of residence (location), telephone number, credit cards numbers, IP-address, related accounts, name change data, political and religious views, list of deleted friends, language of communication, searching requests, etc.

In February 2011 an Austrian media-tourist Maks Shrems suspected that Facebook stored all information on USA users and uses it without following the EU norms. After many requests to the directorate of the social network, Shrems received CD-disc from Facebook with all information on him (information was on 1200 pages) stored in the corporation. When browsing through the data, he found messages that had been deleted and hidden from public view stored in the company databases. Based on these violations his lawyer addressed twice the court in Dublin (Ireland) as to the personal data protection. According to the first claim consideration results, the court obliged the social network to be more responsible with regard to personal data. The second claim was rejected.

In 2013 Shrems addressed the Court of the European Union (Equity court). On the 6th of October 2015 (Case C-362/14; ECLI identifier: ECLI:EU:C:2015:650) this

court passed a decision about the cancellation of the transatlantic agreement about personal data use (“Safe Harbour” Agreement), which allowed American companies transfer data on their European users in USA. The Agreement was acknowledged illegal as it did not allow the European regulators protect the EU citizens, whose rights to personal data protection were violated.

In 2015-2016 the governments of some European Union states blamed the Facebook Corporation for not following the confidentiality principles with regard to its users. Thus, in February 2016 the National Committee for data processing and civil liberties of France which conducts the surveillance over following the personal data protection law, stated that Facebook should stop tracking the site visitors who are not its registered users [11]. According to the results of an analysis conducted by a French regulator, the Facebook directorate decided that any site visitor accepted the social network using conditions on default, even if they were not authorized on the site. The commission states that social network automatically transfers the cookie file into the browser of all site visitors and uses it for collecting the data necessary for the advertising. Apart from this the Committee blamed Facebook that the social network stores the data about religious beliefs, political views and sexual orientation of the users. The representatives of the regulator stated that this approach “violates basic rights and interests of the people, including the right to privacy”.

In response, Facebook stated that the statistics kept by the social network does not identify anyone individually and that Facebook plugins are not installed through cookie by the user who has not had them before, i.e. they should have accepted the user agreement before that.

To ensure personal data protection on 14 April 2016 European Parliament ratified “General Data Protection Regulations (GDPR) [12]. GDPR came into force 17 May 2016, but it is a part of national legal systems from 25 May 2018.

This act presupposes the following:

- right to forget or to delete information (a person may demand the destruction of his/her personal data);
- right to claim (a person will be able to oppose the processing of his/her personal data, including the “profiling” [13]);
- right to the transfer of data (people will be able to apply for sending personal data by one owner to the other);
- fines for the data confidentiality violation (liability is established for the personal data confidentiality infringement, and, depending upon the type of violation, the companies may be brought to the administrative liability in the form of fine amounting to more than 20 million EUR or 4% from the annual world turnover).

Providers outside the EU offering goods and services for EU citizens shall follow the norms of the said provision regardless of whether they hold the personal

data or not. Companies outside the EU conducting monitoring of EU citizens behavior (for instance, the use of cookies on their websites which often contain information on the users to track their behavior) will also be obliged to fulfill the requirements of the new law. Personal data may leave the European Economic Area (EU countries + Norway, Iceland, Liechtenstein) only on the condition that EU laws on personal data protection are valid outside the EU territory.

The reform is conditioned by the unification of the rules and the necessity of creating a unified, reliable and efficient personal data protection mechanism for EU citizens, including but not limited to the Facebook social network. However, this is the user who is to be the personal data protector. You should always pay thorough attention to what you publish on the Network.

#### 4. CONCLUSIONS

In the era of rapid development of information technologies, traditional legal methods and instruments are not enough for solving problems connected to users' privacy. However, the new technologies should not be rejected, it is only important to solve the issues of regulation, accumulation, storage, application and protection of personal information. This will allow customers to realize the potential and advantages of the information technologies and at the same time minimize the risks of losing security and confidentiality.

The adoption of GDPR is a timely and important step to protect the right to privacy in the context of new technological challenges. The provision of the GDPR regulates in detail the protection of personal data and rights arising from the use and creation of personal data. GDPR also aims at preventing and protecting against violations of the distribution of personal data, including the "virtual space" without the consent of the entity to which such data belong. The GDPR establishes provisions that apply to all EU member states and other countries due to the extraterritorial effect of the regulations, which results in these countries' subsequent adaptation of laws in the field of personal data protection according to the GDPR regulations.

#### REFERENCES

- [1] Yael Onn et. al., Privacy in the Digital Environment (Haifa Center of Law & Technology, Niva Elkin-Koren, Michael Birnhack, eds., 2005). [Electronic resource]. – Mode of access: [http://weblaw.haifa.ac.il/he/Research/ResearchCenters/techlaw/DocLib/Privacy\\_eng.pdf](http://weblaw.haifa.ac.il/he/Research/ResearchCenters/techlaw/DocLib/Privacy_eng.pdf) (date of access 25.06.2017).
- [2] Edward Snowden and data security for the Internet of Things [Electronic resource]. – Mode of access: <http://embedded-computing.com/articles/edward-snowden-and-data-security-for-the-internet-of-things/> (date of access 25.06.2017).

- [3] Vault 7: CIA Hacking Tools Revealed [Electronic resource]. – Mode of access: <https://wikileaks.org/ciav7p1/index.html> (date of access 25.06.2017).
- [4] Бернерс-Лі Т. Заснування Павутини: З чого починалася і до чого прийде Всесвітня мережа / Т.бернерс-Лі, М. Фічетті; Пер. з англ. А.Щенка. – К.: Вид. дім «Кисво-Могилянська академія», 2007. – С. 107, 109.
- [5] Three challenges for the web, according to its inventor [Electronic resource]. – Mode of access: <http://webfoundation.org/2017/03/web-turns-28-letter/> (date of access 25.06.2017).
- [6] Політика щодо файлів Cookie компанії «Shell Україна» [Електронний ресурс]. – Режим доступу: <http://www.shell.ua/%D0%BF%D0%BE%D0%BB%D1%96%D1%82%D0%B8%D0%BA%D0%B0-%D1%89%D0%BE%D0%BE-%D1%84%D0%B0%D0%B9%D0%BB%D1%96%D0%B2-cookie.html> (date of access 25.06.2017).
- [7] Брижко В.М. Приватність у хмарних технологіях / Брижко В.М. // Інформація і право. – № 4. – 2016. – С. 56.
- [8] Архипов В.В. Интернет-право: учебник и практикум для бакалаврата и магистратуры / В.В. Архипов. – М.: Издательство «Юрайт», 2016. – С. 236.
- [9] World map of social networks. january 2017 [Electronic resource]. – Mode of access: <http://vincos.it/world-map-of-social-networks/> (date of access 25.06.2017).
- [10] Data policy Facebook [Electronic resource]. - Mode of access: <https://www.facebook.com/about/privacy/> (date of access 25.04.2017).
- [11] La CNIL met publiquement en demeure FACEBOOK de se conformer, dans un délai de trois mois, à la loi Informatique et Libertés [Electronic resource]. - Mode of access: <https://www.cnil.fr/fr/la-cnil-met-publiquement-en-demeure-facebook-de-se-conformer-dans-un-delai-de-trois-mois-la-loi> (date of access 25.06.2017).
- [12] Data Protection Regulation [Electronic resource]. - Mode of access: <http://www.eugdpr.org/eugdpr.org.html> (date of access 25.06.2017).
- [13] Profiling is the analysis of activeness (behavior) of the person in the Internet, including the social networks.

Radoslaw CZAJAJDA<sup>1</sup>

## **GOAL SETTING IN NON-PROFIT PROJECTS. HOW SMART ARE WE?**

In this paper, author analyses goals defined by project managers in Non-profit organisations in Poland under SMART criteria. Aim of this research was to reveal what flaws these goals have and how could NGOs use SMART framework to set and evaluate their goals better. In the result, several drawbacks in defining specific, relevant and time-bound goals were pointed and an extended definition of specific, measurable and achievable goals for Non-profit organisations were proposed.

### **1. INTRODUCTION**

Goals as well as goal setting are important factors affecting organisational performance [1]. Goals focus attention and effort on a concrete area, which implies greater persistence and better strategies to approach given task [2]. The process of goal setting as a part of strategy creation was covered in various ways in the domain of business, by biggest minds in history of management sciences, including Peter Drucker [3]. One of the most popular goal setting approach is SMART method, taught in various Business Schools around the world since 1980s [4]. Even though the methodology is available for three decades already, not all organisations seem to use it in setting goals for their projects. The purpose of this paper is to investigate this phenomenon.

#### **1.1. SMART GOALS**

SMART is an abbreviation of a set of criteria required to evaluate goals defined in various settings and disciplines [5]. The most commonly used criteria are: Specific,

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Measurable, Achievable, Relevant, and Time-bound. The origins of the term SMART Goals differ based on the literature reviewed. Some attribute the concepts to George Doran [4], while others cite Edwin Locke [6] and Latham and Locke [7].

There are several variations of SMART criteria. Most scholars agree on S for Specific and M for measurable, however, ART part is a field of disagreement.

In contrary to achievable, Doran proposes assignable – there should be someone responsible of the goal [4], while Subrt and Brozova propose action oriented – “the plan of attack to make each goal real [8]. Some other scholars mention Attainable and Agreed.

Relevant goals brought similar disagreement among scientists. Some propose reasonable, realistic or results-oriented as more important criteria, without any strong arguments behind it though [9].

Time-bound goals are opposed by Chamberlin [10] with “trackable” to evaluate the progress in goal achievement, especially in long-term goals.

Different criteria were designed for different, concrete cases, yet, specific, measurable, achievable, relevant and time-bound are most commonly used in practice and therefore will be used in this research.

## 2. GOALS CRITERIA

### 2.1. SPECIFIC

According to Subrt and Brozova, specific criteria answers question “What exactly are we going to do, with or for whom?”[8]. Specific goals leave no place for misunderstanding or misinterpretation. A reader presented with specific goal should not need any clarification on the purpose of project to comprehend it fully.

### 2.2. MEASURABLE

SMART goals should be presented in quantitative manner to allow evaluation of level of goal accomplishment. Binary goal approach is not satisfying this criterion. Chamberlin wrote about it: “if you can’t measure it, you can’t manage it, so you won’t know when you’re done”, underlying the importance of defining measurable goals [10].

### 2.3. ACHIEVABLE

McLeod classifies goals as achievable whenever organisation has time, talent and resources available to accomplish this goal [3]. Achievable goals are set based on the

understanding of organisation's background and therefore cannot be evaluated from the goal formulation only. Yet unspecific goals are unachievable by nature.

#### 2.4. RELEVANT

Individuals and the team must know why the goal is relevant to them, their roles as well as the entire direction of the team [11]. For organisation it should comply with the mission, vision and general goals. In practical setting, relevant goals are designed together with the team and based on a thorough research of stakeholders needs. This practice will be main criteria in evaluating relevant goals.

#### 2.5. TIME BOUND

Setting the deadline for activity forms a sense of urgency within team members. To verify if the goal is time bound, one needs to check if it answers a question "When will this be accomplished" [11].

#### 2.6. SMART GOAL EXAMPLE

Tim Totheri, founder of Plotline Leadership defined such goal for one of his projects: During the next four weeks, design a soft-skill course on presentation skills that contains a pre-assessment, three hours of online coursework and a half-day face-to-face training session that features video, a post-course assessment and coaching [12]. It fulfils all SMART criteria.

### 3. RESEARCH METHOD

In March 2018 an online survey was distributed among representatives of non-profit organisations in Poland. The survey contained over 80 different questions focusing on different parts of Project Management. One question required to write specific wording of goals that the evaluated projects were aiming to accomplish. In total 191 valid answers were collected. After collecting the data, author evaluated each goal under SMART framework based on criteria definition to answer two research questions:

*RQ1: Are goals set by NGOs following SMART criteria?*

*RQ2: How suitable SMART framework is to evaluate Non-profit goals?*

## 4. RESULTS

### 4.1. SPECIFIC

Goals evaluated in this study bring several questions and doubts for the reader. Some of them i.e. “Promoting table tennis discipline” lack the definition of a target group – beneficiaries, while others, like “Engaging youth in voluntary work” presents the group but does not specify it narrow enough. Other group of goals do not answer the question about means to reach the perfect state i.e. “Reduction of poverty in the neighbourhood” or mention only means, without defining purpose behind it: “Organise a scientific conference”.

Moreover, some of the NGOs participating in this research have struggle with defining goals properly, phrasing them as social problems or focus areas instead. Project goals such as “Social exclusion of seniors”, “Unemployment” or “Corruption in society”, besides giving goose bumps, are impractical in project management processes.

Specific criterion itself might not be specific enough. A new definition, covering three areas that non-profit organisations participating in this study missed: purpose of the project, means of achieving it and exact target group could reduce the problem in accomplishing this criterion.

### 4.2. MEASURABLE

Only 3 goals evaluated in the study had any measures of accomplishment embodied within. Yet, they were not flawless. One of such goals is: “Increasing knowledge about law in 200 rural area citizens aged 60+”. These measures, assessing amount of people that will be participating in activities is unrelated with the main objective of the project - increasing knowledge about law. If each participant of 8-hour workshop will learn some interesting facts about history of law and nothing more – the goal will still be accomplished.

Some goals could be evaluated by numbers, but its authors didn’t include such measures when phrasing them. For example goals like “Recruiting volunteers aged 60+” or “increase the number of artistic workshops in the county” require only to define the amounts of people recruited and workshops held. Some goals can be measurable, but their authors may not know or have access to the measures – i.e. “developing creativity among children”. Even though there are several measures of creativity that could be used in the programme, some of them are paid or not popular and therefore project managers might not have been aware of a possibility to implement them.

#### 4.3. ACHIEVABLE

Due to fact that achievability criteria are very subjective to organisation and can only be evaluated by their members, author was not able to evaluate all the goals under this condition. However, there were several goals that could be considered not achievable and their analysis can bring another meaning to the achievability criteria. For example, some organisations defined general, unspecific goals, like “Developing creativity among children”, or “Promotion of local history” which will never be achieved, because their undefined range can be too wide. It will be impossible for one organisation to develop creativity of all children or to reach entire globe with some educational programme about local history. Moreover, some goals were continuous in their wording, like “Developing cultural awareness”, or “Integrating local citizens”. These cannot be achieved, since they have no specific end time, quality or quantity. Defining a condition under which the goal will be achieved could be another definition of the achievable criteria.

#### 4.4. RELEVANT

It is not possible to evaluate the relevance of the projects without deep understanding of their background. It is also impossible to design relevant goals without analysing stakeholder’s needs. Therefore, another question from the research could be used to estimate how many organisations had relevant goals. In a multiple selection question “What were the factors influencing the decision to kick off the project?”, only 39% of NGOs declared conveying a needs analysis among stakeholders. Yet, there is no certainty if organisation and team members were concerned in the process of designing project goals. It can be estimated that no more than 39% of project goals in this study were relevant.

#### 4.5. TIME BOUND

Only 1 out of 191 goals considered in the research have had a deadline or specific timeframe for its achievement. Even though some more organisations claimed to define a project schedule before it started (14% used Gantt chart), they do not implement it in the briefest summary of the project purpose, which is the project goal.

### 6. SUMMARY

Some non-profit organisations have major problems with setting goals according to SMART framework. None of the 191 participants of the study made a fully SMART goal and less than 10 made it to fulfil 3 or more criteria. To solve this issue,

author proposes to include 3 supporting areas in “Specific” criterion, namely: purpose of the project, means of achieving it and exact target group. Moreover, ambiguity of achievable criterion could be resolved by phrasing it as “How do you know when the goal is achieved”, instead of subjectively evaluating the probability of success. Finally, a stronger emphasis on the search for project success measures should be made.

## 5. LIMITATIONS

Participants of the study were offered a training in fundraising, project management or marketing in exchange for dedicating 30 minutes to fill in the survey thoroughly. This may have motivated participants lacking these skills and therefore might disrupted possibility to use this sample as representative. Therefore, the sample is not representative for entire group of Non-profit organisations in Poland.

## REFERENCES

- [1] LOCKE EA, LATHAM GP: *A Theory of Goal Setting and Task Performance*. Prentice Hall; 1990: 1-26.
- [2] LATHAM GP, STAJKOVIC AD, LOCKE EA, *The relevance and viability of subconscious goals in the workplace*. *J Manage.* 2010;36(1):234-55.
- [3] MACLEOD, L. *Making SMART goals smarter*. *Physician Executive Journal*, 2002, 68–72
- [4] DORAN, G. T. *There’s a S.M.A.R.T. way to write management’s goals and objectives*. *Management Review*, 70(11), 1981, 35–36
- [5] O’NEILL J AND COZEMIUS A. *The Power of SMART Goals: Using Goals to Improve Student Learning*. Bloomington, 2005
- [6] LOCKE, E. A. *Toward a theory of task motivation and incentives*. *organisational Behaviour and Human Performance*, 3, 1968, 157–189
- [7] LATHAM, G. P., & LOCKE, E. A. *Goal setting – a motivational technique that works*. In J. R. Hackman, E. E. Lawler, & L. W. Porter (Eds.), *Perspectives on behavior in organisations*, 1983, 296–304, McGraw Hill.
- [8] SUBRT, T., & BROZOVA, H. *Multiple criteria evaluation of project goals*. In T. Trzaskalik & T. Wachowicz (Eds.), *Multiple criteria decision making*, 2012, 179–189. Katowice: University of Economics in Katowice
- [9] BROWN, G., LEONARD, C., & ARTHUR-KELLY, M. *Writing SMARTER goals for professional learning and improving classroom practices*. *Reflective Practice*, 17(5), 2016. 621–635. <https://doi.org/10.1080/14623943.2016.1187120>
- [10] CHAMBERLIN, J. Who put the ‘ART’ in SMART goals. *Management Services*, 55(3), 2011, 22–27.
- [11] YEMM, GRAHAM. *Essential Guide to Leading Your Team : How to Set Goals, Measure Performance and Reward Talent*. Pearson Education. 2013, 37–39. ISBN 0273772449
- [12] <https://fitsmallbusiness.com>, visited 12.09.2018

*Key words:*  
*Balanced Scorecard,*  
*Environmental Goods and Services Sector, green jobs,*

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## **STRATEGIC GOALS OF RENEWABLE ENERGY SECTOR\***

Strategic goals are essential for the realization of each strategy, and especially in case of development of Polish renewable energy sector. The aim of this article is to present some common points of different strategies formulated by Polish companies participating in the environmental goods and services sector. The tool to elaborate on this strategy and to indicate shared points of strategy can be a Balanced Scorecard proposed in this article. These common points can be defined by differentiating creating green jobs which are a competitive advantage. This theoretical study examines the possibility of future research in the strategic management area, therefore descriptive method was accepted and supported then by multicriteria analysis of strategy measurement indicators.

### **1. INTRODUCTION**

The modern economy is characterized by dependence on energy supplies, whose production in most cases has a negative effect on the condition and the quality of the natural environment. This is the case in Poland, where the use of hard coal and lignite as the basic sources of energy production causes a significant environmental burden [5]. The energy sector is considered a strategic branch of industry, without whose proper functioning it is difficult to imagine the further socio-economic development of modern states [9]. This sector consists of two subsectors: renewable and non-renewable. The renewable energy sector is also a part of the environmental goods and services sector which is also called the green sector. Organizations which positively

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influence the natural environment can be also a place of green employment. The green jobs are a kind of employment whose impact on the natural environment is neutral or positive in product or services dimension. The renewable energy branch of the energy sector is not the only one which offers the green jobs - there are also others, such as water management, sewage treatment, sanitation, and waste collection.

Strategic management is the managing of the organization development in the long term, based on the use of opportunities and the avoidance of threats from its institutional surrounding [9]. The beginning of a strategic plan is always an analysis of the environment (reality) in which the organization operates. Therefore the natural environment as a source of resources and a recipient of all production effects (emissions, products, and waste). The goals elaborated in such a plan are the effect of combined knowledge about strong and weak points of the organization both threats and opportunities coming from its outside. Moreover, strategic management is implemented by organizations (enterprises) which influence to some level the regional development and development of the sector of the country's economy [13].

A balanced scorecard is a well-known tool used to analyze a company's strategy and processes. The balanced scorecard is a strategic planning and management system that organizations use to communicate what they are trying to accomplish, align the day-to-day work that everyone is doing with strategy, prioritize projects, products, and services, and measure and monitor progress towards strategic targets.

The aim of this article is to present some common points of different strategies formulated by Polish companies participating in the environmental goods and services sector. This theoretical study examines the possibility of future research in the strategic management area, therefore descriptive method was accepted. Based on this considerations, a set of indicators can be chosen in future to measure described by the balanced scorecard perspectives.

## 2. THE GREEN ECONOMY IDEA IN STRATEGIC PLANNING

Green economy is defined as an economy that aims to reduce environmental risks and ecological scarcities, and whose purpose is sustainable development without degrading the environment. It is closely related to ecological economics, but it has a more political focus, including notions such as green jobs [4]. The green economy was characterized in the strategy Europe 2020 prepared by the European Commission and was described as a low-emission and resource-saving economy, which is important to achieve intelligent, durable and sustainable development. Green activities are the key actions of policymakers in countries and regions across the world that can be created in almost all economic sectors, which help in sustainable development leading to greening the economy and which are an important tool in counteracting unemployment. The proper management of natural assets or natural capital is relevant

for improving productivity and, therefore, improving the competitiveness of the national economy [3]. Governments around the world increasingly recognize that creating long-term citizen society value depends also on the state's ability to understand and respond to increasing demands from the society [7]. It is not surprising that the topic of green initiatives has been gaining ground, as governments seek to incorporate concepts such as sustainability and responsible corporate behavior into their assessments of the country's long-term development plan [7]. The green economy idea is a concept of the sustainable development implementation which progress takes some steps [10].

The concept of green jobs began to spread with the development of the theory of green economy, which is conceptually linked to the idea of sustainable development. Its introduction requires structural changes, including the creation of green jobs. Green jobs (colloquially referred to as green-collar jobs) exist in various sections and sectors. Their creation is important from an economic, ecological and social point of view [10].

The current ecological situation depends, to a great extent, on industrial production practices and the decisions enterprises and business take to achieve their business goals [6]. Therefore strategy can be understood as a management process consisting of three stages: strategic analysis, strategic planning, and strategy realization [1]. The wider concept of strategic management is presented in figure 1.

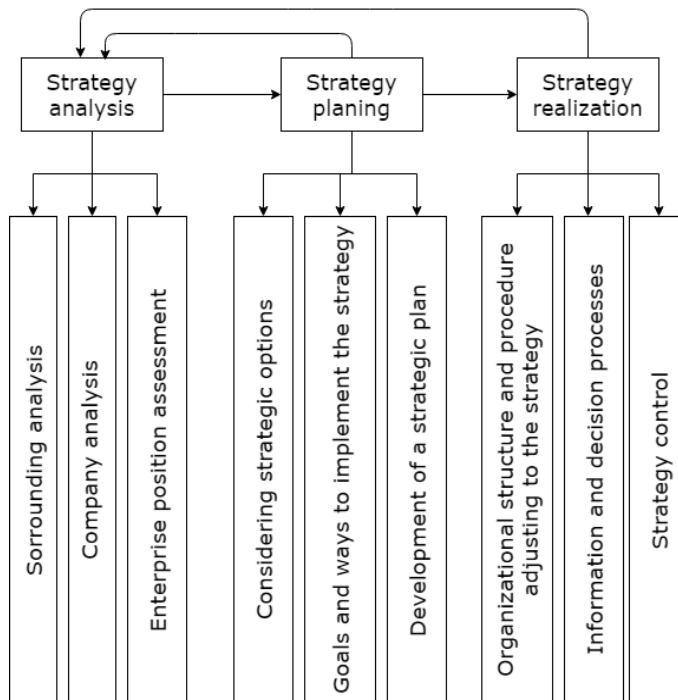


Fig. 1. Strategic management process. Source: [2]



The need for new environmentally friendly ways and approaches to production management is becoming more evident. One of the world-acknowledged approaches to solving ecological problems is ecological or green management. Its implementation can be monitored and executed by a special tool – a balanced scorecard [14].

### 3. BALANCED SCORECARD

Therefore, it is important to achieve benefits from intellectual assets and not only from material assets. Enterprises or sectors that only achieved their success through the financial indicators will become less and less competitive in the new reality [1]. Contemporary enterprises and sectors need tools that will enable them to focus on a defined strategy. Balanced Scorecard could be such a tool. The Balanced Scorecard is used today at the enterprise level. However, the government should undertake activities related to the implementation of strategies for important sectors of the national economy [1]. The essence of the Balanced Scorecard is the presentation of financial and non-financial indicators in the form of four perspectives linked together. These are the financial perspective, the customer's perspective, the perspective of internal processes and the perspective of growth and learning [1]. All perspectives are based on the formulated vision and the company's strategy. Each of the four perspectives of the Balanced Scorecard consists of objectives, measures, adopted targets and initiatives to be undertaken by the company to achieve its objectives. Links between particular perspectives are of a cause and effect nature [1].

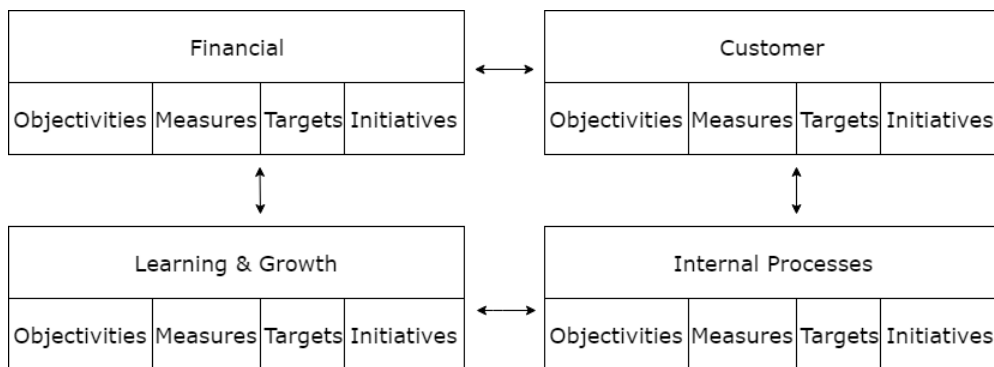


Fig. 2. Balanced Scorecard, including a cause and effect sequence. Own elaboration based on: [11]

Strategic objectives can only be achieved through strategic initiatives. Therefore full implementation of the strategy means that each strategic objectives must be

achieved through assigned strategic initiatives. The degree of strategy implementation in the Balanced Scorecard can be monitored using measures. The beginning of the strategy implementation is breaking down the more abstract concepts like mission and vision into measurable objectives. Actions that an organization takes should be helping to achieve all of the strategic objectives. Examples might include: increasing revenue, improving the customer or stakeholder experience, or improving the cost-effectiveness.

The activities of many entities on the renewable energy sector should be focused on the adopted energy strategy under the document "Energy Policy of Poland until 2030". Implementation of this strategy may take place through the Balanced Scorecard, which allows targeting activities of individual entities within the RES sector. The factor that distinguishes this method is the use of quantitative measures to determine the degree of implementation of the adopted strategy and its continuous monitoring.

### 3.1. FINANCIAL PERSPECTIVE

The first action in the process of developing the scorecard is for the decision makers to determine the financial objectives that result from the adopted strategy. This is a particularly important task because the goals and measures included in other perspectives are related to the objectives included in the financial perspective [1]. The main goal of the financial perspective is to increase the value of the company (wider in the sector of the country's economy) [2]. Examples of indicators of objectives in the financial perspective are ROI (*return on investment*), ROE (*return on equity*), ROA (*return on assets*) [14].

### 3.2. CUSTOMER'S (STAKEHOLDERS) PERSPECTIVE

An enterprise (or sector) cannot achieve satisfactory financial results without providing its customers with products and services that meet their expectations and meet specific needs. In this aspect, decision-makers make decisions related to the selection of a market segment. This is important because it is related to the future activities related to marketing or product distribution[9]. Effective activities in a specific market segment will bring revenues to the enterprise (or the sector). In this context, the financial perspective is combined with the customer's perspective. The basic measures in the customer perspective include market share, customer retention, customer acquisition, customer satisfaction and customer profitability [1].

### 3.3. THE PERSPECTIVE OF INTERNAL PROCESSES

The third perspective in the Balanced Scorecard is the perspective of internal processes. The goals related to the client's and financial perspectives are implemented

by the processes taking place in the enterprise (or the whole sector). Identification of key processes takes place only after setting goals and measures in the first two perspectives [1]. Examples of measures in this perspective are the number of new products or services, cost of the process costs, time of the process.

### 3.4 PERSPECTIVE OF GROWTH AND LEARNING

The development of an organization or a sector is possible only through continuous improvement. The result of the improvement activities is the increase in the efficiency of the entire organization or sector [1]. The perspective of growth and learning is, therefore, a complement to the perspectives described earlier because the process of creating this perspective is based on defining goals and measures that have a significant impact on the development of the entire company or the sector [2].

## 4. METHOD

Indicated above perspectives of Balanced Scorecard meet in the indicators for monitoring the implementation of energy policy on the national level presented in table 1. The environmental goals are common line established for each organization of energy sector by the country policy [8].

Table 1. Basic indicators for monitoring the implementation of energy policy

	The name of the indicator	The base value of 2007	Expected value till 2030	Source of information
1	Average annual change in primary energy consumption in the country since 2005 (%)	2,7	<1	MSO
2	Ratio of extraction to domestic consumption (in terms of tonnes) of hard and brown coal (%)	105	>100	MSO
3	Maximum share of natural gas and crude oil imports in total (converted to toe) from one direction to the national consumption of both raw materials (%)	85	<73	ME
4	Ratio of the reachable capacity of domestic generation sources (conventional and nuclear) to the maximum demand for electric power (%)	130	>115	ME
5	Share of nuclear energy in electricity production (%)	0	>110	ME
6	Share of energy from renewable sources in final energy consumption (%)	7,7	>15	ME
7	Annual volume of co2 emissions in occupational energy compared to the domestic electricity production (tons/MWh)	0,95	<0,70	ME

Source: [8]; MSO = Main Statistical Office (*pol. Główny Urząd Statystyczny*), ME = Ministry of Economics (*pol. Ministerstwo Gospodarki*).

Among the seven indicators for monitoring the strategy declared by the Polish government to make energy sector more green because of the expected direction of change, there are four stimulants (the larger the better) and three destimulants (the smaller the better) [12].

Based on this set of stimulants it is possible to group some regions of Poland using multicriteria analysis formulated first by Zdzisław Hellwig. This method is used to construct the systematic variables. If an indicator is a destimulant (the smaller the better), it is normalized according to the  $x_1$  indicator transformed according to the formula:

$$x_{ij} = \frac{1}{x_i} \quad (1)$$

where  $i$  – is an object number, and  $x$  – is a an indicator. The other features were standardized according to the formula:

$$z_{ij} = \frac{x_{ij} - \bar{x}_{ij}}{s_j} \quad (2)$$

where:  $i$  – is object number,  $j$  – feature number,  $s$  – is standard deviation. Such transformed features were subject of calculations of taxonomic distances between the investigated factors values and the reference model. This distance was calculated according to the formula:

$$d_i = \sum_{j=1}^m |z_{ij} - z_{0j}| \quad (3)$$

The same calculations were performed also the for the indicators marked as  $y_i$ . Obtained  $d_i$  values were used to compute Hellwig's synthetic measure of green development:

$$z_i = 1 - \frac{d_i}{d_0} \quad (4)$$

The  $z_i$  indicator assumes values within the range [0;1], where values closer to the model are associated with high level of the investigated object. Obtained values  $z_i$  were arranged in linear manner in four groups:

$$1. \quad z_i \geq \bar{z} + s_z \quad (5)$$

$$2. \quad \bar{z} \leq z_i < \bar{z} + s_z \quad (6)$$

$$3. \quad \bar{z} - s_z \leq z_i < \bar{z} \quad (7)$$

$$4. \quad z_i < \bar{z} - s_z \quad (8)$$

Where:  $\bar{z}$  is an arithmetic mean,  $s_z$  – standard deviation. Then, values of  $z_i$  indicators were calculated for regions (voivodeships) of Poland based the indicators listed in Table 1. Recognizing differences between each region of Poland while creating a common strategy for the development of the energy sector requires an approach combining interventions at different levels, which can be described by three main factors [12].

## 5. CONCLUSIONS

Indicators identified as the common points of the strategy in the energy sector can be recognized as the tool of measurement of progress in achieving a goal which is green economy. Although these goals are established for the whole energy sector in Poland, each region of the country is different and these differences are visible when Hellwig's pattern method is used.

Environmental factors have to be taken into consideration in the formulation and implementation of the policies that regulate economic activities and other forms of social organization. Therefore, a new model of development can be achieved - a model that can be environmentally and socially sustained and durable. In turn, it is to be expected that environmental policy will be changed as a result of the growing interdependencies between parts of energy sectors.

## REFERENCES

- [1] Chandler A.D, Jr., *Scale, Scope The Dynamics of Industrial Capitalism*, Harvard University Press, Cambridge, Mass. 1990.
- [2] Kaplan R.S and Norton, D.P, *Strategiczna Karta Wyników. Jak przełożyć strategię na działanie*, PWN, Warszawa 2001.
- [3] Kasztelan A., "Środowiskowa konkurencyjność regionów - Próba Konceptualizacji," *Probl. Ekorozwoju*, 2010.
- [4] Kasztelan A., "Green Growth, Green Economy and Sustainable Development: Terminological and Relational Discourse," *Prague Econ. Pap.*, 2017.
- [5] Kozar Ł., "Zielone miejsca pracy na przykładzie sektora odnawialnych źródeł energii w Polsce", [in:] *Ekonomia i nauki o zarządzaniu w warunkach integracji europejskiej*, P. Urbanek, E. Walińska [eds] ser. „Ekonomia i Zarządzanie w Teorii i Praktyce”, T. 9, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2016, p. 285–300.

- [6] Kryk B., "Kreowanie zielonych miejsc pracy w sektorze energetyki odnawialnej," *Kwartalnik Kolegium Ekonomiczno-Społecznego Szkoły Głównej Handlowej, Studia i Prace*, 2010.
- [7] Melecký L. and Staničková M., "Cost efficiency of EU funded projects: Case of selected SMEs in the Moravian-Silesian Region," in *SMSIS 2017 - Proceedings of the 12th International Conference on Strategic Management and its Support by Information Systems 2017*, 2017.
- [8] Ministerstwo Gospodarki, *Polityka energetyczna Polski do 2030 roku*, Warszawa 2009. <https://www.gov.pl/energia/polityka-energetyczna-polski-do-2030-roku> [access: 28.08.2018].
- [9] Oblój K. and Trybuchowski M., "Zarządzanie strategiczne," *Zarządzanie. Teor. i Prakt.*, 2009.
- [10] Pakulska J. and Rutkowska-Podołowska M., "Environmental management systems according to ISO 14001," *Adv. Intell. Syst. Comput.*, 2017.
- [11] Ryńca R., *Zrównoważona karta działania jako metoda pomiaru efektywności procesów i działań*, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2009.
- [12] Sulich A., Zema T., Zema P. „Green entrepreneurship in the European Integration Context”. In: *Proceedings of the 4th International Conference on European Integration 2018, ICEI 2018: May 17-18, 2018, Ostrava, Czech Republic. Pt. 3* / [Eds. Michaela Staničková i in.]. Ostrava: VŠB - Technical University of Ostrava, cop. 2018. s. 1393-1400.
- [13] Stańczyk-Hugiet E., "Routines in the process of organizational evolution," *Manag.*, 2014
- [14] Świdarska G.K. (ed.), *Rachunkowość zarządcza i rachunek kosztów wyników t. II.*, Difin, Warszawa 2003.



**Students'  
Science  
Conference**

**II**

**BIOTECHNOLOGY  
AND  
BIOENGINEERING**

*Key words:*  
*lumbar spine biomechanics, intrinsic spinal shape, weightlifting*

Emilia PANICZKO<sup>1</sup>, Marcin WERACHOWSKI<sup>2</sup>, Ewa BORUCIŃSKA<sup>3</sup>

## **THE INFLUENCE OF LOADS CHANGE AND NATURAL SPINAL SHAPE ON THE LIFTING MANOEUVRE\***

The human spine is an amazing structure, able to handle incredibly heavy loads placed on the human body. Recent studies have proven the presence of an individually shaped Intrinsic Lumbar Spine Shape (ILSS), determined by environmental and genetic factors. They also showed that ILSS has an influence on the lifting maneuver of light loads. People with curvier lordosis have a tendency to bend over or use a stoop technique to lift a weight and the subjects with the straighter spine chose to bend their knees and squat. The researches were made to apply those results with increasing loads. The aim of this study is to explore the influence of ILSS and the increasing load lifted by humans on their lifting technique.

### **1. INTRODUCTION**

Lower back pain is reported to be one of the main causes of global disability and it has been studied for many years but the mechanism by which it is manifested is not well understood. [1] Previous studies have demonstrated the presence of Intrinsic Lumbar Spine Shape (ILSS) which could be due to two different factors: environmental and genetic. [2, 3]

Recent studies have shown the presence of an intrinsic shape to the lumbar spine, which is specific to each individual and potentially determined by two factors:

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environmental and genetic. [3] Current evidence on intrinsic lumbar spine shape suggests that it is not only the spinal structure but also its shape that affects its ability to bear diversified loads and assure stability. [2]

For these reasons it is important to investigate the change of the movement method while lifting increasing weights. Understanding the differences in posture between lifting very heavy and light weights by weightlifters may illustrate novel features of how our spines support loads. The study should provide information about the kinematic process of lifting and explore the relationship between the load placed on the spine and the lifting method. [4, 5]

## 2. MATERIALS AND METHODS

For the study, professional weightlifters were recruited and none of them reported the low back pain problem before. They were asked to proceed with a warm-up within 10 repetitions using a standard barbell with the smallest, preferred load. With increasing load the number of repetitions decreased. For the heaviest weight each weightlifter made only one repetition as his deadlift trial, and it was designated as 70% of the maximum weight the subject could lift at once. This value was determined to prevent any possible injuries which could affect the weightlifter.

The data were collected in two different ways. In the first step the application of Positional Magnetic Resonance Imaging (pMRI) delivered the information on the natural shape of the lumbar spine and it was used to build the statistical spinal model as well as to determine two structures - spinal curviness and evenness. [6] In the second step the VICON system was applied to register the weightlifting manoeuvre. The markers were placed from first lumbar vertebrae (L1) to first cross vertebrae (S1) as well as on the pelvis and most important joints of the lower limb. They allowed for the construction of a sticky lifting model. A force plate under each foot was synchronized with the video and together they recorded the ground reaction force. In a related study, data were recorded from individuals during weightlifting while standing on a piezoelectric force platform (Kistler) to measure the reaction between the floor and feet of the subject.

The data previously collected were analysed in two different ways. For the angles we used points registered by the infrared camera. The forces were calculated by the leader method. First the force platforms registered feet-floor reactions. Forces were then calculated starting with the ankle joints and finishing at the lumbar spine, although the lumbar forces may not be reliable because the model does not take into account the curvature of the spine or the mechanism enabling it to bear loading. During the calculation all values were smoothed, normalised to the full range, and interpolated to provide percentage changes because each subject lifted at a different

speed. Because of that process the time-series data were described by 101 points for each of the weightlifters. [3, 4]

The most important information about each weightlifter were presented in Table 1.

Table 1: The most important information about each subject

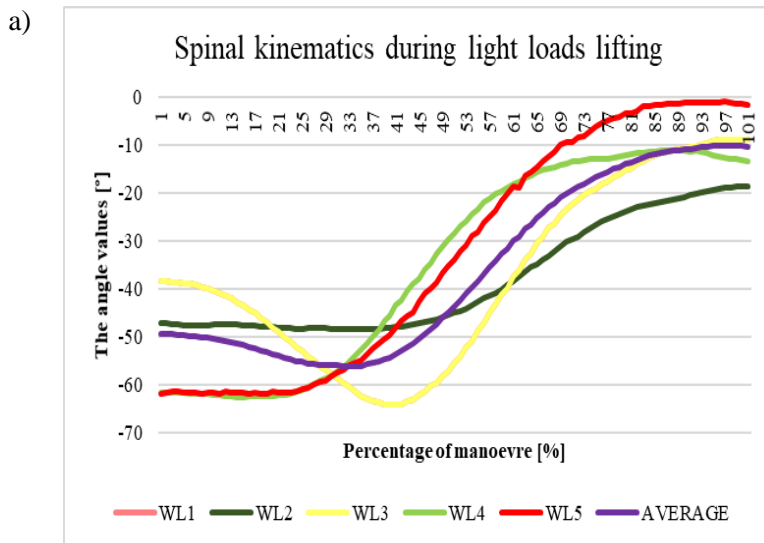
ID	1	2	3	4	5	Av.
height (cm)	180.6	178.6	167.56	178.6	179.2	176.91
Weight (kg)	96	84.4	73.9	107.2	82.6	88.82
age	26	19	20	50	24	27.8
BMI	29.4	26.5	26.3	33.6	25.7	28.3
Warm up weight [kg]	20	60	50	50	80	52
Deadlift weight [kg]	140	90	160	120	220	146
Curviness/Evenness	0.58	0.29	0.48	0.40	0.85	0.52

### 3. RESULTS

The research concentrated on the kinematics of lumbar, pelvis and knee area. The following information was received during the analysis of each body part for light and heavy loads.

#### 3.1. LUMBAR SPINE KINEMATICS

The motion itself is described in the Figure 1 for both lifting methods.



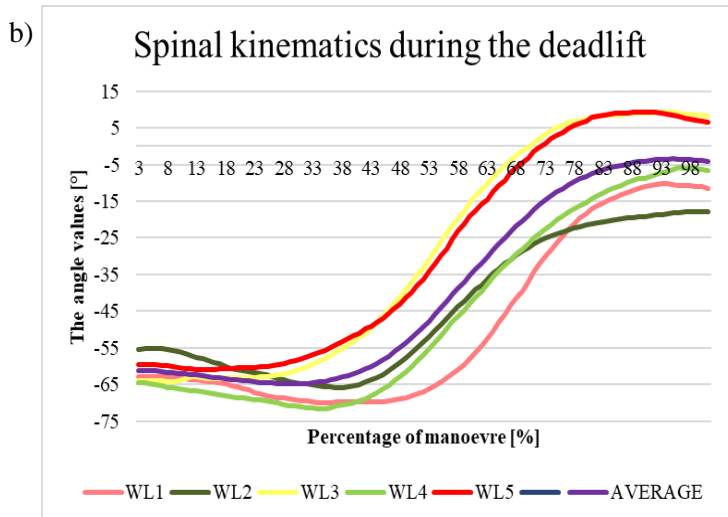


Fig. 1. The spinal kinematics during the lifting manoeuvre for light loads (a) and deadlift (b)

All dipped slightly on starting to lift, the greatest by up to about 10°, before starting to extend. WL5, with the curviest spine dipped least and WL2, with the straightest spine dipped the most whereas the range of motion was smaller for WL2 than for WL5.

The starting posture was with the hands grasping the bar and the start of the lift was determined by picking up the load. For three of the weightlifters there was no change in global lumbar angle until about 20% of the way through the lift when the angle increased monotonically to a plateau at about 70-80% of the lift. For weightlifter 2 (WL2), who had the straightest spine, the change in angle was delayed to about 45% of the way through the lift and never properly reached a plateau. Weightlifter 1 dipped at the start of the lift, increasing the angle of flexion, before starting to rise at about 40% of the lift. The greatest change in angle was found in Weightlifter 5, who had the curviest spine.

### 3.2. PELVIS' KINEMATICS

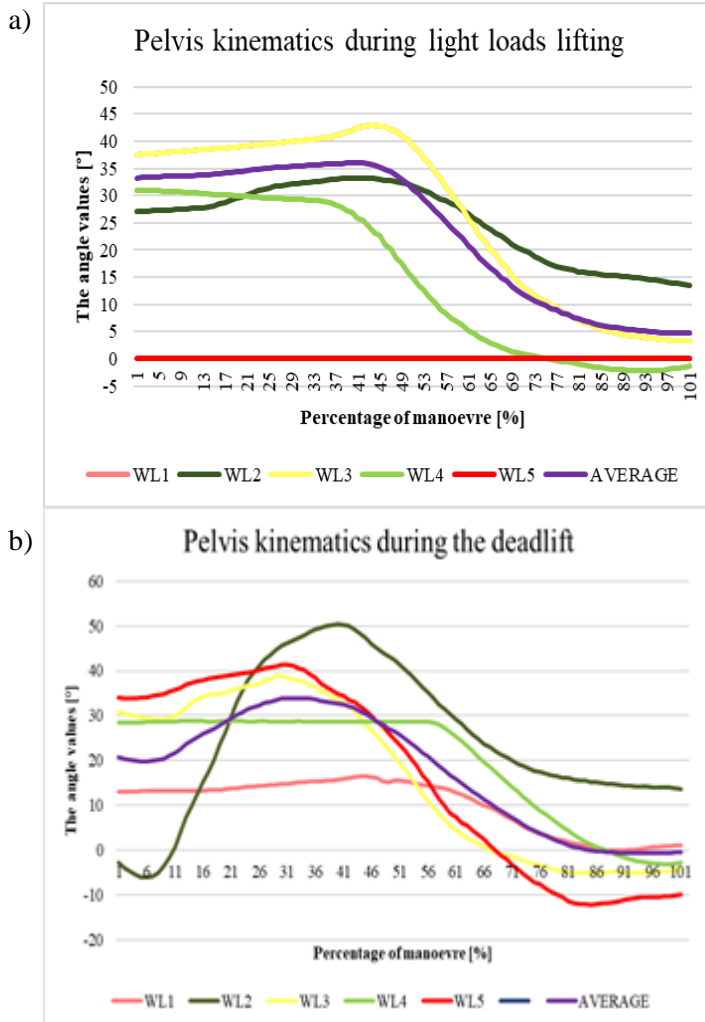


Fig. 2. The pelvis kinematics during the lifting manoeuvre for light loads (a) and deadlift (b)

The diagram shows the difference in the pelvis angle for each weightlifter. For WL2 the tenor of curve started from small angles; then the pelvic angle rose quickly and dropped gently with visible flexion at the final phase of the recorded values.

For weightlifters 1 and 4 at the moment of taking the weight from the ground the angle remained constant for more than half the lift before falling steadily.

Weightlifters 3 and 5 increased their pelvic angle through the first third of the lift before, again, the angle falling towards zero.

For weightlifter 2 once again we observed that his body did not flex a lot in this area. For other subjects analysed, there are visible extensions in the pelvis area with the biggest one for weightlifter 1. The data for weightlifter 3 trail was not recorded.

### 3.3. KNEES' KINEMATICS

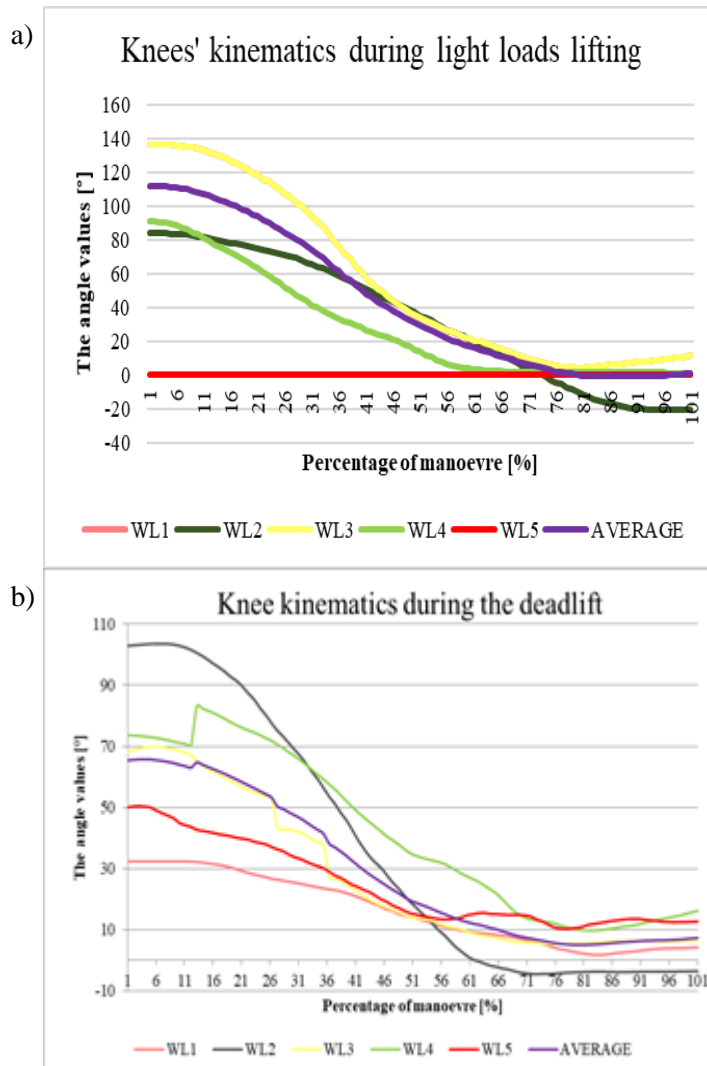


Fig. 3. The knee kinematics during the lifting manoeuvre for light loads (a) and deadlift (b)

There was a noticeably smaller value for weightlifter 1. At the end of the lift there was still a small flexion for most of the weightlifters. Only weightlifter 5 presented a small extension at the end of the lift, which could be caused by the large weight he lifted (220 kg).

Knee flexion reflects how deeply the subject squatted. WL1 adopted a very different position than the others. The knee flexion angle of weightlifter 4 dropped the quickest, indicating a more rapid straightening of the leg during the lift, in comparison with weightlifters 2 and 5. The data for weightlifter 3 trail was not recorded.

#### 4. DISCUSSION

The aim in this study was to look at the kinematic process of lifting, especially where a heavy weight is involved. Joints analysed in this study were global lumbar, pelvis and knee joints. During the study the average values for hips, knees and ankles angles and forces were used. The registered angles should be similar. The markers which peeled off pushed us to use the values registered only for one side.

The data collected for all subjects had been summed up in Table 2. It showed the differences in spinal position of each of weightlifters.

Table 2: The kinematics general information presenting the minimal and maximal spinal position for analysed joints

		WL1		WL 2		WL 3		WL 4		WL 5	
		LL	HL	LL	HL	LL	HL	LL	HL	LL	HL
Global lumbar	min	-38.42	-69.99	-47.15	-65.85	-62.28	-64.21	-61.66	-71.64	-61.95	-60.94
	max	-8.93	-10.26	-18.6	-17.73	-8.21	9.3	-13.24	-5.9	-1.69	9.28
	Amp	29.49	59.27	28.55	48.12	54.07	73.51	48.42	65.74	60.27	70.22
pelvis	min	3.23	-0.10	13.48	-6.09	n/a	-5.11	-1.32	-3.07	-2.29	-12.15
	max	37.48	16.52	26.99	50.40	n/a	38.89	31.00	28.81	38.55	41.45
	Amp	34.25	16.61	13.51	56.50	n/a	44	32.32	31.00	40.84	53.6
knee	min	11.44	1.78	-20.24	-4.68	n/a	5.18	0.88	88	17.76	10.11
	max	136.77	32.24	83.76	103.54	n/a	69.91	90.85	83.11	73.27	50.35
	Amp	125.33	30.46	104.00	108.22	n/a	64.73	89.96	73.49	55.56	40.23

#### 4.1. KINEMATICS OF THE LIFTING MANOEUVRE

We investigated the course of the angle during the lifting. At the beginning, we were looking at lifting of light weights. We could notice that the lifting technique during the warm-up is similar to the one used for box lifting presented by Anastasia Pavlova. [2] That confirmed that the subjects with 'curvy' spine had a tendency to bend over or use a stoop technique to lift the weight. People with straighter spines chose to bend their knees and squat. [7]

However, while analysing the kinematics of deadlifting we observed a tendency to the unification of the lifting style. The weightlifters adapt their bodies to the weight taken. Differences presented before are replaced by a technique which became common for all weightlifters. Their lifting manoeuvre showed that when they were taking heavy loads, they presented a tendency to bend their bodies.

Lifting of heavy weights showed us that even if the differences in the spinal curviness were significant we could see that even for normalised data the manoeuvre had a similar course. The studies showed that each subject had done the weightlifting with his own speed but the speed of the trial did not have any influence on kinematics.

If we compare the obtained results to the works of A.V. Pavlova [2] and J.R. Meakin [4], we observe a similarity between the lifting mechanism of a 5 kg box described by them and lifting of light loads. At this stage of the experiment ILSS has a significant influence on the manoeuvre. Contrary to warm-up, ILSS does not play a significant role in the lifting manoeuvre, which emphasises that as the load increases, the body adapts to the exercise by taking the preferred position - the squat. This thesis had been also confirmed by A.V. Pavlova in 2018 [8] where the squat is shown as preferential lifting technique.

#### 4.2. LIMITS OF THE STUDY

The sample size is much too small to compare all degrees of spinal curviness of the subjects. Five different spines considered in this study represent different shapes for all weightlifters analysed. A bigger sample consisting of at least 30 subjects can provide us with a more reliable image of the problem analysed by us.

The comparison of the weightlifters showed different abilities of each subject during the lifting manoeuvre. For each subject we can find different durability of the musculoskeletal system and what is significant, the deadlift weight for one subject should be the warm-up or one of the middle weights for any other of them.

The study was also limited by the group of the subjects who were professional weightlifters whose bodies were already adapted to lifting heavy weights, so their muscles are better trained than the muscles of humans who practise the sport only occasionally.

## 5. CONCLUSION

The presented study demonstrated that even if the differences in the lifting technique are significant during the lifting of small loads, the increasing weight becomes the reason to normalize the lifting technique for all subjects and it is a natural process. The lifting manoeuvre depends on the weight but not on the ILSS.

In order for persons with weightlifting experience to perform the exercise, similar tests should be initiated on the basis of results obtained for an average population that is not professionally involved in weightlifting. The untrained sample will be more relative to an average person and it could provide more realistic data.

## REFERENCES

- [1] HOY, D.; BROOKS, P.; BLYTH, F.; BUCHBINDER, R. The epidemiology of low back pain. *Best practice & research Clinical rheumatology*, 24(6), 2010. p.769-781.
- [2] ROHLMANN, A., ZANDER, T., RAO, M. BERGMAN, G., Applying a follower load delivers realistic results for simulating standing. *Journal of biomechanics*, 42(10), 2009. p.1520-1526.
- [3] PAVLOVA, A.V.; MEAKIN, J.R.; COOPER, K.; BARR, R.J.; ASPDEN, R.M., The lumbar spine has an intrinsic shape specific to each individual that remains a characteristic throughout flexion and extension. *European spine journal*, 2014. 23(1), p.26-32.
- [4] MEAKIN, J.R.; GREGORY, J.S.; ASPDEN, R.M.; SMITH, F.W.; GILBERT, F.J., The intrinsic shape of the human lumbar spine in the supine, standing and sitting postures: characterization using an active shape model. *Journal of anatomy*, 215(2), 2009. p.206-211.
- [5] OGATA, Y.; ANAN, M.; TAKAHASHI, M.; TAKEDA, T.; TANIMOTO, K.; SAWADA, T.; SHINKODA, K., Relationships Between Trunk Movement Patterns During Lifting Tasks Compared With Unloaded Extension From a Flexed Posture. *Journal of manipulative and physiological therapeutics*, 41(3), 2018. p.189-198.
- [6] WALUYA, B.; MARIANI, S., Development of innovative problem based learning model with PMRI-scientific approach using ICT to increase mathematics literacy and independence-character of junior high school students. In *Journal of Physics: Conference Series* (Vol. 983, No. 1, p. 012099). IOP Publishing. 2018, March.
- [7] ZEHR, J.D.; CARNEGIE, D.R.; WELSH, T.N.; BEACH, T.A., A comparative analysis of lumbar spine mechanics during barbell-and crate-lifting: implications for occupational lifting task assessments. *International Journal of Occupational Safety and Ergonomics*, 2018. p.1-8.
- [8] PAVLOVA, A. V., MEAKIN, J. R., COOPER, K., BARR, R. J., & ASPDEN, R. M., Variation in lifting kinematics related to individual intrinsic lumbar curvature: an investigation in healthy adults. *BMJ open sport & exercise medicine*, 4(1), e000374, (2018).



*Key words:*  
*nodal force, remote force, force to surface, FEM*

Dominik PACHNICZ<sup>1</sup>

## **MANDIBLE MUSCLES MODELING IN FEM ANALYSIS: A COMPARISON OF DIFFERENT FORCE APPLYING METHODS**

Finite element methods are frequently utilized in the analysis of mandible bone. Based on the currently available literature, muscle work is usually modeled in form of forces applied in the area of muscle insertions. Numerical software allows on three different ways of force applying. Those methods require different effort on the level of model preparation. To analyze the differences between them, static simulations of the masticatory system have been performed. In the article, a comparison of three methods of force implementation to the model is presented. In the first method, the forces were applied to the geometrically separated surfaces of the muscle insertions. The second method utilized nodal forces, while the third method implemented remote forces were. In the methods utilizing nodal load, two types of selecting nodes in muscle insertion area were used: conversion from the face geometry and manual picking. The results collected using all these methods show strong resemblance. Therefore, they are likely to be utilized interchangeably.

### **1. INTRODUCTION**

Numerical analysis is a commonly utilized tool in research of biological structures. Accurate reconstruction of real working conditions for human body parts is a challenging task due to the need of assuming correct material properties and model load conditions. Furthermore, active structures such as muscles can be difficult to be placed under numerical analysis because of their complex functions and structure. As active biological structures, the skeletal muscles are responsible for producing force, as well as setting the skeleton into motion. What is more, the muscle tissue is very complex, as it is built of elongated, columnar cells, the contraction of which generates motion. In addition, some muscles can be divided into separate heads, only connate at

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the place of their insertion. Resultant forces generated in each head can vary in terms of both direction and magnitude, which further impedes valid imitation of the muscle structure.

In order to put muscle structures under numerical analysis, appropriate assumptions and simplifications are required. Different methods of modeling muscles are commonly utilized. The first method is the most accurate one, as it recreates muscle tissue in its full three-dimensional form using a volumetric model. The second method involves certain simplifications, as the muscles are represented by one or a group of one-dimensional strings attached to a bone model. Among researchers, the most popular method of modeling muscle influence is application of appropriately calculated force at the point of muscle insertion/origin. However, the use of the last approach introduces more assumptions and, along with the intuition of the model creator, requires certain experience. In the numerical software, the application of the force to the model can be performed in three different ways. Research presented in this paper evaluates the sensitivity of numerical calculations for biological structures, with regard to the adopted method of force application.

The evaluation is based on the analysis of the displacements and strains occurring in the model of human mandible subjected to the load. The mandible bone was chosen due to the author's experience in analysis of this kind of bone structure.

## 2. MODELING OF THE MUSCLE FORCE

The muscle is built of numerous fibers, bundled into fascicles. The composition of the fibers is unidirectional, oriented between places of muscle origin and insertion. Analysing muscles in their anatomical form is a demanding task. Because of that, the most commonly utilized method in the numerical analyses of the mandible bone is recreating muscles in the form of forces placed on the area of their insertions, as it allows easy conversion into a numerical model. Contrarily to other methods, it does not require using any additional elements such as body parts or strings, which is advantageous in terms of the simulation solving time. The calculation of muscle forces is based on the static loading schemes, in which they are usually represented by vectors. The majority of the mandible bone analysis research refers to the Nelson's work [1], where muscle work is converted into a set of forces of given magnitude, direction and point of origin.

Software environments for performing structural analyses allow applying forces on solid models (area, lines, keypoints) or finite element models (nodes, elements). In the first option, the load is independent of finite element mesh. Moreover, it involves easier load application, requiring only simple selection of model entities. However, in this approach problems with constraints may occur. In the method of finite-element

loading, the constraints expansion problems are eliminated, nonetheless every modification of the finite element mesh invalidates the load [2]. In the structural simulation, force can be applied in three different ways: as a surface load, as nodal force or as remote force (Fig. 1). In the first method, the force is distributed across the face [3]. In the second method, the force is applied to an individual node or a set of nodes. The remote force is equivalent to both aforementioned methods, however, the spatial location of the force origin can be discretely specified. Therefore, additional momentum can occur.

In biomechanical models of bone structures, muscle force application requires defined muscle insertion areas. In the solid models, additional procedures of extracting surfaces are necessary, for example face splitting by the projected sketch. It gives the possibility of both applying surface force and nodal force by converting geometrical face into mesh nodes. In FE models, the group of nodes can be also selected manually (Fig 2b), although graphical picking is inconvenient.

Briefly, the finite element method is based on a calculation of nodal displacement functions. For this reason, structural loads of different types are approximated to nodal forces, which produce external work equivalent to the applied load. While the nodal force is being applied, its total value can be easily divided by the number of selected nodes. Considering equal division of the vector's magnitude the resultant load intensification can vary over the area of muscle insertion, due to unevenly accumulated nodes (Fig. 2a). This simple and intuitive distribution of nodal force by assigning equal parts of total load magnitude is appropriate for rigid body parts, but in the case of deformable parts the results may be incorrect. Calculation of the consistent nodal forces in structural engineering is usually done using the method of load lumping.

Concentrated load, schematically represented by vector, acts over small portion of a structure, and therefore it can be easily applied to the specific node. However, it is not common to use this kind of load in structural design, for it results in stress concentrations. Muscle force, depicted by the vector, is applied to the model in the same way as nodal forces which are statically and kinematically equivalent to the approximated load.

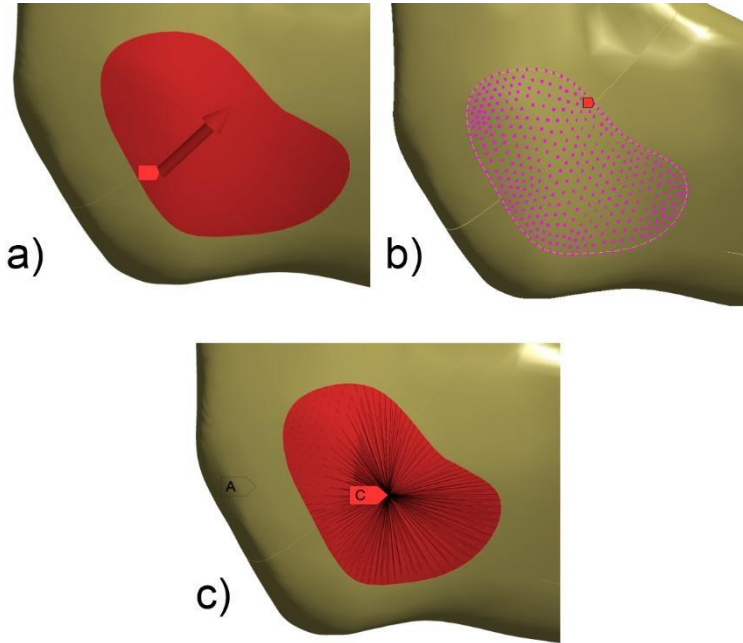


Fig. 1 Force applying methods : a) surface load, b) nodal force, c) remote load

Numerical software converts the surface load into pressure. Due to the fact that pressure acts upon a surface, such like distributed load, it is considered as a surface traction loading. The work done by pressure, described with the formula (1), has to be equal to the work done by nodal forces. For this reason, the calculated equivalent force in each node is expressed by following formulae (2):

$$\int_A \delta \bar{u} \cdot (P d\bar{A}) = \int_A \sum_{I \in E} N_I(\bar{r}) \delta \bar{\Delta}_I \cdot (P d\bar{A}) \quad (1)$$

$$\bar{F}_I = \int_A N_I(\bar{r}) P d\bar{A} \quad (2)$$

where  $\delta u$  is an increment of the displacement at any point on the element (E) face,  $\delta \Delta$  is an corresponding increment in the nodal displacement of the element,  $N_I(r)$ - shape function,  $r$ - point within single element,  $P$ - pressure,  $A$ - area of face or faces [4].

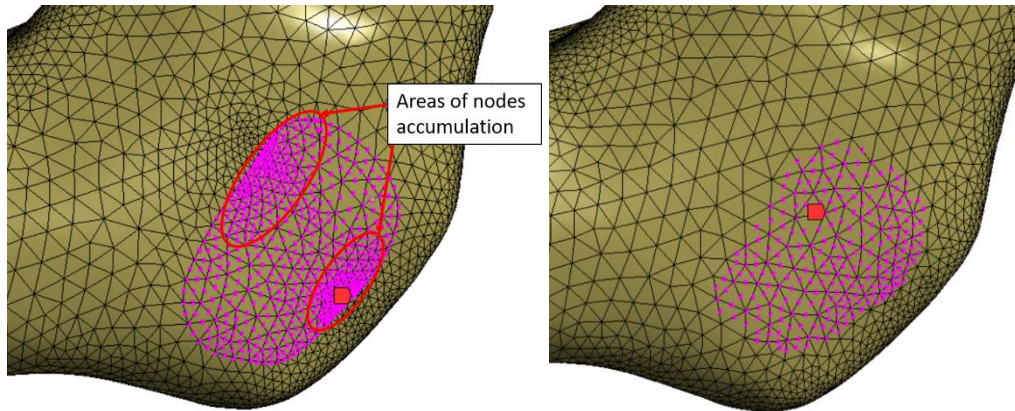


Fig. 2 Nodes of masseter muscle insertion: a) nodes converted from surface, b) graphical selection of nodes

### 3. MATERIALS AND METHODS

Three different methods of loading models with force were considered. Five simulations were performed, one for surface load and two for nodal force and force applied to reference point (first option – muscle insertions were converted from a geometrically extracted model of the face; second option – nodes were selected manually). A reference point was placed in the middle of the muscle insertion area and moved away from surface by 1 mm. Connection between nodes and reference point allowed scoped geometry on deformation. In the simulations, a digital model of human polyurethane mandible was used. The geometry of the bone was reconstructed from CT images. Two structures of cortical and trabecular bone were distinguished. For model discretization, tetrahedral elements of higher range were utilized. The material properties were considered isotropically and linearly, and assigned with the reference to [5], that is:  $E= 16,42$  GPa,  $\nu= 0,32$  for the cortical bone,  $E= 0,482$  GPa and  $\nu= 0,26$  for the cancellous bone. In the simulations, the load of three main masticatory muscles was considered. Directions and magnitudes of total vectors for each muscle were calculated from the proportions given by Chladek [6]. The applied load produced a biting force of 75 N and 150 N for the incisors. The mandible model was constrained in three translational degrees of freedom, at the heads of condyles, as well as vertically, at the place of incisors. Simulations were performed in Ansys 16.0.

#### 4. RESULTS AND FINAL REMARKS

The obtained results are presented in the Table 1. The values of considered parameters for all force loading cases are identical. The only difference is observed for the remote point force loading for manually selected node regions. While the value of maximum principal elastic strain is similar to those in other methods, the deformation is significantly greater (approximately by 44%).

Table 1. Results of the simulations

		Surface load	Nodal force (1)	Nodal force (2)	Remote load (1)	Remote load (2)
75 N	Deformation [mm]	0,018	0,018	0,019	0,018	0,026
	MaxPES [mm/mm]	0,00049	0,00049	0,00046	0,00049	0,00046
150 N	Deformation [mm]	0,037	0,037	0,037	0,037	0,051
	MaxPES [mm/mm]	0,00099	0,00098	0,00092	0,00098	0,00093

Figure 3 presents exemplary distribution of analysed parameters for the model in which the surface load was applied. Deformation as well as strain in the bone model patterns are very similar in all cases. The greatest strain is observed in the area of the incisor teeth.

The presented analysis shows that all available methods of applying force give the same results and can be utilized interchangeably. Manual node picking is the simplest and the quickest way of selecting muscle insertion areas, however every change of finite element mesh invalidates all loads. For this reason it can be recommended only for primary analyses. Remote load gives the possibility to directly set the force loading point according to data available in literature. It may be important for comparative analyses, in which identical reconstruction of boundary conditions is necessary.

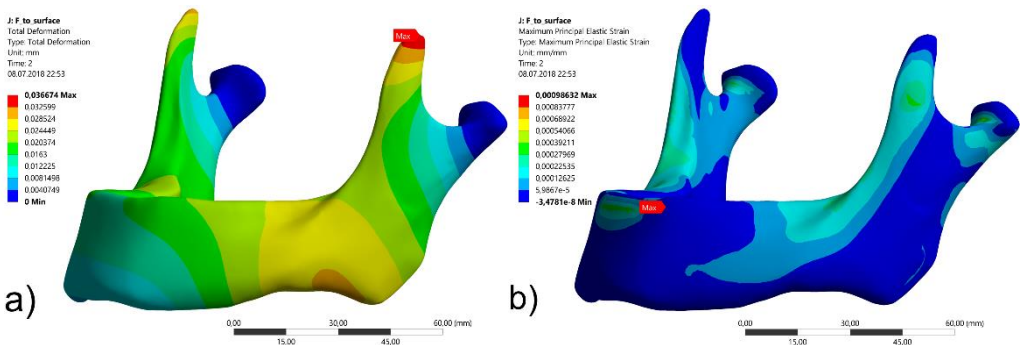


Fig. 3 Parameter distribution pattern: a) Deformation [mm], b) Maximum Principal Elastic Strain [mm/mm]

Nodal loading, that is the application of nodal force or remote loading, contrarily to surface loading, allows to perform simulations using simplified models. An exact reconstruction of the geometrical form of the bone is not essential. It can be replaced by a frame model based on one-dimensional elements.

#### ACKNOWLEDGMENTS

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#### REFERENCES

- [1] NELSON, Gregory J. Three dimensional computer modeling of human mandibular biomechanics. 1986. PhD Thesis. University of British Columbia.
- [2] [www.sharcnet.ca](http://www.sharcnet.ca)
- [3] LEPI, Steven. Practical guide to finite elements: a solid mechanics approach. CRC Press, 1998.
- [4] [www.colorado.edu/engineering/CAS/courses.d/IFEM.d/](http://www.colorado.edu/engineering/CAS/courses.d/IFEM.d/)
- [5] DING, Xi, et al. Effect of orthotropic material on finite element modeling of completely dentate mandible. *Materials & Design*, 2015, 84: 144-153.
- [6] CHLADEK W., System modelowania wybranych stanów mechanicznych żuchwy ludzkiej, *Zeszyty Naukowe. Hutnictwo/Politechnika Śląska*, 2000, 59: 1-108.

*Key words:*  
*music tempo, music articulation, ECG,*  
*PPG, biomedical signal processing*

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## **INFLUENCE OF MUSIC ON HUMAN HEART RATE**

The influence of music on human physiological reactions and emotional states is a subject of many contemporary studies. Investigations performed in order to uncover the influence of specific elements of music can partially explain the similarities and differences between various ways of music perception among population and they can also provide knowledge about new ways in which to use audio material. This article presents results of the study on the influence of tempo and articulation on human heart rate. Four versions of the same fragment of a music piece (L. van Beethoven's finale of IX Symphony to the words of "Ode to Joy") were presented consecutively to a sample group of 33 people at the age of 17-27, in the same conditions (being seated in a bright room, with their eyes open, using wireless headphones). Between consecutive music test examples, a change was applied to only one element of music (for example, change of tempo), while the remaining elements were left unchanged. The data was acquired with the Biopac toolkit. To determine the influence of changes on heart rate, the Student's t-test was applied. It was observed that a decrease in the tempo of music caused a deceleration of the heart rate. A change in articulation technique, from legato (fluent change of tones) to staccato (shortened duration of tones, played in a "spiky" manner), also resulted in acceleration of the heart rate.

### **1. INTRODUCTION**

Music has accompanied humankind since the beginning of the civilization shaping processes, being a natural element of human activity, which developed alongside the progress of cultural expansion with no exceptions [1]. Attempts to uncover the influence of music on human physiology and emotional states have become more popular recently – however relatively few studies focus on testing influence of certain elements of music (except for rhythm, which is well described and widely used as a stimulus, also for therapeutic purposes, for example in rehabilitation

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of movement disorders) [2]. Perception of melody and harmony can be influenced, to some extent, by personal taste, with objective reactions emerging due to existence of musical patterns – eg. patterns of western music, which we learn during the process of growing up [1]. Affective meaning of major and minor modalities confirmed the influence of melody, as an isolated element of music, on human music perception [3]. Similar work was performed in order to find out about the influence of music tempo on emotional states [4]. Changes of tempo can also trigger common physiological reactions like acceleration of the heart rate, along with increase in blood pressure and breathing frequency [5].

The heart belongs to a group of the most important human organs. Electrical impulse, which initiates its mechanical contraction, is propagated along the surface of muscle cells, specially adapted to his role, which form the electrical conduction system of the heart controlled by the extrapyramidal system [6]. Heart rate, which can be easily acquired and precisely analyzed with a range of modern methods, can be thus a source of reliable information about autonomic nervous system activity. Electrocardiography (ECG) and pulse pletysmography (PPG), among others, belong to the most popular heart rate acquisition methods. During an ECG test, electrodes are attached to the patient’s body – if the electrodes are attached correctly, an accurate measurement of electrical field changes can be made. A “lead” in electrocardiography refers to difference of voltage between two (test and reference) electrodes. Commonly, a 12-lead system with 3 bipolar Einthoven leads, 3 unipolar Goldbeger leads and 6 precordial (chest) leads is used [6]. During a PPG test, infrared waves are emitted to tissues of the finger and the intensity of reflected radiation is measured. As an effect, changes in the volume of blood that is flowing through arterioles and venules in the fingers can be detected, determining a heart cycle. Raw ECG and PPG signals have to be filtered in order to eliminate artifacts (noise, isoelectric line drift, miopotentials). The best attempt to retrieve information about the time of the heart contraction can be achieved by determining positions of the ECG and PPG signals local maxima (Fig. 1).

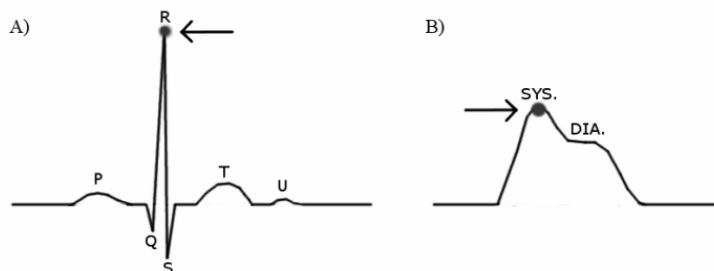


Fig. 1. A) ECG signal period with local maximum, peak of QRS complex representing contraction of the heart left ventricle. B) PPG signal period with local maximum, representing systolic blood flow through the vessels

## 2. MATERIALS AND METHODS

In this study, the sample group consisted of 33 people at the age of 17-27 (20 participants without music education, 8 participants after several music lessons and 5 participants after music school).

The test material consisted of four versions of a music piece fragment, which was L. van Beethoven's finale of IX Symphony to the words of "Ode to Joy", played on the piano by the same performer. The piece had two variants of tempo (fast and slow) and two versions of articulation technique (*legato*<sup>1</sup> and *staccato*<sup>2</sup>). To observe the link between changes in the tested factors and changes in the heart rate, a modification was applied to only one element of music between following one by one test samples, while the remaining elements were left unchanged. The fast tempo value was 125 with meter 4/4, whereas the slow tempo value was 85 with meter 4/4. Consecutive examples were separated by a 5-second break.

For all the participants, the test fragments were presented in the same conditions (being seated in a bright room, with their eyes open, using wireless headphones SENNHEISER TR130). The data was acquired with the BSL PRO 3.7.3 system and the Biopac MP36 unit – the SS4LA pletysmography sensor and the SS2L electrode lead in connection with single-use SORIMEX EK-S 60 PSG electrodes were used. Sensors were attached to the body of the participant according to the Biopac MP36 system documentation [9]. Preparation of the test music track and signal digital filtering and analysis were performed in the MATLAB 2015a programming environment.

In order to obtain information about signal local maxima localizations, threshold detectors were applied on primarily filtered ECG and PPG signals. In terms of analysis, 30-second long fragments of recordings were used – corresponding to the last 30 seconds of the musical pieces fragments presentation, having taken into account the time of heart rate adaptation. The results were presented in the form of showing the time intervals between consecutive heart contraction actions, not yet in *BPM*<sup>3</sup>, since it was desirable to work on highly precise data. The analysis, made in order to find statistically significant differences between the heart rate acquired during the presentation of selected auditory stimuli, was performed in the STATISTICA 13.1 software. At first, the Shapiro-Wilk normality tests were carried out, then, if the data was found to be normally distributed, the Student's t-test for dependent variables was conducted. For all the participants, medium and median values of time intervals between consecutive heart contraction actions were examined.

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<sup>1</sup> *Legato* – used to describe music that is played in a smooth, continuous way [7].

<sup>2</sup> *Staccato* – used to describe musical notes that are short and separate when played [8].

<sup>3</sup> *BPM* – beats per minute.

### 3. RESULTS

The Shapiro-Wilk normality tests results showed that arithmetic mean and median values of the measured time intervals were distributed normally at the ECG and PPG channels.

The Student's t-test for dependent variables results for arithmetic mean values are presented in Tab. 1. Results for median values are shown in Tab. 2.

Tab 1. Student's t-test for dependent variables results concerning arithmetic mean values. Statistical significance coefficient value was  $\alpha = 0.05$ , significant differences are marked in bold

Variable	Channel	Mean	Standard deviation	Difference	Std. dev. difference	<i>t</i>	<i>p</i>
Fast, staccato	ECG	0.76799	0.10422	-0.00145	0.03420	-0.24314	0.80945
Fast, legato	ECG	0.76944	0.09991				
<b>Fast, legato</b>	<b>ECG</b>	<b>0.76944</b>	<b>0.09991</b>	<b>-0.02483</b>	<b>0.04025</b>	<b>-3.54408</b>	<b>0.00124</b>
<b>Slow, legato</b>	<b>ECG</b>	<b>0.79427</b>	<b>0.11313</b>				
<b>Slow, legato</b>	<b>ECG</b>	<b>0.79427</b>	<b>0.11313</b>	<b>0.01914</b>	<b>0.03597</b>	<b>3.05754</b>	<b>0.00448</b>
<b>Slow, staccato</b>	<b>ECG</b>	<b>0.77513</b>	<b>0.10685</b>				
Fast, staccato	PPG	0.76532	0.10241	-0.00369	0.03626	-0.58479	0.56279
Fast, legato	PPG	0.76901	0.09868				
<b>Fast, legato</b>	<b>PPG</b>	<b>0.76901</b>	<b>0.09868</b>	<b>-0.02459</b>	<b>0.04114</b>	<b>-3.43390</b>	<b>0.00167</b>
<b>Slow, legato</b>	<b>PPG</b>	<b>0.79360</b>	<b>0.11276</b>				
<b>Slow, legato</b>	<b>PPG</b>	<b>0.79360</b>	<b>0.11276</b>	<b>0.01870</b>	<b>0.03504</b>	<b>3.06604</b>	<b>0.00439</b>
<b>Slow, staccato</b>	<b>PPG</b>	<b>0.77490</b>	<b>0.10698</b>				

Tab 2. Student's t-test for dependent variables results concerning median values. Statistical significance coefficient value was  $\alpha = 0.05$ , significant differences are marked in bold

Variable	Channel	Mean	Standard deviation	Difference	Std. dev. difference	<i>t</i>	<i>p</i>
Fast, staccato	ECG	0.76558	0.10451	-0.00258	0.03853	-0.38495	0.70282
Fast, legato	ECG	0.76816	0.10168				
<b>Fast, legato</b>	<b>ECG</b>	<b>0.76816</b>	<b>0.10168</b>	<b>-0.02346</b>	<b>0.04239</b>	<b>-3.17968</b>	<b>0.00327</b>
<b>Slow, legato</b>	<b>ECG</b>	<b>0.79162</b>	<b>0.11669</b>				
<b>Slow, legato</b>	<b>ECG</b>	<b>0.79162</b>	<b>0.11669</b>	<b>0.01956</b>	<b>0.04081</b>	<b>2.75335</b>	<b>0.00964</b>
<b>Slow, staccato</b>	<b>ECG</b>	<b>0.77206</b>	<b>0.10944</b>				
Fast, staccato	PPG	0.76556	0.10501	-0.00307	0.03843	-0.45842	0.64975
Fast, legato	PPG	0.76862	0.10198				
<b>Fast, legato</b>	<b>PPG</b>	<b>0.76862</b>	<b>0.10198</b>	<b>-0.02261</b>	<b>0.04286</b>	<b>-3.02974</b>	<b>0.00481</b>
<b>Slow, legato</b>	<b>PPG</b>	<b>0.79123</b>	<b>0.11668</b>				
<b>Slow, legato</b>	<b>PPG</b>	<b>0.79123</b>	<b>0.11668</b>	<b>0.01915</b>	<b>0.03869</b>	<b>2.84378</b>	<b>0.00771</b>
<b>Slow, staccato</b>	<b>PPG</b>	<b>0.77208</b>	<b>0.10887</b>				

Statistically significant differences were observed in arithmetic mean values and median values for music tempo change from fast to slow (with legato being used) and for changes in articulation technique from legato to staccato (with slow tempo

being used). To illustrate the trend of heart rate changes, the charts were prepared (Fig. 2), for mean (part A) and median values (part B).

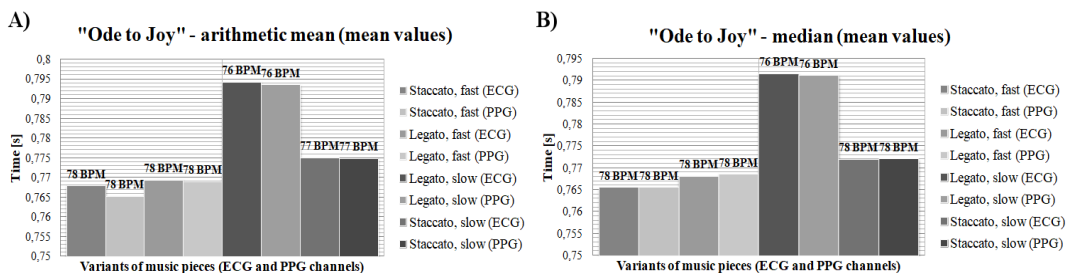


Fig. 2. Tendency of heart rate changes. A) Changes in arithmetic mean values of heart contraction times among participants. B) Changes in median values of heart contraction times

#### 4. DISCUSSION AND SUMMARY

In accordance with the common practice of putting forward and accepting the research hypotheses, the following assumptions in this study have been made: the null hypothesis  $H_0$  did not presume the existence of statistically significant differences between the heart rate before and after applying a change in both of the two performed tests (change of tempo or articulation technique). Alternative hypothesis  $H_1$  for the tempo change test implied deceleration of the heart rate along with decrease in music tempo. Alternative hypothesis  $H_1$  for articulation technique change test implied acceleration of the heart rate corresponding with the technique change from legato to staccato and similarly deceleration of the heart rate along with the change from staccato to legato. The other alternative hypothesis  $H_2$ , in both cases implied that other statistically significant differences, than those implied in  $H_1$ , occurred there. Based on the results of the music tempo change test, obtained during this study, the null hypothesis  $H_0$  may be rejected in favor of adopting the alternative hypothesis  $H_1$ , with the conclusion that deceleration of the heart rate appears as a result of decrease in tempo of music. Regarding articulation technique change test, the null hypothesis  $H_0$  could be rejected in one case in favor of accepting alternative hypothesis  $H_1$ , with the conclusion that the change in articulation technique from legato to staccato causes acceleration of the heart rate. However, attention should be paid to the fact that the test results during the change of techniques from staccato to legato (at fast tempo) did not reach the required level of statistical significance to be considered as a representative result for the population. It may have happened because of the dominant influence of the fast tempo, which affected the heart rate.

Concluding, influence of changes in music tempo (with its dominant role) and articulation technique on human heart rate was perceived and confirmed. Thanks

to the simultaneous implementation of ECG and PPG channel tests, a link was observed between electrical and mechanical heart activity. Carrying out the acquisition on two channels concurrently also helped in the evaluation of the measured time intervals, if artifacts (caused by miopotentials) occurred in one from the signals.

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#### REFERENCES

- [1] FITCH, W. T. *Four principles of bio-musicology*. Phil. Trans. R. Soc., 2015, B 370: 20140091.
- [2] THAUT, M.H.; ABIRU, M. *Rhythmic Auditory Stimulation in Rehabilitation of Movement Disorders: A Review of Current Research*. Music Perception: An Interdisciplinary Journal, Vol. 27 No. 4, April 2010; (pp. 263-269).
- [3] HEVNER, K. *The Affective Character of the Major and Minor Modes in Music*. The American Journal of Psychology, Vol. 47 No. 1, 1935; (pp. 103-118).
- [4] HEVNER, K. *The Affective Value of Pitch and Tempo in Music*. The American Journal of Psychology, 1937; (pp. 621-630).
- [5] BERNARDI, L.; PORTA, C.; SLEIGHT P. *Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence*. Heart, Vol. 96, 2006; (pp. 445-452).
- [6] SORNMO, L.; LAGUNA, P. *Bioelectrical Signal Processing in Cardiac and Neurological Applications*. Elsevier Academic Press, 2005; (Ch. 6, pp. 411-430).
- [7] CAMBRIDGE DICTIONARY, url: [dictionary.cambridge.org/dictionary/english/legato](http://dictionary.cambridge.org/dictionary/english/legato) (06.07.18).
- [8] CAMBRIDGE DICTIONARY, url: [dictionary.cambridge.org/dictionary/english/staccato](http://dictionary.cambridge.org/dictionary/english/staccato) (06.07.18).
- [9] BIOPAC SYSTEMS INC., *Biopac Student Lab PRO Manual*; (pp. 41-63).

*Key words:*  
*liposomes, extrusion, Hofmeister series, ionic strength, lipid bilayer*

Joanna HAJDUK, Paulina DAŁEK<sup>1</sup>

## **EFFECT OF SELECTED CATIONS FROM HOFMEISTER SERIES ON MECHANICAL PROPERTIES OF EXTRUDED LIPOSOMES**

Liposomes are spherical vesicles built from one or more phospholipid bilayers. In biophysical studies of cell membranes liposomes are often used as experimental models, because they allow reduction of the complexity of the experimental system. Liposomes are also increasingly used as targeted drug delivery systems. Understanding how various salts or ions affect lipid membrane properties may be significant in creating liposomal drugs or measuring different liposome properties in buffers that contain ions. The main purpose of this study was to determine the effectivity of the extrusion process, extrusion force and size of created liposomes are affected by selected biologically important ions. The effect of four different cations ( $K^+$ ,  $Na^+$ ,  $Ca^{2+}$  and  $Mg^{2+}$ ) at physiological concentrations has been studied. MLV (multilamellar liposome vesicles) were extruded through a polycarbonate membrane with fixed speed and the force needed for this process have been measured. No significant changes in extrusion force were observed. However it has been shown, that ionic strength can affect liposome size and polydispersity index.

### 1. INTRODUCTION

Liposomes are small spherical vesicles, consisting of the water phase, surrounded by one (unilamellar vesicles) or many lipid bilayers (multilamellar vesicles MLV) [1]. Unilamellar vesicles, depending on size, are divided into 3 groups: small unilamellar vesicles (SUV) up to  $0,1 \mu m$  in diameter, large unilamellar vesicles (LUV) with diameter  $0,1-1 \mu m$  and giant unilamellar vesicles (GUV)  $> 1 \mu m$  in diameter [2]. Lipid bilayers are built from phospholipids, which have two distinctly different regions: hydrophobic tails and hydrophilic heads. Because of these amphipathic properties, in

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water lipids spontaneously form lipid bilayer (or another structure, depending on the molecular shape of the phospholipid) [3].

Measurements of biomembranes are difficult due to their complexity. Therefore for biophysical studies of membrane properties, different kinds of models are used. One of them are liposomes [4]. Liposomes are also used as nanocarriers in drug delivery, for example in cancer treatment. They can deliver drugs directly to diseased tissue, reducing the drug toxicity and extend the tissue exposure [5].

At the end of 19<sup>th</sup> century, Franz Hofmeister noticed that different salts have different abilities to salt out the proteins from solutions. His research resulted in categorise the ions in Hofmeister series, depending on their salting out effects [6]. Ion–interfaces interaction affects the stability and properties of biomembranes, nucleic acid, enzymatic activity and many biological processes [7].

In polar medium dispersed particles may acquire surface charge, what affect the distribution of ions nearby. According to the Gouy-Chapman-Stern model in electrolyte solutions around objects electric double-layer is formed, composed from counter-ions and co-ions. Counter ions are ions of opposite charge, and co-ions has the same charge as the charged particle. The first layer is called the Stern layer and it is created by absorbed counter-ions. The second layer – the diffuse layer – is composed of free counter-ions and co-ions [8, 9]. Debye length ( $\kappa^{-1}$ ) is the thickness of the diffuse double layer. It is given by a formula:

$$\kappa^{-1} = \sqrt{\frac{\epsilon_0 \epsilon_r k T}{2 N_A e^2 I}} \quad (1)$$

Where:  $\epsilon_0$  – permittivity of free space,  $\epsilon_r$  – dielectric constant,  $I$  – ionic strength,  $k$  – Boltzmann constant,  $T$  – absolute temperature,  $e$  – elementary charge,  $N_A$  – Avogadro number.

Modification of ionic concentration in solution cause change of electric bilayer thickness and hence it affects particles diffusion speed. The higher conductivity media, the smaller is a measured hydrodynamic diameter of a particulate [10].

## 2. MATERIALS AND METHODS

### 2.1. MATERIALS

Potassium chloride (99,5%) was purchased from POCH (Gliwice, Poland). Sodium chloride and chloroform were from VWR Chemicals (Radnor, USA). Magnesium chloride and calcium chloride of purity > 99% were purchased from Champur (Piekary Slaskie, Poland) and rapeseed lecithin from Somar (Wachock, Poland). All

chemicals were used without further purification. Solutions were prepared with deionized water (Wodimed, Krakow), with the conductivity less than 2  $\mu\text{S}/\text{cm}$ .

## 2.2. PREPARATION OF LIPOSOMES AND EXTRUSION

Liposomes were prepared using the lipid film hydration method. First, lecithin was dissolved in chloroform in a glass bottle and mixed until the clear solution was obtained. Then organic solvent was evaporated, using argon stream in a fume hood. As a result, on the walls of the bottle thin lipid film was formed. The bottle was placed under the vacuum overnight, to make sure that all the solvent had been removed. Next step was the rehydration of the dry lipid film with prepared in advanced aqueous solution and shaking the sample for about 10 minutes to get a milky suspension [11]. As a result of the procedure, the multilamellar vesicles were formed.

To reduce the size of MLV liposomes and create small or large unilamellar vesicles, external energy must be delivered to the system due to LUVs and SUVs have higher free energies than MLVs [12]. One of many techniques of downsizing particles is an extrusion.

Created multilamellar vesicles were extruded through the polycarbonate filters with pore size 100 nm (Whatman, UK). The extruder used for measurements (Fig. 1) was designed for the purpose. The device allows to select the process parameters and to measure the force needed to extrude liposome suspension through the membrane.

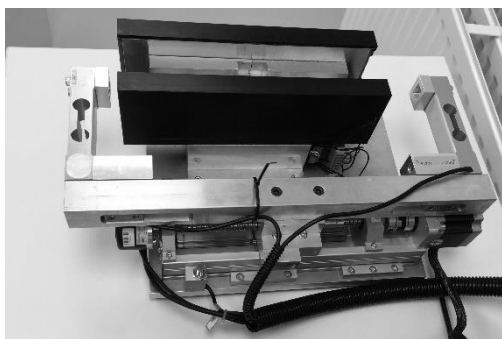


Fig. 1. Extruder used for measurements



Fig. 2. The set of removable part in the extruder

## 2.3. EXPERIMENTAL DESIGN

For the measurements chlorides of four different biologically important cations have been selected:  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ . They are located in different places of Hoffmeister series. We used  $\text{NaCl}$  and  $\text{KCl}$  at concentrations of 70 mM and 140 mM,  $\text{CaCl}_2$  and  $\text{MgCl}_2$  at concentrations of 3 mM, mixed with 140mM  $\text{KCl}$  or 140 mM



NaCl. Those concentrations are similar to physiological ones. Liposome suspensions with deionized water were also prepared as a control sample. Preparation of every sample was repeated 3 times. Every sample was extruded 11 times through membrane with constant speed 1,5 mm/s. After every extrusion liposomes size was measured using a dynamic light scattering technique (NanoSizer, Malvern, UK). The capacity of used syringes was 1 ml (Fig. 2). Liposome concentration in each sample was 2 mg/ml.

## 2.4. DATA ANALYSIS

Fig. 3. shows an example of data received from one extrusion cycle. It has been arbitrary divided into 4 phases. In the first phase force is equal zero, when the arms of extruder did not start to push syringe plunger. In the second phase force grows rapidly.

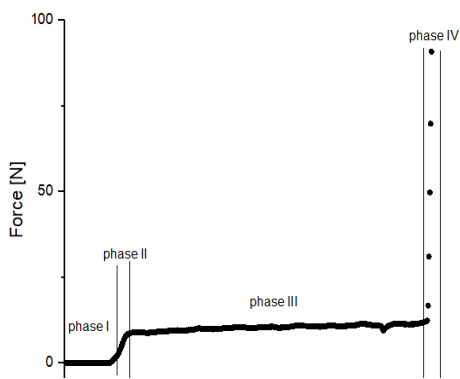


Fig. 3. First cycle of extrusion of liposomes dispersed in 70 mM KCl

The force, applied to first syringe plunger increases fluid pressure and cause the fluid flow to the second syringe. In the third phase the force rises slowly. This phase lasts about 30 seconds. In fourth phase a sudden rise of force up to threshold value (190N) has been observed, when the force is applied to the empty syringe.

Mean value of force was calculated from third, stable phase of the extrusion cycle. In this case standard deviation was taken as measurement uncertainty.

Mean values were calculated only from three first cycles, because they were considered as reliable. Mean extrusion forces for selected solvents for all series, are presented in Fig. 4A-C.

Data received from size measurements were averaged for every 3 series. The standard deviation was calculated. PDI values not always were less than 0,1, what may be caused by heterogeneity of used material. Correlation functions for all samples were correct – quality parameters were fulfilled.

## 3. RESULTS AND DISCUSSION

The main goal of measurements was to determine how different ions at physiological concentrations affect extrusion force and size of created liposomes. Until now there is no uniform theory about how ions influence lipid membranes mechanical properties [13]. It has been previously shown that 100 mM NaCl cause reduction of bending rigidity modulus compared to pure water [14]. However

according to other studies, KCl and KBr salts do not affect bilayer structure and bending rigidity [15].

In this study, new measurement method was used. It should be remembered that not only membrane stiffness might affect the measured force, but also osmotic pressure, flow velocity and lipid concentration.

As it is shown in Fig. 4A-C, there are no significant changes in measured force depending on salts used, especially during the first cycle. However it may be seen that there is a force change for 70 mM KCl in cycle 2 and 3. Values calculated from student's t-test are below 0,05 and therefore the result is statistically significant.

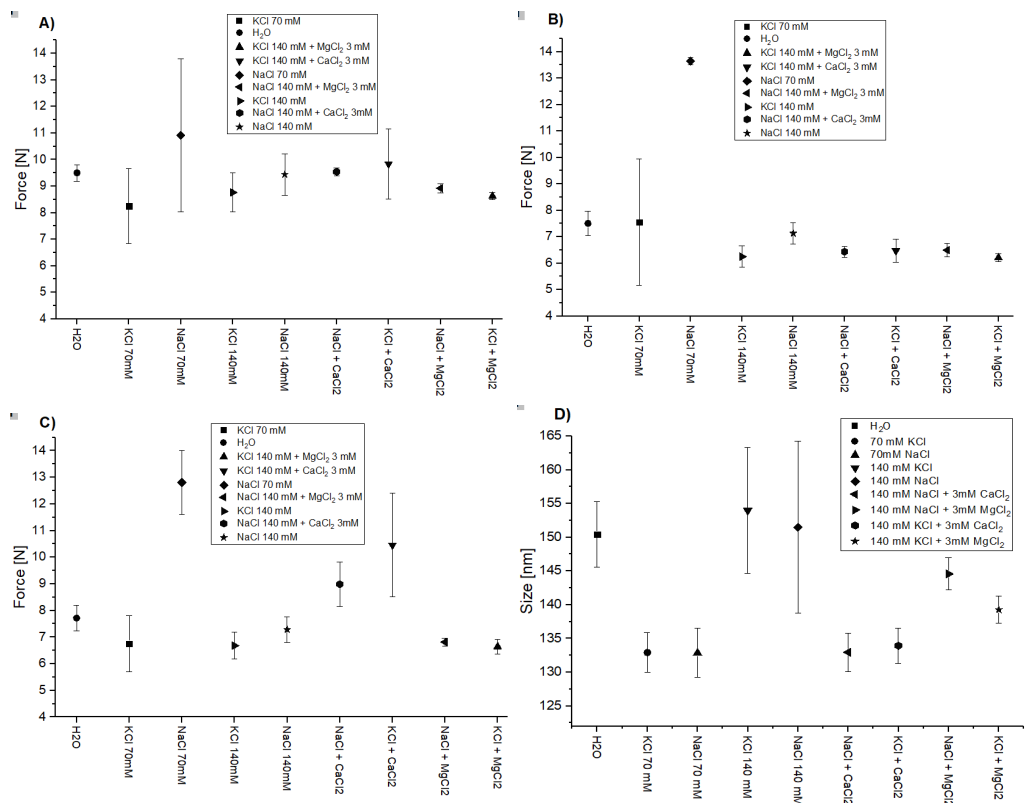


Fig. 4. Mean extrusion force in different solvents and size of liposomes after extrusion. (A) Mean force values for cycle 1 (B) Mean force values for cycle 2 (C) Mean force values for cycle 3. (D) Mean size values after extrusion

In some samples values are different between cycles for the same salt. It may suggest that the small amount of solution stayed in the syringe.

Fig. 4D shows liposomes size after extrusion. PDI values for different salts are shown in Fig. 5. There is a relationship between size and ionic strength, however when we consider values with error bars, changes are not very significant. The largest size was obtained for monovalent ions in concentration 140 mM. They also have the biggest polydispersity and standard deviation. 70 mM  $K^+$  and  $Na^+$  gave similar liposomes size as  $K^+/Ca^{2+}$  and  $K^+/Mg^{2+}$  mixture. Mixtures with magnesium ions gave liposomes a little larger than calcium ions. Liposomes in pure water have the size similar to 140 mM KCl and NaCl. Their polydispersity index is equal to  $0,075\pm 0,011$ .

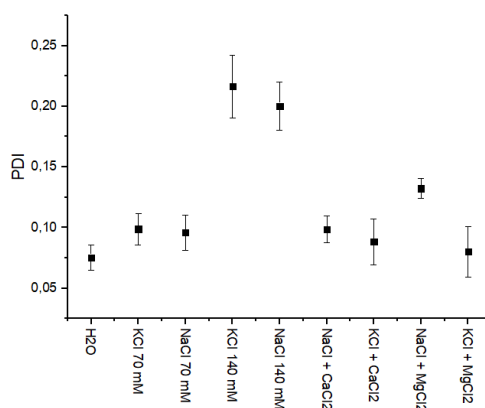


Fig. 5. Mean polydispersity index values depending on salts used

According to those observations it can be concluded, that in presence of 140 mM  $Na^+$  and  $K^+$  effectivity of extrusion process decreases and created liposomes are characterized by largest size dispersity.

## REFERENCES

- [1] EEMAN M., DELEU M., *From biological membranes to biomimetic model membranes*, Biotechnology, Agronomy, Society and Environment Vol. 14, No. 4, 2010, 719–736.
- [2] RAJABI M., MOUSA S., *Lipid Nanoparticles and their Application in Nanomedicine*, Current Pharmaceutical Biotechnology, 17, 2016, 662–672.
- [3] ALBERTS B. et al., *Molecular Biology of the Cell*, Garland Science, New York, 2002.
- [4] HIANIK T., OTTOVA-LEITMANNOVA A., TIEN H., *Physical and Chemical Aspects of Liposomes and Some of Their Applications*, In: Vesicles. Surfactant science series, Rosoff M., Marcel Dekker, Inc., 1996.
- [5] SERCOMBE L., VEERATI T., MOHEIMANI F., et al., *Advances and Challenges of Liposome Assisted Drug Delivery*, Front Pharmacol., 6, 286, 2015.
- [6] CHO Y., HLADÍLKOVÁ J., OKUR H., REMBERT K. et al., *Beyond the Hofmeister Series: Ion-Specific Effects on Proteins and Their Biological Functions*, The Journal Of Physical Chemistry B, 121, 2017, 1997–2014.
- [7] KUNZ W., NOSTRO P., NINHAM B., *The present state of affairs with Hofmeister effects*, Current Opinion in Colloid and Interface Science, 9, 2004, 1–18
- [8] SHAW D., *Introduction to Colloid and Surface Chemistry*, Elsevier Science Ltd., 1992, 174-189.
- [9] USKOKOVIĆ V., *Dynamic Light Scattering Based Microelectrophoresis: Main Prospects and Limitations*, Journal of Dispersion Science and Technology, 33, 2012, 1762–1786.
- [10] M. Instruments, *Dynamic light scattering: an introduction in 30 minutes*, Technical Note, Malvern, MRK656-01, 2012

- [11] PRZYBYŁO M., DRABIK D., ŁUKAWSKI M., LANGNER M., Effect of Monovalent Anions on Water Transmembrane Transport, *J. Phys. Chem. B*, 118, 2014, 11470–11479.
- [12] LASIC D., The mechanism of vesicle formation, *Biochemical Journal*, 256, 1988, 1–11.
- [13] GENOVA J., Martin Mitov Lectures: Measuring the Bending Elasticity of Lipid Bilayers, *Advances in Planar Lipid Bilayers and Liposomes*, 17, 2013, 1–26.
- [14] BOUVRAIS H., DUELUND L., IPSEN JH., Buffers affect the bending rigidity of model lipid membranes, *Langmuir*, 30, 2014, 13–16.
- [15] HARRIES D., PETRACHE H., TRISTRAM–NAGLE S. et al., Swelling of phospholipids by monovalent salt, *The Journal of Lipid Research*, 47, 2, 2006, 302–309.

*Key words:  
water, cleaning*

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## **RESEARCHES OF THE ALTERNATIVE WAYS OF CLEANING WATER**

The article reveals the urgency of solving the problem of finding alternative water cleaning ways and presents a new method, according to Viktor Schaubberger's radical and fundamentally new understanding of the groundwater table's coming into being and functioning in relation to soil temperature.

### **1. INTRODUCTION**

#### **1.1. THE MAIN PROBLEM**

The whole world talks about the problem of water pollution and enormously small amount of water that is suitable for drinking. For more than 100 years all of the leaders in medical research have been saying that drinking up to 2 liters per day will make us much healthier, much more beautiful and will increase life expectancy up to 90-100 years. Fairytale, is it not?

Of course, science does not stand still and so many bright minded scientists are looking for new methods of “fighting” with water pollution.

#### **1.2. MODERN WATER CLEANING METHODS**

Nowadays, the most popular way of water treatment in big cities are chlorination, fluoridation, and using combined filter systems – their prevalence is mainly caused by their low cost and accessibility. Chlorine, being a powerful disinfectant, kills a great

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amount of bacteria, both beneficial and harmful. It also has a detrimental effect on health, caused by its ability to accumulate in the body.

Although the chlorination of drinking and household water-supplies ostensibly removes the threat of water-borne diseases, it does so to the detriment of the consumer. In its function as a water sterilizer or disinfectant, chlorine eradicates all types of bacteria, beneficial and harmful alike. More importantly, it also disinfects the blood (about 80% water) or sap (ditto) and in doing so kills off or seriously weakens many of the immunity-enhancing micro-organisms resident in the body of those organisms constantly forced to consume it. This eventually impairs their immune systems to such a degree that they are no longer able to eject viruses, germs and cancer cells, to which the respective host-bodies ultimately fall victim [1].

Adding fluorosilicates (fluoride) to drinking water has its cons and pros as well.

### 1.3. THE MAIN ADVANTAGES OF ALTERNATIVE WATER CLEANING METHODS

Our scientific research was inspired by the works of the Austrian inventor Viktor Schaubeger. His theories provide new insights into the naturally correct management of water. This includes its proper handling, storage, and conduction by means that promote its self-purification, retention and enhancement of its natural energies and health. The close interconnection between water and the forest (as a water producer - not a water consumer) and the problems of soil salinity, how this comes about through over-exposure of the soil to the radiance of the sun through deforestation and faulty agricultural practices, are also addressed. Indications are given as to how these may be avoided and overcome, according to Viktor Schaubeger's radical and fundamentally new understanding of the coming into being and functioning in relation to soil temperature [1].

Typically, in modern cities, public water supplies are recycled as many as twenty times. Even if the physical contaminants have been removed, their vibrational imprint is still carried in the water's memory bank, no matter how many times it has been recycled. Just as water can carry restorative energies, such as in homeopathy, so it can transmit negative or destructive imprints that can cause disharmony or disease in the body [2].

## 2. THEORETICAL AND PRACTICAL PARTS

### 2.1. BASIC PROCESS PRINCIPLES

As a natural organism, water is formed and functions according to nature's laws and geometry, the latter exhibiting none of the elements of the straight line, circle and

point, the basis of modern mechanical and technological constructs. Reflecting nature's principal constant, namely that of continuous change and transformation, the vortex epitomizes this form of open, fluid and flexible motion. Through his study of the vortices occurring naturally in flowing water and in the air in the form of cyclones and tornadoes, Viktor Schauberger developed his theories of implosion. It was through the research and development of these theories that he was able to produce spring-quality water and generate considerable energy in, and with, water and air.

The water restructuring produced by the better vortex treatment systems, such as the Living Water Jug, which employs Viktor Schauberger's technology should allow superimposed natural vibrations to erase the memory of water's previous abuse. The vortex, being the transmuting agent or the enabling gateway between different qualities or levels of energy, encourages the water to absorb the etheric or cosmic level of energy that surrounds us all. Rather than allowing brilliant sunlight and fresh air to fill a musty room, it will quickly transmute the stale energy, so the more refined energy always prevails over the coarser. We would recommend a combination of an efficient plumbed-in double-carbon filter with a vortex-type re-energizing system [2].

An example of the vortex technique is shown in Fig. 1: (1) the Aquagyro type, (2) the Stuttgart experimental type. (Centrum = center, utlopp = outlet, förorenat = polluted, periferi = peripheral, renare = purified, vatten = water)

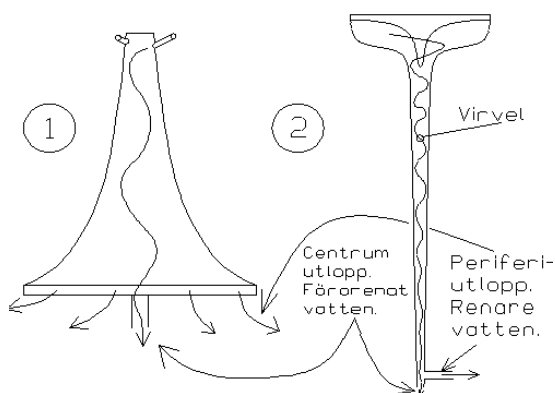


Fig.1. Vortex technique

The goal is to lead water into a big vortex inside a tube. A large amount of the polluting particles is then gathered in the center axis of the vortex. Changes of the chemical properties in the water have been reported, i.e. changes of the content of oxygen, precipitation and bonding of metal ions. Preliminary tests indicate that a multiplied centripetal movement is applied on the media, i.e. spirals within spirals. This movement creates centripetal forces that concentrate the particles in downward space spiral around the central axis.

Viktor Schauberger has reported light phenomena emitting from the tube, something that can derive from rotation excitation. Schauberger also built different kinds of free energy machines, all based on the spiraled shape of the movement.[3]

## 2.2. MAIN FACTORS AFFECTING THE PROCESS

According to Viktor Schauberger, apart from the more familiar categories of water, there are as many varieties of water as there are animals and plants. Were water merely the sterile, distilled H<sub>2</sub>O, as claimed by science, it would be poisonous to all living things. H<sub>2</sub>O or "juvenile water" is sterile, distilled water which is devoid of any so-called "impurities". It has no developed character and qualities. As a young, immature, growing entity, it grasps like a baby at everything within reach. It absorbs the characteristics and properties of whatever it comes into contact with or is attracted to itself in order to grow to maturity. This "everything" - the so-called "impurities" - takes the form of trace elements, minerals, salts and even smells. Were we to drink pure H<sub>2</sub>O constantly, it would quickly leach us out of minerals and trace elements, debilitating and, ultimately, killing us. Like a growing child, juvenile water takes and does not give. Only when mature, i.e. suitably enriched with raw materials, is it in a position to give, to dispense itself freely and willingly, thus enabling the rest of life to develop. Before the birth of water, life was not [1].

Apart from other factors (some cannot be defined quantitatively), encompassing such aspects as turbidity (opaqueness), impurity, and quality, the most crucial factor affecting the health and energy of water is temperature. As a liquid, the behavior of water differs from all other fluids. The latter become consistently and steadily denser with cooling, while water reaches its densest state at a temperature of +4° Celsius (+39.2°F), below which it grows less dense. This is the so-called "anomaly point", or the point of water's anomalous expansion, which is decisive in this regard and has a major influence on its quality. Below this temperature it once more expands. This highest state of density is synonymous with its highest energy content, a factor to be taken carefully into account, since energy can also be equated with life or life-force. Therefore if water's health, energy and life-force are to be maintained at the highest possible level, then certain precautions must be taken, which will be addressed later [1].

Conceived in the cool, dark cradle of the virgin forest, water ripens and matures as it slowly mounts from the depths. On its upward way it gathers trace elements and minerals. Only when it is ripe, and not before, will it emerge from the bowels of the Earth as a spring. As a true spring, in contrast to a seepage spring, it has the temperature of about +4°C (+39.2°F). Here in the cool, diffused light of the forest it begins its long, life-giving cycle as a sparkling, lively, translucent stream; bubbling, gurgling, whirling and gyrating as it wends its way towards the valley. In its natural,



self-cooling, spiraling, convoluting motion, water is able to maintain its vital inner energies, health and purity. In this way it acts as the conveyor of all the necessary minerals, trace elements and other subtle energies to the surrounding environment. Naturally flowing water seeks to flow in darkness or in the diffused light of the forest, thus avoiding the damaging direct light of the sun [1].

### 3. CONCLUSIONS

In order to analyze the above theories and simulate the process, a series of experiments will be held and mathematical cryptography will be conducted using the CAD and CAE systems – Solidworks 2016 Educational Edition and Ansys Workbench.

### REFERENCES

- [1] C.Coats. “THE MAGIC & MAJESTY OF WATER”, Nexus Magazine. (1997, Apr.) [Online]. Available at: <https://www.alivewater.com/viktor-schauberger> [July 28, 2018].
- [2] “Water Purification”. [Online]. Available at: <http://schauberger.co.uk/water-purification/> [July 28, 2018].
- [3] C.Hallberg. “The VORTEX WORLD. Water purification”. [Online]. Available at: <http://www.vortex-world.org/rensnurr.htm> [July 29, 2018].

Monika CZERNIEJEWSKA<sup>1</sup>

## **THE USE OF D-PENICILLAMINE IN NANOTECHNOLOGY\***

Semiconductor nanocrystals are nanopoies smaller than 100 nm and characterized by an energy gap which depends on the particle size [1], [2]. Thanks to the compounds that create them and their unique spatial structure, they have special optical properties [3]. Nanoparticles belong to structures in which the motions of charge carriers can be limited in one, two, or three dimensions [4]. In order to obtain new properties, and the possibility of using them in, for example, biological systems, nanoparticles can be subjected to surface modifications. Adaptations enabling nanostructures to transfer from a hydrophobic environment to a hydrophilic environment are called functionalization processes [5]. D-Penicillamine is used to functionalize nanoparticles as a ligand, due to its small size, non-toxicity, bipolarity, and biocompatibility. The attachment of d-penicillamine to nanoslabs gives them a hydrophilic character [6].

### 1. INTRODUCTION

The term “nanocrystals” refers to nanoparticles typically smaller than 1000 nm with an ordered structure [1]. Nanocrystals may be mono- or polycrystalline [2].

Semiconductor nanocrystals are characterized by an energy gap, which depends on the size of the particles - the effect of quantum confinement. This means that the crystal composition and its size depend on the energy emitted by the excitation of photons [7]. Due to the number of directions (dimensions) in which the size of the nanocrystals is limited to several nanometers, we can distinguish three types of structures: one-dimensional - quantum wells, two-dimensional - quantum wires, and three-dimensional - quantum dots [8].

Another division of semiconductor nanocrystals is the consideration of their dimensionality, i.e. the structure in which the movement of holes and electrons is

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limited in one, two or three directions of space. In this case, the phenomenon of quantizing energy levels occurs, i.e. the phenomenon of a quantized size effect. One-dimensional structures in which the movement of electrons takes place in only one direction are quantum wires. Two-dimensional structures are quantum wells, and zero-dimensional - quantum dots [9], [10].

Depending on the chemical composition, semiconductive nanocrystals are crystalline particles whose diameter is usually in the range of 1 to 10 nm. They are made of several hundred or even several thousand atoms and [11] are synthesized from materials with different physical and chemical properties [12]. In the case of colloidal nanocrystals in their structure, we can distinguish the core and the surrounding coat. The core is made of inorganic semiconductor material, usually from compounds of elements II and IV of the periodic table (eg CdSe, CdTe, ZnS), as well as III and V (eg InP, GaAs) [3]. They are shielded with an organic, outer layer with surface-active molecules, i.e. ligands, ensuring high dispersibility of nanocrystals in the solvent and at the same time repulsive between crystals to prevent their aggregation [11]. To increase the quantum photoluminescence efficiency, the nanocrystal core can be additionally covered with an inorganic jacket with a larger energy gap [13]. In this way, there is an additional spatial separation of the excited holes and electrons from the surface of the nanocrystal, i.e. from the place of potential non-radiation recombination, which limits the intensity of the observed emission from the nanocrystals.

The role of ligands is also extremely important during the synthesis (nucleation and growth) of nanocrystals, because ligands affect the surface energy of nanoparticles, and thus the thermodynamics and kinetics of growth reactions. Therefore, the appropriate selection of ligands allows to obtain not only spherical nanoparticles, but also those with anisotropic shapes, eg wires [14], rods [15], or plates [13] (Fig.1)

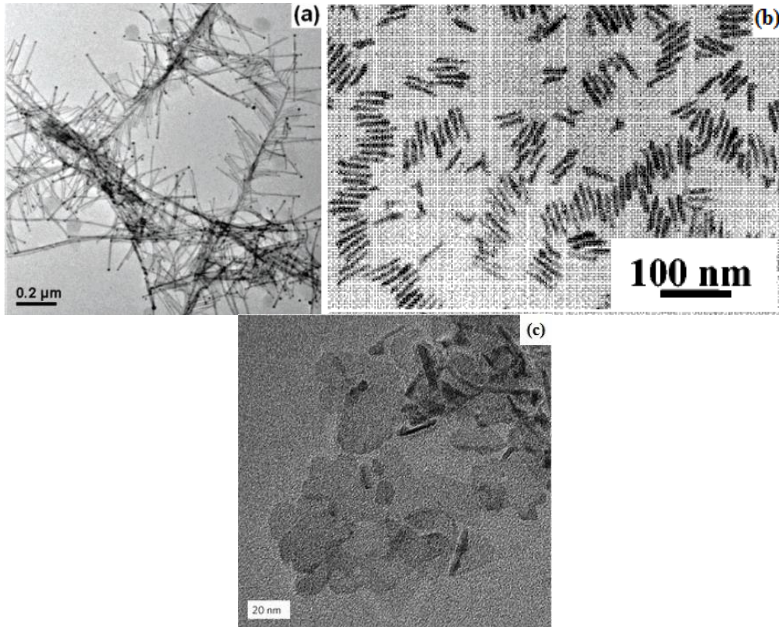


Fig. 1. Spectrum from transmission electron microscopy (TEM) for (a) ZnSe nanowires [14] (b) CdSe nanorods [15] (c) CdS nanowires [13].

Semiconductor nanocrystals have unique physical properties that are strongly dependent on their size [16]. In semiconductors, shape is also an important parameter because it significantly affects the electron spectrum of charge carriers as well as the optical properties of nanocrystals (anisotropic properties of absorption and light emission) [13]. Changes in optical properties depending on the size are a characteristic feature of nanocrystals. Reducing the size of semiconductor nanocrystals increases the energy gap between the basic state and the lowest excited state [17]. At the same time, the bands, valence and conductivity are disconnected, at discrete energy levels.

Semiconductor materials can absorb photons of light with a specific energy, which involves the excitation of electrons, that is, their transition from the ground state to one of the available levels with higher energy [7]. In the ground state, the electrons are located in the semiconductor band. After absorbing a light molecule (photon) of the appropriate wavelength (energy) they can go from the lower band to the higher band, i.e. the conduction band. Radial recombination is one of the ways of returning the excited electron to the ground state. The phenomenon can be observed in the form of photoluminescence [18]. Between the valence band and the band of conductivity there is an excitation band that is inaccessible energetically. For the electron to be excited, the energy supplied must have a greater value than the energy gap [19]. In the case of

semiconductor nanocrystals exhibiting the effect of quantum entrapment, the band gap expands and the valence and conductance bands are split into separated energy levels [17].

## 2. SYNTHESIS OF NANOPARTICLES

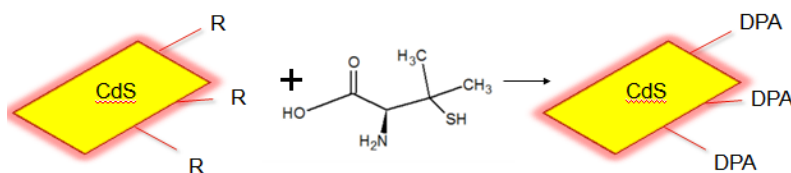
The synthesis of semiconductor nanocrystals in organic solutions consists of injecting precursors into a hot solvent. Precursors, giving monomers of nanocrystals, decompose as a result of thermolysis. Selected organic solvents can be used at high temperatures, thanks to which they can be effectively used in the synthesis of nanocrystals. The variety of solvents used affects the growth rate and the shape of the nanoparticles [12]. Good quality structural and optical nanocrystals are formed at high temperatures, above 200 ° C. The aim of the synthesis is to obtain monodisperse nanomaterials, and it is difficult to do so at low temperatures [20]. Oleic acid is often added to the reaction solution, and, acting as a ligand, it allows controlling the structural and optical properties of the nanoparticles. In this case, the growth of the nanocrystals is more stable and particles are not aggregated [20].

The ligand type can also directly affect the energy levels of the nanocrystalline core. As shown in the literature, induced surface dipoles bound to a ligand molecule may, depending on this structure, shift the absolute arrangement of energy levels by as much as 0.9 eV. This property opens new possibilities when designing efficient electronic devices based on semiconductor nanocrystals [21].

Nanocrystals, due to their very small size, have a very large surface to volume ratio. A relatively large surface area can cause enzymatic degradation to be a very efficient process. Due to the fact that there are confirmed suspicions related to the increased toxicity of these structures, dangerous ions may be released, such as cadmium ions being released from the nanocrystalline core [22]. Cadmium has been classified as toxic because it may cause liver dysfunction or renal failure. To use nanoparticles in medicine, and thus in the human body, it would be beneficial to replace cadmium with other metals, e.g. zinc. This would prevent the formation of carcinogenic cells and other disorders [23]. Unfortunately, such replacement turns out to be disadvantageous due to optical properties. It would shift the absorption and emission bands from the visible range to the ultraviolet range. Another way to reduce unwanted toxic properties would be to use an inorganic shell that surrounds the inside of the nanocrystals. In this case, only the outer cladding can be made of non-toxic semiconductor compounds. For example, a core composed of CdSe molecules can be surrounded by e.g. zinc sulphide - ZnS [24].

An additional challenge to be considered concerning the use of nanocrystals in various fields of science and technology is their hydrophobic character, caused by the use of oleic acid as a ligand in the synthesis process. Therefore, various methods of

surface modification are used to change the character of nanocrystals from hydrophobic to hydrophilic (so-called water transfer). At the same time, specific functional groups are introduced into the organic layer, which allow to increase the range of interaction with the environment. This process is called the functionalization of nanocrystals [25]. An example of the transfer of nanocrystals to water in combination with their functionalization is the process of exchange of ligands from oleic acid to D-penicillamine. D-Penicillamine is a commonly used ligand of small size, which has non-toxic and biocompatible properties [25]. Additionally, it has three functional groups in its structure: a carboxyl group (-COOH), a primary amino group (-NH<sub>2</sub>) and a thiol group (-SH). Due to the diversity of functional groups and their activity, DPA can participate in many reactions such as: nucleophilic addition, oxidation, joining with various metals or free radical transformations [26].



### 3. FUNCTIONALIZATION OF NANOPARTICLES

Surface modifications are a key factor in improving the stability of nanocrystals after their synthesis and they also provide new properties or functions of these particles. These adaptations are also important in terms of phase transfer, i.e. transfer from an organic to inorganic (water) environment. Nanoparticles with a hydrophobic character cannot be dispersed in aqueous solutions, therefore they require changes on their surface, which will expand the possibilities of using nanoparticles for new purposes, e.g. studies of interactions in combination with biological systems [26]. The aforementioned process of change of ligand from oleic acid to d-penicillamine is an example of a frequently used type of functionalization.

The exchange of ligand involves the exchange of primary chemical compounds attached to surface of the structure to other ones that create stronger bonds. These modifications are used to transfer particles to the second phase, reduce toxicity, change the nature of the particles from hydrophobic to hydrophilic, increase stability and control aggregation [21]. The advantage of exchange of ligands is that it provides a possibility of selecting a new ligand, and thus, there is a possibility of shaping almost all properties of nanoparticles. However, in the process of exchange of ligands, it is necessary to disconnect primary ligands. This is a serious threat, as nanocrystals at this time can agglomerate and precipitate from the solution, and their surface can oxidize, which in turn leads to a decrease in photoluminescence performance. Therefore, only an optimal selection of ligand exchange parameters enables full

process performance with high efficiency, while maintaining the initial optical properties of nanocrystals.

#### 4. APPLICATION OF NANOPARTICLES

Nanoparticles have found application in many fields, for example in optoelectronics, electronics or medicine. They are used for the production of electroluminescent diodes, gas sensors, flow reactors, resistors, etc. [27]. Nanocrystals are a future-proof solution for the detection and treatment of tumors [28]. However, the mechanism of action of nanocrystals in the body has not been completely understood as of yet. Researchers have been analyzing the operation of these structures because there are no conclusive research results on the best methods of use, the amount that should be delivered or the metabolism of nanoparticles in the body. These are important parameters that must be known to give a basis for proper determination of the method, location and time (period) of the nanocrystals. The relationships between the composition, size and shape of the particles, and the way of administration and distribution in the body are currently intensively studied, as they constitute extremely important empirical aspects [23, p.].

Penicillamine stimulates the immune system by regulating the immune response of the body. In people with rheumatoid arthritis, who received the drug with the active substance DPA, the level of rheumatoid factor was reduced [29]. D-Penicillamine has anticancer properties and also induces apoptosis by combining with the p53 transcription factor. It reacts with copper, inhibiting the formation of blood vessels of unwanted tissues [30]. Penicillamine is used primarily as a chelating agent for toxic heavy metals such as lead and mercury [31]. DPA was introduced by Walshe in 1956 as an active substance in the treatment of Wilson's disease, which involves the disruption of copper metabolism in the body [32]. In addition, DPA is also used in arsenic compound poisoning therapies [33] and in the treatment of systemic sclerosis [34]. Due to its properties and action, it is an interesting ligand used in various reactions.

#### 5. SUMMARY

Nanoparticles are used in almost every area of life, e.g. electronics, cosmetics, energy, medicine. Thanks to the use of various materials, they constitute an interesting object of research. Their structure at the nano scale allows to obtain new, interesting properties, differing from macro-scale structures. Nanoparticles are currently a tool for bionanotechnology. Semiconductor fluorescent nanocrystals can be associated with

biologically active molecules. However, to be useful, they must meet several conditions, i.e. : water dispersion, small size, chemical stability and high quantum yield of fluorescence. The specific functionalization of nanocrystals with biocompatible compounds allows for a wide range of applications. The functionalization process makes it possible to use nanoparticles in biological systems and, among others, also in cancer therapies. The exchange of ligand allows to obtain hydrophilic nanoparticles, and the use of substances such as d-penicillamine, provides new properties and examples of application.

#### REFERENCES

- [1] J. Misiewicz and P. Podemski, *Optyka struktur półprzewodnikowych*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej, 2008.
- [2] J. L. Burt, J. L. Elechiguerra, J. Reyes-Gasga, J. Martin Montejano-Carrizales, and M. Jose-Yacamán, 'Beyond Archimedean solids: Star polyhedral gold nanocrystals', *J. Cryst. Growth*, vol. 285, no. 4, pp. 681–691, Dec. 2005.
- [3] J. S. Son et al., 'Large-Scale Soft Colloidal Template Synthesis of 1.4 nm Thick CdSe Nanosheets', *Angew. Chem.*, vol. 121, no. 37, pp. 6993–6996, Sep. 2009.
- [4] S. Ithurria, M. D. Tessier, B. Mahler, R. P. S. M. Lobo, B. Dubertret, and A. L. Efros, 'Colloidal nanoplatelets with two-dimensional electronic structure', *Nat. Mater.*, vol. 10, no. 12, pp. 936–941, Dec. 2011.
- [5] A. M. Smith, H. Duan, M. N. Rhyner, G. Ruan, and S. Nie, 'A systematic examination of surface coatings on the optical and chemical properties of semiconductor quantum dots', *Phys. Chem. Chem. Phys.*, vol. 8, no. 33, pp. 3895–3903, 2006.
- [6] S. Tamang, *Synthèse et fonctionnalisation des nanocristaux émettant dans le proche infrarouge pour l'imagerie biologique*. Grenoble, 2011.
- [7] A. M. Smith, H. Duan, A. M. Mohs, and S. Nie, 'Bioconjugated quantum dots for in vivo molecular and cellular imaging', *Adv. Drug Deliv. Rev.*, vol. 60, no. 11, pp. 1226–1240, Aug. 2008.
- [8] P. Harrison and A. Valavanis, *Quantum wells, wires and dots: theoretical and computational physics of semiconductor nanostructures*. John Wiley & Sons, 2005.
- [9] H. D. John, *The Physics of Low-dimensional Semiconductors: An Introduction*. Cambridge University Press, 1998.
- [10] M. J. Kelly, *Low-dimensional Semiconductors: Materials, Physics, Technology, Devices*. Clarendon Press, 1995.
- [11] P. Reiss, 'Synthesis of semiconductor nanocrystals in organic solvents', in *Semiconductor Nanocrystal Quantum Dots*, Springer, Vienna, 2008, pp. 35–72.
- [12] S. Kudera, L. Carbone, L. Manna, and W. J. Parak, 'Growth mechanism, shape and composition control of semiconductor nanocrystals', in *Semiconductor Nanocrystal Quantum Dots*, Springer, Vienna, 2008, pp. 1–34.
- [13] D. Dorfs and A. Eychmüller, 'Multishell Semiconductor Nanocrystals', *Z. Für Phys. Chem.*, vol. 220, no. 12, pp. 1539–1552, 2009.
- [14] A. Dong, R. Tang, and W. E. Buhro, 'Solution-Based Growth and Structural Characterization of Homo- and Heterobranching Semiconductor Nanowires', *J. Am. Chem. Soc.*, vol. 129, no. 40, pp. 12254–12262, Oct. 2007.



- [15] Z. A. Peng and X. Peng, 'Nearly Monodisperse and Shape-Controlled CdSe Nanocrystals via Alternative Routes: Nucleation and Growth', *J. Am. Chem. Soc.*, vol. 124, no. 13, pp. 3343–3353, Apr. 2002.
- [16] B. Mahler, B. Nadal, C. Bouet, G. Patriarche, and B. Dubertret, 'Core/Shell Colloidal Semiconductor Nanoplatelets', *J. Am. Chem. Soc.*, vol. 134, no. 45, pp. 18591–18598, Nov. 2012.
- [17] A. P. Alivisatos, 'Semiconductor Clusters, Nanocrystals, and Quantum Dots', *Science*, vol. 271, no. 5251, pp. 933–937, Feb. 1996.
- [18] L. Jacak and A. Wójs, 'Kropki kwantowe', *Postępy Fiz.*, no. T. 49, z. 1, pp. 1–14, 1998.
- [19] M. A. El-Sayed, 'Small Is Different: Shape-, Size-, and Composition-Dependent Properties of Some Colloidal Semiconductor Nanocrystals', *Acc. Chem. Res.*, vol. 37, no. 5, pp. 326–333, May 2004.
- [20] Y. A. Yang, H. Wu, K. R. Williams, and Y. C. Cao, 'Synthesis of CdSe and CdTe Nanocrystals without Precursor Injection', *Angew. Chem.*, vol. 117, no. 41, pp. 6870–6873, Oct. 2005.
- [21] P. R. Brown et al., 'Energy Level Modification in Lead Sulfide Quantum Dot Thin Films through Ligand Exchange', *ACS Nano*, vol. 8, no. 6, pp. 5863–5872, Jun. 2014.
- [22] F. M. Winnik and D. Maysinger, 'Quantum Dot Cytotoxicity and Ways To Reduce It', *Acc. Chem. Res.*, vol. 46, no. 3, pp. 672–680, Mar. 2013.
- [23] B. A. Rzigalinski and J. S. Strobl, 'Cadmium-containing nanoparticles: Perspectives on pharmacology and toxicology of quantum dots', *Toxicol. Appl. Pharmacol.*, vol. 238, no. 3, pp. 280–288, Aug. 2009.
- [24] V. V. Breus, A. Pietuch, M. Tarantola, T. Basché, and A. Janshoff, 'The effect of surface charge on nonspecific uptake and cytotoxicity of CdSe/ZnS core/shell quantum dots', *Beilstein J. Nanotechnol.*, vol. 6, pp. 281–292, Jan. 2015.
- [25] I. Yildiz, B. McCaughan, S. F. Cruickshank, J. F. Callan, and F. M. Raymo, 'Biocompatible CdSe–ZnS Core–Shell Quantum Dots Coated with Hydrophilic Polythiols', *Langmuir*, vol. 25, no. 12, pp. 7090–7096, Jun. 2009.
- [26] M. Friedman, 'Chemical Basis for Pharmacological and Therapeutic Actions of Penicillamine', in *Protein Crosslinking: Nutritional and Medical Consequences*, M. Friedman, Ed. Boston, MA: Springer US, 1977, pp. 649–673.
- [27] F. E. Kruijs, H. Fissan, and A. Peled, 'Synthesis of nanoparticles in the gas phase for electronic, optical and magnetic applications—a review', *J. Aerosol Sci.*, vol. 29, no. 5, pp. 511–535, Jun. 1998.
- [28] J. Conde, G. Doria, and P. Baptista, 'Noble Metal Nanoparticles Applications in Cancer', *Journal of Drug Delivery*, 2012. [Online]. Available: <https://www.hindawi.com/journals/jdd/2012/751075/abs/>. [Accessed: 18-Jun-2018].
- [29] J. E. Maddison, S. W. Page, and D. B. Church, *Small Animal Clinical Pharmacology*. Elsevier Health Sciences, 2008.
- [30] Pubchem, 'Penicillamine'. [Online]. Available: <https://pubchem.ncbi.nlm.nih.gov/compound/5852>. [Accessed: 04-Nov-2018].
- [31] S. J. S. Flora and V. Pachauri, 'Chelation in Metal Intoxication', *Int. J. Environ. Res. Public Health*, vol. 7, no. 7, pp. 2745–2788, Jun. 2010.
- [32] J. M. Walshe, 'Penicillamine, a new oral therapy for Wilson's disease', *Am. J. Med.*, vol. 21, no. 4, pp. 487–495, Oct. 1956.
- [33] J. Magdalan, M. Smolarek, B. Porebska, M. Zawadzki, and P. Dyś, '[Two different clinical cases of acute arsenic trioxide intoxication].', *Przegl. Lek.*, vol. 64, no. 4–5, pp. 336–338, 2007.
- [34] 'Extracorporeal photophoresis in the treatment of skin disease - ProQuest'. [Online]. Available: <https://search.proquest.com/openview/aa574bcbf86bed7d9a582ca04284a2cb/1?pq-origsite=gscholar&cbl=1286337>. [Accessed: 04-Nov-2018].





**Students'  
Science  
Conference**

# **III**

**COMPUTER SCIENCE, ELECTRONICS  
AND TELECOMMUNICATIONS**

*Key words:*  
*NLP, Machine Learning, Keyword, Watson, Classification*

Csaba AMBRUZS<sup>1</sup>

## **APPLYING HYBRID METHOD IN TEXT CLASSIFICATION**

In this article an automated hybrid text analytics method, which can categorize short English language text in the field of IT risk and compliance into few hundred categories, is shown. The analyses are performed along a 4-level hierarchy with hundreds of categories. The investigation included three analyzing tools: IBM Watson Classifier based on plain machine learning method, Python-based keyword searching method, and IBM Watson Natural Language Understanding. The tools mentioned cannot achieve the right accuracy ratio as standalone tools. In this case, Classifier API can achieve 62% hit ratio on the top categories, and 0% on the fourth level, while the Keyword search engine can achieve about 55% hit ratio on the top categories and about 17% on the lower two levels. The Natural Language Understanding API is used mostly for filling dictionaries with relevant keywords. Based on this result set we can assume that a combination of these tools can reach higher hit ratio. In this article a hybrid algorithm which can achieve more accurate results is proposed.

### **1. INTRODUCTION**

In today's IT, a lot of data is generated every day both in our everyday and business processes.[1] We produce and collect data which we need to analyse later in our decision making processes. The interpretation of these records has been a very important area for decades. This article's basis is a specified data mining method called Natural Language Processing. [1] The NLP was developed in the 1950s as an intersection of artificial intelligence and linguistics and since then this area of data mining has gained more and more interest. [1] Nowadays with NLP APIs which use AI (Artificial Intelligence), we easily can develop applications for text categorization but these methods need extensive training data to work efficiently if the number of categories growing. Our present task is to create a model which can interpret texts in the specific language area described. The specialty is defined by two things: firstly, text cannot be interpreted based on normal daily speech and, secondly, this IT service

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related language area is continuously improving and changing. We need to think of a solution that can support these specialties.

During the planning, we looked at some alternatives and selected two on which we decided to focus:

- traditional solutions based on language analytics (keywords, dictionary-based)
- context-based analytics (machine learning, context analysis).

We decided that both solutions should be analyzed and implemented. The keyword driven analysis was the one with which we started, considering that it will provide information about linguistic forms required for the next step, that is applying machine learning and contextual analysis. The topic of the article is to introduce the approach applying traditional language analytics.

The difficulty of the solution is increased by the four-level category hierarchy which describes approximately 300 categories. These categories often cover each other on sublevels, so it is hard to make a good decision.

The purpose of the analysis is to interpret these audit data, categorize texts and identify the risk issues in an automated way. As it was mentioned earlier, this was done manually [1]. The data will be described later in detail in the Data and Method section.

The purpose of this article is to answer the question if an individual text classification method can reach efficient result on the given text type and given classification system or not, and if not, then whether is there any combination of these tools, a Hybrid method that can reach acceptable result for this hardly categorizable IT Risk text-area.

## 2. DATA AND METHOD

### 2.1. DATA

Some problems revealed during the examination of the data records [1]. Audit records are textual IT risk/problem descriptions. These specific data is restricted to IT areas and within our project; it is limited to English text processing. The data During processing what makes the challenge to be more complicated, that the concerns identified through the audit process are described in compound sentences or a single paragraph might be referring to several problem areas. Because of these, it is required to define a splitting method based on rules, and the analysis must run on these data for the efficient processing.[1] The splitting method will be describer later in detail in the methodology section. One audit record contains several information, about the problem, for example: audit date, account, datasheet name etc., but for text analysis

only one column relevant, and that is the *Concern* field. This field has variable length, so this field is not structured, as they have free text nature.[1].

## 2.2. TOOLS

Two kinds of tool were tried, as it was mentioned earlier. One is a keyword based searcher and the other two are based on Machine learning.

This tools are the follows: a keyword-based Python script, IBM Watson Classifier API (later CLS) and IBM Watson Natural Language Understanding API (later NLU). Finally, IBM Database2 (DB2) is used to store data, and presentation of the results is made by Cognos BI environment.

The IBM Watson Natural Language Classifier API[2] is a machine learning based tool what is able to interpret and evaluate texts. The process starts with the compilation of a CSV file called "training data", which places similar or earlier texts similar to the later text and completes it with the most preferred class / category description, so we can explicitly specify where this text should go our category hierarchy.[2] After making the enough amount and distribution of training text, the next step is the training process itself, which does not require user intervention outside of the upload. The main advantage of this tool is that it is entirely based on machine learning.

We also use the IBM Natural Language Understanding (NLU) API, as the NLU allows natural language processing. This tool has many features, but in this project, we use only one function. This function is that the NLU capable to highlight words, or phrases which are suitable for characterizing the given text, but in this case needed to use another tool what can categorize the highlighted text.

The python script is a keyword based searching device, which uses hundreds of dictionaries with given category names. These dictionaries are filled up with keywords and the python script is searching for these words in the text, and gives back the dictionary name if the keyword matches with the text. For one sentence this could give several findings, and need to take a decision choosing the most relevant from these categories. This selection based on weighted average statistical method.

## 2.3. METHODS

We need to determine rules for the splitting. Some sentences absolutely irrelevant for the analysis, or some sentences just only detail the problem. With this method we can increase the wrong classifications. Let's see an example:

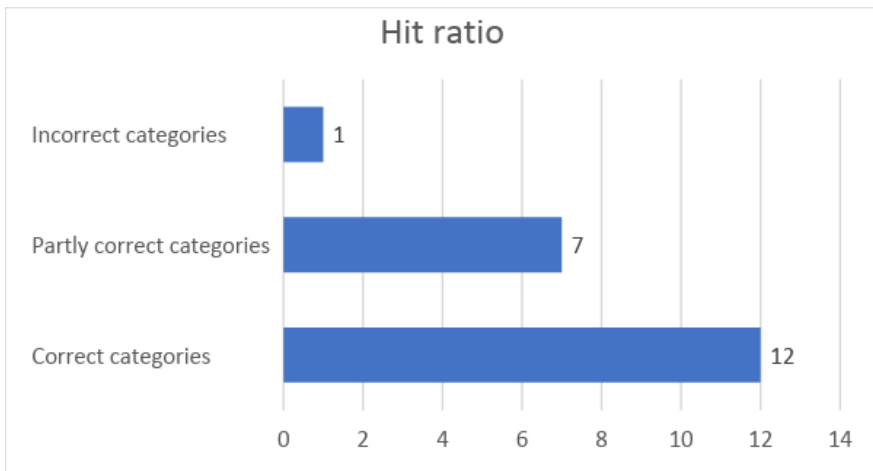
„The password for 'root and factory' had not been set. Further, the password for 'admin' was last changed on April 3, 2017. The password for 'user' was changed the day before testing, but it was unclear what the trigger for this was.”

We can see 3 sentences and this concern describes 2 problems. The second sentence highlighted with yellow detail the problem so it's a concatenate rule, while the third sentence whit the red is a breaking rule. and there are a third rule, what is a deleting rule. This means if a sentence is predicting a problem this sentence is not relevant for analysis for example if a sentence is starts with “This led to”.

The statistical methods are used in this article to enlarge the Classifier hit-ratio, by splitting the result set into two groups, acceptable, or not.

### 3. RESULTS AND DISCUSSION

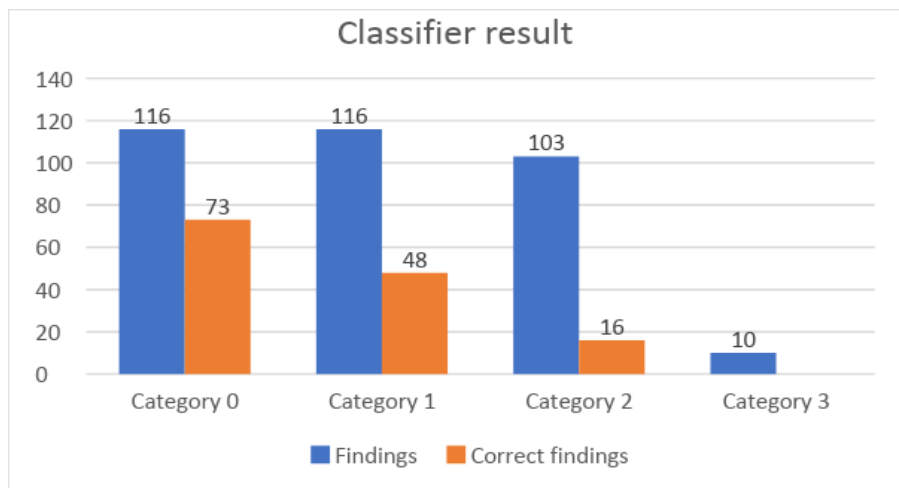
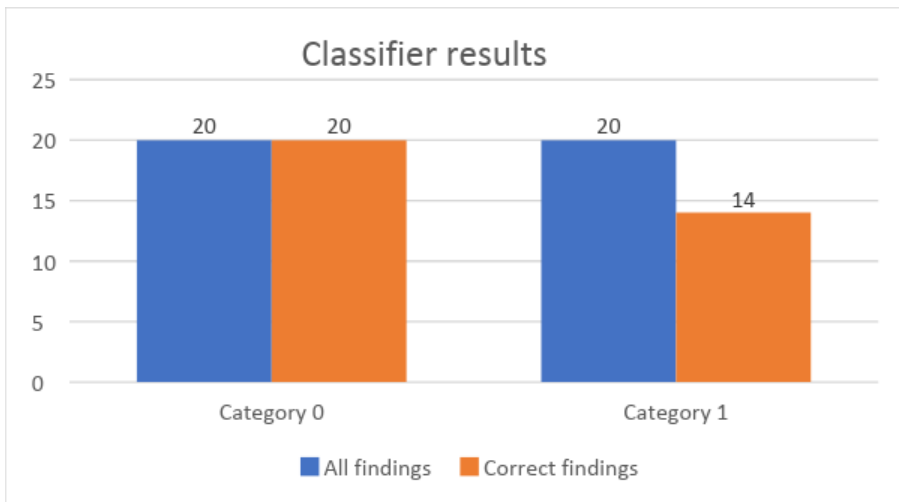
The analysis of 20 *concerns* were evaluated by the keyword-based search. In this case the 20 concerns were selected for 2 main categories including their sublevel categories which have almost perfectly filled dictionaries to the analysis. The Fig 1. shows the hit ratio for the keyword based search, the model sometimes gives same points to findings.



We could see that in this case the keyword based analysis give an acceptable result. In Fig1 the partly correct column means that the top categories matched correctly but the lower levels have mismatch.

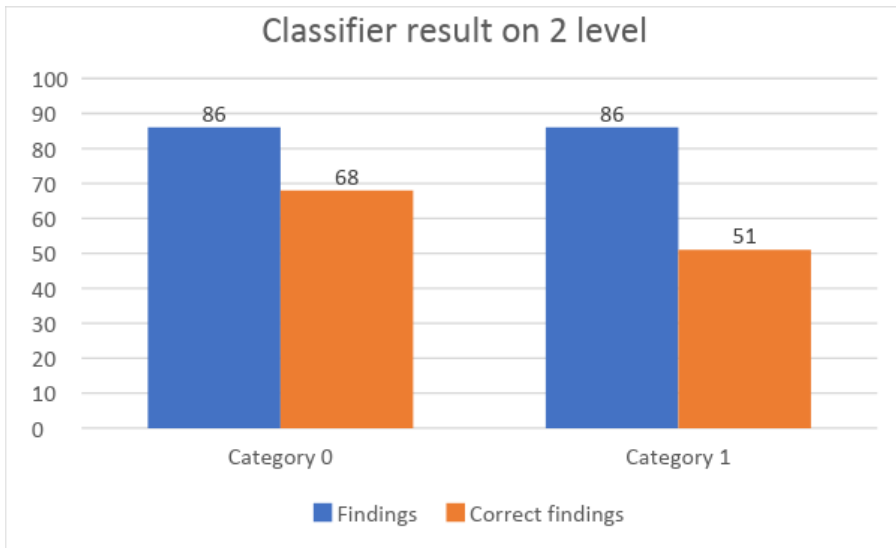
In our real project however, the dictionaries do not fill up with enough words, or they have quality problem, so this result do not show the reality. In the reality there is no way to fill all hundreds of categories efficiently. So, this method is useful only with small number of categories or if the model has well separated categories.

The IBM Watson Classifier results were evaluated similarly to the keyword-based search, and CLS results were evaluated on the same information set. Firstly, the classifier has been used to categorize the text through four level. The Fig 2. shows the result.





We can see that the classifier was not sufficient to categorize the text through 4 level with hundreds of categories. The Classifier work efficiently with small number of categories, so for the next test the training set was modified for only 2 level of the hierarchy. The Fig 3. shows the result of this approach.



We can see that the results are more accurate but, not enough. The results depend on the training file, and to complete this file correctly with many categories is hard or impossible.

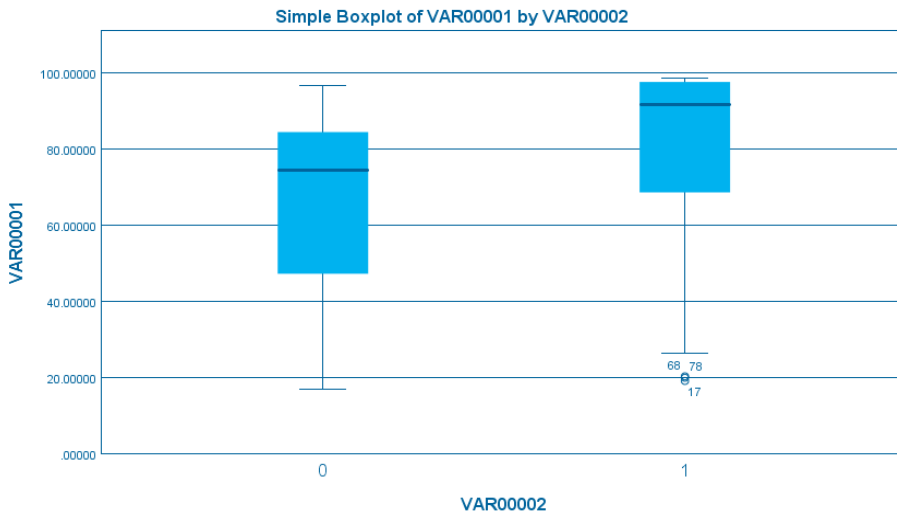
Based on previous result let's see an example similarly to the keyword based model. Get two main categories and their sub levels, what have enough training set, then see what is the result.

The problem with this tool is that it can reach the right hit rate along a small number of categories and with a sufficient number of teaching sentences. Based on an overview of our projects, it is probable that, along this great space, this tool alone cannot provide full classification functionality, but here is a chance to enlarge classifier result with weak training data. In this case we lose some finding because we drop them but the not dropped findings are mostly goods.

The classifier returns a set of categories with a relevance index; this index is between 0% and 100%. We need to set a breaking line for what result is correct or what result is probably bad. We choose this line to 80% based on the next statistical results.

The first is a box-plot method what shows us the shows the percentage deviation of the correct and incorrect results.

In Fig5 in the diagram 0 means that the tested bad records, and the one is the correct records. On the VAR00001 axis we see the relevance in percentage. Based on this box-plot diagram there is not a clean edge what separates the two sets from each other.



Since our dataset consists of a high-level variable and a nominal variable, let's make a variance analysis for the two groups:

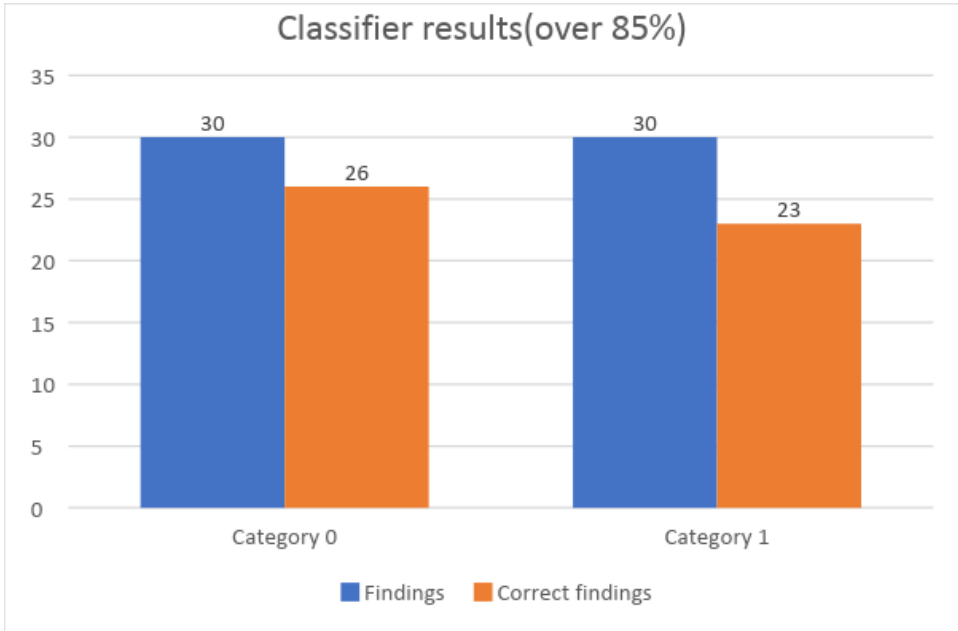
ANOVA

VAR00001

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2563.435	1	2563.435	4.174	.044
Within Groups	51591.718	84	614.187		
Total	54155.153	85			

This result is substantiating the previous result, that we can measure a weak relationship, so a higher percentage of certainty gives a better chance of choosing a good category.

So, we picked up approximate value with 85%. That means if the Classifier result index is over 85% then we accept it as a correct finding. On the next diagram we can see the Classifier result for the top 2 categories with this 85% boundary.



7. Fig. Classifier result with 85% boundary

We can see that with this rule the Classifier can achieve good hit ratio on the top two categories

In this approach the Natural Language Understanding API only used for filling the dictionaries incrementally with words.

From these results we can see that these tools absolutely good for problems what have only few numbers of categories. There are several approaches for all of this method using, but in this specified case the big number of categories makes impossible to use this tools as a standalone application. In the conclusion we provide a Hybrid methodology what could be useful for problems like this.

#### 4. CONCLUSION

As explained it is preferable to use a combination of these devices to increase the result hit ratio, because any combination of these tools can achieve more efficient hit ratio than run of this application one by one singly but, based on the possibilities described in the table, we can still see that there is still a result that will not be consistent either with CLS results after cutting or using the combination.

A method is described, what is combine the keyword based method results and the classifier result, based on some rules. These rules are determined basically on test cases, and a lot of reconciliation with the team who's before did this categorization manually.

**Rule 1:** we need to define a matrix what shows the result, what should be analyzed by the user. The matrix is shown on Fig. 5.

Classifier	Keyword based analysis	Result
a	b	0
a	a	1

As we see there are two options, the first is when the Classifier gives “a” category and the keyword analysis gives “b” category. In this case the result is 0 what represents that this finding is not guaranteed to be correct. If this result is got then the result is set to the Classifier result because this finding is mostly correct on the top levels and that’s more than if we set an incorrect full result. The second options if the tools give the same result, in this case the result is set to the keyword result because this give a more detailed result.

**Rule 2:** is based on rule 1. Combinate the CLS and the keyword results based on the next method. If we get a CLS result with 85% relevance, we pass this findings to the user to take decision, if the relevance over 85% we try to find an additional finding from the keyword based method result (weighted average). We use the CLS Top categories for searching in the keyword result set. If there is a match this finding is going to accepted with the full category of keyword search method. If there is no matching in this case the user can pick a category from them.

As we have described, there is a state where a given record is classified into the wrong category, since the sentence also includes aspects of other categories, but only the human brain is able to separate essential information from the non-essential. a challenge for our age by means of language processing tools. However, machine tools also have an approach or application that can break individual sentences into sub-assemblies. Below the sub-units, we refer to some of the elements of the parts, for example: noun, object. Another important fact is that achieving a 90% rating is a very good result, as 100% classification is not achieved by colleagues as they are mistaken for machines as well.

Based on our findings and experiences, the device is in the present state of text classification, but the results do not reach the 90% -100% limit, which has the

consequence that in some cases, solving the problem still requires human activity. However, looking for additional devices, we discovered the Python NLTK (Natural Language Tool Kit) tool that can break the sentences into the previously mentioned tokens / subunits. Based on a separate evaluation of the individual units, we expect our device to reach the 90-100% ratio even though the individual devices only analyze parts of the sentence. This way we can ensure that the definition of each category is perfect. The method is based on the fact that the main categories can be given with the description of the main nouns, so they describe the problem, while the lower verbs dominate the verbs than the individual parts / moments of each major process. Further development of this tool can be achieved by implementing this guideline into our tool.

## 5. REFERENCES

- [1] A. Csaba and H. Dominik, "Hibrid módszerek alkalmazása szövegklasszifikációs problémában." 2018.
- [2] M. M. Manhaes, "Front cover Building Cognitive Applications with IBM Watson Services : Volume 4 Natural Language Classifier," vol. 4.

*Key words:*  
*gestures, sign language,*  
*convolutional neural network, automatic classification*

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## **GESTURE RECOGNITION USING DEEP LEARNING METHODS**

Gesture is defined as any movement made by someone knowingly or unconsciously, with a certain meaning. Gestures are also part of the "golden triangle" of non-verbal communication, accompanied by gaze and vocalization (vocal communication). All the movements of hands seen during a conversation are called gestures and are mainly used to strengthen the verbal communication.

In this paper a convolutional neural network (CNN) was used for the automatic classification of 87 028 images of the sign language alphabet. Each one of the images served as an input to CNN. The deep learning model extracts the characteristic features from the given gesture, downsamples and prepares it as an input of the artificial neural network. Then the neural network is trained and tested on the prepared dataset.

The CNN was initially trained on 69 600 images of the letters A-Z, then tested on 17 428 images. The final result of this paper is an application whose aim is to recognize and classify human hand gestures from video feed.

In the future this systems may serve, for example as a plugin for video chat applications in automatic translations of sign language to text or sound.

### **1. INTRODUCTION**

Gestures have accompanied people for centuries, they are a very important and inseparable element of our life. They often express emotions, have a certain meaning in the communication process, and even define a person's personalized body language. Not all gestures are universal and they do not mean the same everywhere. They are usually understood only by a certain group of people who originate from the same environment or the same culture.

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Nowadays, with well-developed technology, new solutions are introduced to improve the user's interaction with electronic devices. With the help of gesture recognition not only can a specific application be launched by the user by waving his/her hand in a particular pattern in front of a sensor or camera, but also the communication of Deaf people can be facilitated. These technologies are familiar to most people through the presence of Wii Fit, X-box and PlayStation games such as “Just Dance” and “Kinect Sports”.

Gesture recognition solutions most often use image processing methods, for example, the analysis of the shape of the hand through a number of vertices or the normalized hand's area [10][11]. There are also methods based on detecting the real or filtered skin color, for example based on a RGB for HSV components. In the work of (Sasha Gazman [12]) upper and lower HSV borders were determined for which the region was considered as skin, then the frame underwent dilatation, erosion and Gauss filtration process.

However, most solutions focus on simple functionalities such as controlling a personal computer, display or other device [9]. There are a few applications of gestures recognition for communication. Still, most of the solutions do not have gesture dictionaries or they are based only on a few simple gestures [11].

The high efficiency of the artificial neural networks (ANN) provides an opportunity to teach the program to recognize a large number of elements, e.g. the entire sign language. A convolutional neural network (CNN) is a type of machine learning algorithm that derives from artificial neural networks. It is especially designed to work with images. The algorithm can be divided into two steps: (1) input image processing, (2) applying the artificial neural network. The network is made of neurons that have learnable weights and biases. Each neuron receives some inputs, performs a dot product and optionally follows it with a non-linearity [13].

The huge potential of the CNN is why we decided to use it in our research to develop an application that would use deep learning methods to recognize and classify human hand gestures from a video feed. For this purpose, we used an extensive database of sign language gestures to increase the performance and expand the program's capabilities.

## 2. MATERIALS AND METHODS

### 2.1. MATERIALS

The dataset of 87 028 gestures including signs of the letters A-Z is divided into training and testing set (69 600 and 17 428 images, respectively). The images originate from the *Kaggle* open source science platform and are in .jpeg format.

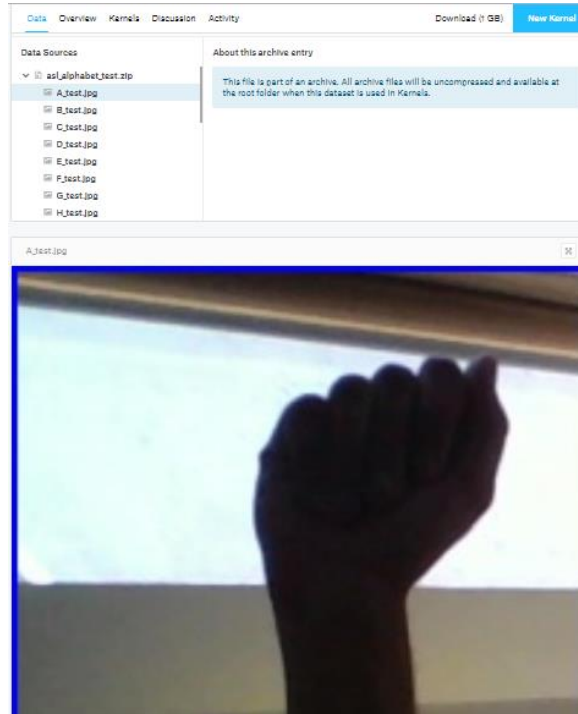


Fig. 2.1. Example image from *Kaggle*

## 2.2. METHODS

All images serve as an input of the CNN that was implemented in the Python and Spyder environment. The deep learning model extracts the characteristic features from the given gesture, downsamples and prepares it as an input of the artificial neural network. Then the neural network is trained and tested on the prepared dataset.

The first step of the image processing part is to apply convolutional operation on an image. This step is done in order to reduce the size and to extract the most valuable and unique combination of features from a given image.

After the convolution, a rectifier activation function is applied to the feature map to remove linearity from image. In simple terms, it replaces all the negative values with zeros.

The feature map is then flattened – a vector is created from the set of pixels obtained in the previous step and is fed to the artificial neural network.

The ANN gathers knowledge by detecting the patterns and relationships in data and learns through experience, not programming.

The CNN might learn to identify images that contain gestures by analysing



example images that have been labelled with letters of the alphabet and use the results to identify the signs in other images. They do this without any prior knowledge about these gestures. Instead, they evolve their own set of relevant characteristics from the learning material that they process.

Convolutional neural network used in this project consist of:

- six layers of convolution,
- two fully-connected layers,
- eleven hidden layers,
- one flattening layer,
- three dropout layers.

### 3. RESULTS

The attempt to recognize gestures using a convolutional neural network was successful. The learning process lasted five epochs, after that the value of network's loss function (Fig.3.1) decreased to 0.149 and the accuracy stood at 95.21% (Fig.3.1).

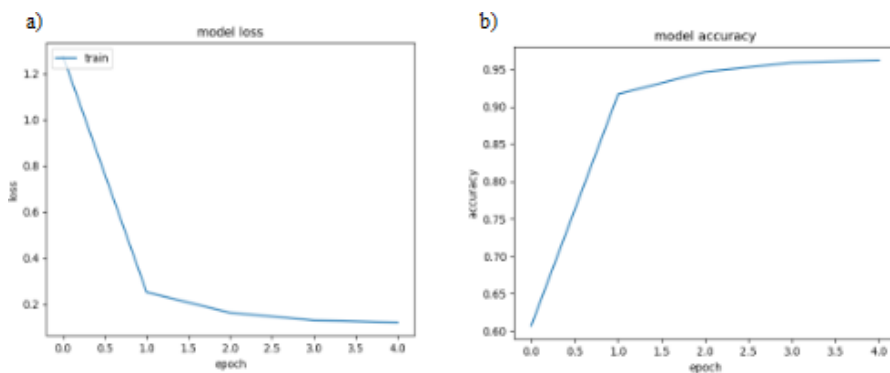


Fig. 3.1. The loss function (a) and accuracy of the convolutional neural network model (b)

Table 3.1. The result obtained after the compilation of the artificial neural network, after 5 epochs

Epoch	Loss Function	Accuracy
1	1.3778	0.5724
2	0.3555	0.8813
3	0.218	0.9269
4	0.1731	0.9438
5	0.1491	0.9521



Fig. 3.2. “A” and “D” letter from American Sign Language Alphabet

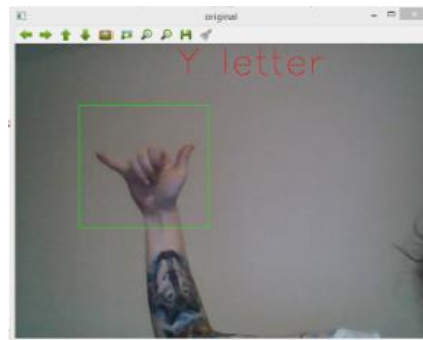
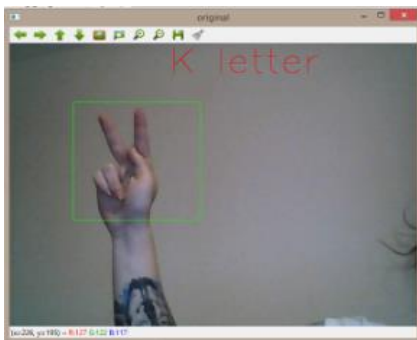


Fig. 3.3. “K” and “Y” letter from American Sign Language Alphabet

#### 4. DISCUSSION

The goal of the presented research was to create an application to recognize and classify human hand gestures from video feed using Python and Spyder environment. This goal was achieved as the accuracy stands at 95.21%. This high result was achieved in an unchanged environment, thanks to the use of an extensive database of 87 028 images and a convolutional neural network. In the future this system may serve, for example as a plugin for video chat applications in automatic translations of sign language to text or sound.

## ACKNOWLEDGMENTS

We would like to express sincere gratitude to our supervisor Paula Stępień and Jacek Kawa for providing comments and suggestions throughout the course of the project.

## REFERENCES

- [1] URBANEK P., *Sztuczne sieci neuronowe, ang. Artificial neural network*, [ftp://zly.iis.p.lodz.pl/pub/laboratoria/P.UrbaneK/PSI\\_BUD/SSN-wyk%B3ad%201.pdf](ftp://zly.iis.p.lodz.pl/pub/laboratoria/P.UrbaneK/PSI_BUD/SSN-wyk%B3ad%201.pdf), [access 20.05.2018].
- [2] TADEUSIEWICZ R., KORBIĆ J., RUTKOWKI L., DUCH W., *Sieci neuronowe w Inżynierii Biomedycznej*, Akademia Oficyna Wydawnicza EXIT.
- [3] STEFANOWSKI J., *Sztuczne sieci neuronowe*, lecture Poznań 2006 <http://www.cs.put.poznan.pl/jstefanowski/aed/TPDANN.pdf> [access 20.05.2018].
- [4] CHORZYK A., *Biocybernetyka – sieci neuronowe*, Akademia Górniczo-Hutnicza, wydział Elektroniki, Automatyki, Informatyki i Inżynierii Biomedycznej.
- [5] <http://www.komunikacjaniewerbalna.com.pl/strona-glowna/gesty/>, [access 20.05.2018].
- [6] <https://encyklopedia.pwn.pl/encyklopedia/gest.html>, [access 20.05.2018].
- [7] <https://keras.io/>, [access 20.05.2018].
- [8] <https://www.kaggle.com/grassknotted/asl-alphabet/home>, [access 20.05.2018].
- [9] <https://ieeexplore.ieee.org/document/6274349>, [access 20.05.2018].
- [10] <https://www.hindawi.com/journals/tswj/2014/267872>, [access 20.05.2018].
- [11] <https://medium.com/@muehler.v/simple-hand-gesture-recognition-using-opencv-and-javascript-eb3d6ced28a0>, [access 20.05.2018].
- [12] [https://github.com/sashagaz/Hand\\_Detection](https://github.com/sashagaz/Hand_Detection), [access 20.05.2018].
- [13] <http://cs231n.github.io/convolutional-networks> [access 20.05.2018].

*Key words:*  
*Optical character recognition,*  
*learning, educational applications*

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## **BENEDICTINE STUDENT ASSISTANT – A CHARACTER RECOGNITION TOOL**

Early 20th century is considered to be the beginning of the history of character recognition. Emanuel Goldberg invented a machine which could read characters and convert them into telegraph code to help the visually impaired. One hundred years later, Optical Character Recognition (OCR), a set of techniques and mechanisms for character recognition, is used to convert text contained in images into editable files. The aim of the presented paper is to introduce the Benedictine Student Assistant – an application which allows to extract and edit text from scanned materials or presentations without the need for cumbersome transcription. The OCR algorithm included in the Benedictine involves capturing the image, preprocessing, detecting Maximally Stable Extremal Regions (MSER), removing non-text regions based on Basic Geometric Properties, Stroke Width Transform, and merging letters into words. The project was developed using ASP.Net MVC technology and has shown large development potential to help students learn faster and better.

### 1. INTRODUCTION

Optical Character Recognition (OCR) is a set of techniques and mechanisms for character recognition which is used to convert text contained in graphics into editable files [1]. Currently, there are several companies working on OCR, but their programs are expensive and students cannot afford buying them. The most well-known company, ABBYY, sells their OCR product for nearly 900 zł [2].

The aim of this project is to create a tool accessible to students who want to save their time and energy while learning from book scans. Graphic files cannot be searched through for keywords and their content cannot be copied directly into text files and edited. To save time, students often learn on the go, for example, when they are on their way to the university. Most frequently they use their phones, but the

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document pages tend to be bigger than phone screens, small characters are illegible and the document has to be read horizontally and swiped back and forth. The presented web application – the Benedictine Student Assistant solves this problem by converting the image online into an editable and scalable text.

## 2. BENEDICTINE STUDENT ASSISTANT

The project was implemented using the ASP.NET MVC platform which is used for writing web applications based on Model-View-Controller pattern using ASP.NET Framework. The website of the project was developed using HTML, CSS and JavaScript. External libraries like Iron Ocr were used to perform the OCR, Cropper.js to eliminate pictures from the image, jQuery and Ajax to exchange information between JavaScript and C#, and quill.js to edit processed text in rich-text editor.



### 2.1 OCR ALGORITHM

Fig. 1. Workflow

The proposed processing algorithm consists of five steps (Fig. 1):

1. Capturing the image – downloading the image on which the OCR operation will be performed.
2. Image pre-processing – the initial preparation of the downloaded image, searching for global contrast based on histogram analysis, followed by subjecting the image to binarization.
3. MSER – region of text occurrence determination. Text is defined as a single difference in contrast (white colour is recognized as background and black colour as text).
4. Removing non-text regions based on Basic Geometric Properties – shape analysis in regions initially recognized as text fields. Unusual shapes are rejected, shapes resembling letters are subject to further analysis. This is due to the inaccuracy of MSER (not every region with large difference in contrast are text regions).
5. Merging recognized letters into words and words into sentences.

The user uploads the graphic file to the website. After that, the uploaded picture is displayed on the screen and the user has the possibility to cut non-text regions and other regions they do not want to process. After accepting, the OCR algorithm commences and the result is shown as plain text which still can be edited. After editing and accepting, the text is ready to be displayed on various devices and browsers.

## 2.2 APPLICATION TESTING

The application was tested on three texts [3-5] from English literature in both good (Fig. 2) and bad (Fig. 3) quality. The letters and words were counted, and the correctness of the approach was calculated as the ratio of correctly recognized items (letters or words) to the number of all items.

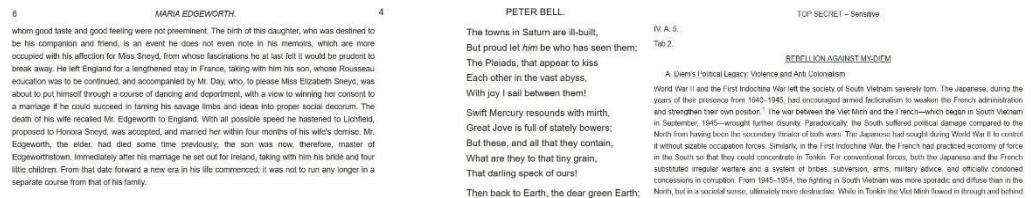


Fig. 2. Text before OCR – good quality

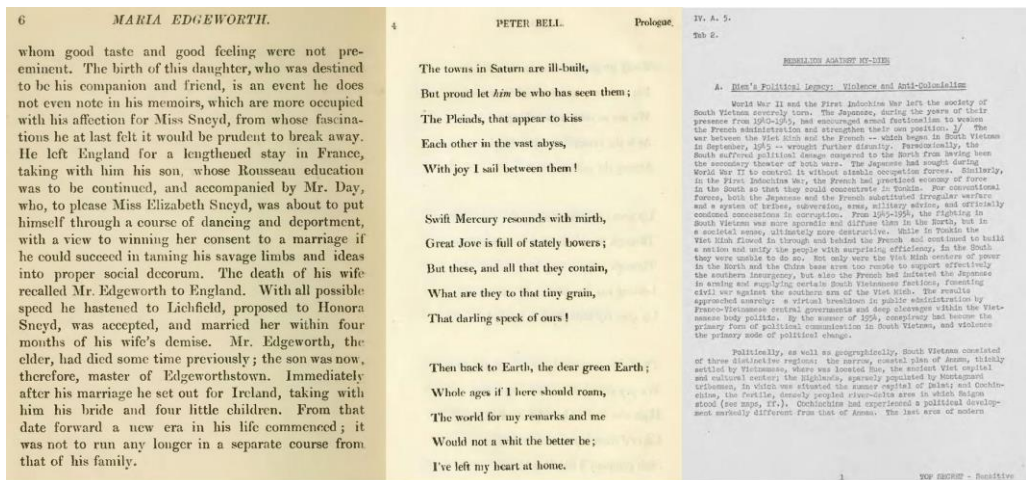


Fig. 3. Text before OCR – bad quality

## 3. RESULTS

An attempt to process those texts into editable ones was successful. For texts in good quality 99.8% of letters and 99.2% of words was recognized correctly. The

results of the test performed on the worse quality texts were less satisfying (Fig. 4). The algorithm failed in 180 out of 4407 letters, which gives 96% and 91.2% correctly recognized letters and words, respectively.

[j] NA 1.711 EDNEWORTII. whom good taste and good feeling were not pre- eminent. The birth of this daughter, who was destined to be his companion and friend, is an event he does not even note in his memoirs, which are more occupied with his affection for Miss Sneyd, from whose fascina— tions he at last felt it would be prudent to break away. He left England for a lengthened stay in France, taking whose Rousseau education was t | l accompanied by Mr. Day, who, t 1 eth Sneyd, was about to put himself through a course of dancing and dcpormcnt, with a view to winning her consent to a marriage if he could succeed in taming his savage limbs and ideas into proper social decorum. The death of his wife recalled Mr. Edgworth to England. W ith all possible speed he hastened to Lichfield, prOposed to Honora Sneyd, was accepted, and married her within four months of his wife's demise. Mr. Edgworth, tho elder, had died some time previously ; the son was now, therefore, master of Edgworthstown. Immediately after his marriage he set out for Ireland, taking with him his bride and four little children. From that date forward a new era in his life commenced; it was not to run any longer in a separate course from. that of his family.

PETER BELL. Prologue, Tho towns in Saturn are ill-bnilt, But proud let him be who has seen them; The Pciads, that appear to kiss Each other in the vast abyss, \With joy I bail between them! Swift Mercury rcmnds with mirth, Great Jove is full of stately l)0\VC!S; But these, and all that they contain, What are they to that tiny grain, Tlmt darling speck of ours ! Then back to Earth, the dear green Earth; \Wlmc :lch if I here should roam, The world for my remarks and me Would not a whit the better be; I've left my heart at home.

IV. A. 5. Tab 2. HEBELIOH (N\AKST MY-DIE-i A. Diem'n Political Mecx: Violeneennz\ Anti-Coloninic: World war II and the First. Indoching War left, the society of South Vietnam Severely tom. Tn' Japanese, during the years of their presence fra 1910-1935, had encouraged umcd factiomlinm to vcaken the French administration and strengthen their om position. y The war between the Valet l-linh and the French -- which began in Ssouth Vietnam in September, 1945 -- wrought further d15m1ty. Pamdoxicnly, the South suffered political duage cmwred to the Mr": rm having been the secondary theater of both wars. The Japonecc had sought during world Var II to control it. without sizable occupation forces. Similarly, in the First. Indoching War, the French hud practiced econxy of force in the South so that they could concentrate in Tenkin. For conventional forces, both the Japanese and the French substituted irregular warfare and a gyste: of bribes, subversion, ems, rilitary advice, and oft'icinally condoned concessions in eormyton. Hon 1916-1951, the fighting in South Vietnam was more sporadic and diffuse than in the North, but, in u societal sense, ultimately core destructive. 3mm in Tonkin the Viet l-linh flawed in through and behind the l-Tanch and continual to build a nation and uniyi the people with nurprining efficiency, in the South they were

Fig. 4. Text after OCR – bad quality

## 4. CONCLUSIONS

Only selected results of conducted research were presented in this paper. Still, the 96% accuracy for letters recognition and 91.2% for full word recognition in the case of texts with bad quality is satisfying.

Benedictine Student Assistant – a character recognition tool project has shown large development potential. Our demo application shows what we want to achieve. In the future, we plan to add support for other languages, eliminate character errors, and automatize picture extraction. In its final version, the tool should be very helpful not only for students, but also for professionals like physicians, teachers or librarians.

## 5. ACKNOWLEDGEMENTS

We would like to thank our supervisor, Paula Stępień, for systematically managing our work, without which the application could not be created.

## REFERENCES

- [1] S. Mori, C. Y. Suen and K. Yamamoto, "Historical review of OCR research and development," in Proceedings of the IEEE, vol. 80, no. 7, pp. 1029-1058, Jul 1992. doi: 10.1109/5.156468
- [2] <https://www.abbyy.store> [access 6.07.2018r].
- [3] [https://en.wikisource.org/wiki/Page:Marie\\_Edgworth\\_\(Zimmern\\_1883\).djvu/18](https://en.wikisource.org/wiki/Page:Marie_Edgworth_(Zimmern_1883).djvu/18) [access 6.07.2018r].
- [4] [https://en.wikisource.org/wiki/Page:Peter\\_Bell\\_\(Wordsworth\).djvu/20](https://en.wikisource.org/wiki/Page:Peter_Bell_(Wordsworth).djvu/20) [access 6.07.2018r].
- [5] [https://en.wikisource.org/wiki/Page:Pentagon-Papers-Part\\_IV.\\_A.\\_5.djvu/98](https://en.wikisource.org/wiki/Page:Pentagon-Papers-Part_IV._A._5.djvu/98) [access 6.07.2018r].

*Key words:*  
*social robot, educational robot, play and learn, robotic teacher, HRI, technology in preschools, geography for children*

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## **THE APPLICATION OF THE SOCIAL ROBOT IN TEACHING PRESCHOOL CHILDREN**

Nowadays, traditional teaching methods are increasingly replaced by modern ones. It is caused by rapid technology development, present in almost every part of our life. Using a social robot can be a practical method to teach children. The purpose of this research is to examine the reactions of preschool children to the social robot and their level of involvement in the geographic game. This is hopefully going to be an effective way to get basic knowledge about the world. The innovative geographical game for preschoolers, implemented on the EMYS robot, has been used as a test platform. The project was created as a part of a learning program at the Wrocław University of Science and Technology. The studies have been performed on three groups of children aged 5 to 7. During the study, the children's level of interest in the robot and their reactions were observed. Later conversations with children and their caretakers largely confirmed earlier assumptions.

### **1. INTRODUCTION**

“Do your parents or sibling play with you often?” This question was asked to children aged 5-7. Unfortunately, the answer was: NO. The social robot can easily fill this hole in the needs of children. The aim is to create a robot that can present the child with the world around them through an interactive game. There are many other robots that found application in education [1] e.g. LEGO Mindstorms robots that teach children ROILA (RObot Integration LAnguage) or Robovie the humanoid robot that teaches English. This assignment is about the educational game intended to teach children geography and examine how the preschoolers react to it. Of course, nothing

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can replace human contact, but can a social robot be a useful teaching instrument? The answer to this question is contained in this article.

The first paragraph contains a description of the created game and its components. The next section describes the test of the EMYS GeoGame that took place in the nursery school. The last paragraph is devoted to the authors' conclusions about the project.

## 2. GEO GAME ELEMENTS



Fig. 1. Components of GeoGame

The main components of the EMYS GeoGame (fig. 1) are: EMYS head with Xbox Kinect, RFID (Radio-frequency identification) reader mounted inside the suitcase, 4 boards representing suitcases from different countries, 8 tiles for each country which include objects, and display (optional). The robotic head has been designed and built within the EU FP7 LIREC project at the Wroclaw University of Science and Technology. EMYS uses the URBI software (open-source software platform in C++ used to develop applications for robotics) that is responsible for controlling the robot and allows it to be programmed in urbiscript language. This platform also provides a GUI (Graphical user interface) software for easily creating state machines – Gostai Studio. RFID reader is used to check the tile or suitcase tag. The actual situation in game is presented on the screen.

### 2.1. GEOGAME DESCRIPTION

Due to Kinect onboard elements and modules implemented by EMYS developers, the robotic head can track the participant's face and understand simple voice commands. EMYS breathes, blinks and moves constantly. He attracts people in his line of vision and invites them to play. The game is divided into two parts. The first is the training mode, in which the robot presents the information about the scanned tile and the second is the right game. As soon as the country suitcase is within the RFID reader's range, EMYS proposes starting the game.

To play GeoGame children have to be divided into teams (1–4 teams, 1–4 children per team). Each group has their own suitcase representing a single country (China,

USA, France or Italy). Each board has to be scanned by the robot's reader. The order of the teams is determined by the order of adding suitcases to the game.

Once the game has begun, the robot points to whose turn it is. The game is played with tiles, which may be covered or not, depending on the children's age and abilities. During their turn, the team has to find the tile that matches the country they represent. After choosing a tile and scanning it into the suitcase with the reader, EMYS performs the appropriate speech depending on the correctness of the tile. If the tile does not match the team's country, the robotic head says that it's incorrect, and tells them what is on the tile. If the tile is correct, the child will hear a short description about the place or thing and can put the tile on the board with the suitcase. The game ends when one of the teams collects all the tiles from their country. The robot will then congratulate them and take a photo of the winners. At this point the game can be continued or concluded.

## 2.2. EMYS BEHAVIOURS

EMYS is the leader of the GeoGame. This means that the robot has to be spontaneous and react appropriately to the current situation in the game. Reactions and behaviors (including lines) have been grouped into corresponding functions, e.g. *ReactForGoodAnswer()*, *ExpressHappiness()*, etc. The EMYS libraries contain ready-made solutions that allow you to move each part separately or perform a full behavior pattern. Apart from ordinary smiles or nodding, the robotic head can make funny faces or even dance. It is essential because children may benefit more from the expressive robot than from the flat one [2].

The performance time of every reaction pattern has to be balanced not to disturb the game dynamic but still be easily noticeable and interpreted by a child. To achieve this goal every one of the behaviors has been tested by several people and the dialogs have been written in a way that is understandable for children. A simple confirmation can give the effect of further action and denial can end it.

## 3. FIELD RESEARCH

One of the purposes of this research was to expose children in kindergarten to the robot (fig. 2). Children had an opportunity to play GeoGame with EMYS. After they were done playing, children had to answer



Fig. 2. Research in nursery school

questions about their interaction with the robot.

The interview was carried out among three different groups. The first group was composed of children aged 6 and 7 years, the second aged 5 and 6 years, and the third group aged 6 and 7 years.

### 3.1. CHILDREN'S REACTION TO EMYS

From the very beginning the project intended to present the finished robot to a group of children aged 5-7. The experiment was conducted with the three following groups:

- a) The first two groups were composed of 4 girls and 4 boys that were previously matched in pairs. In these groups, the illustrations on the tiles were visible.
- b) The third group consisted of 9 children, including 7 girls and 2 boys. In this group the pictures on the tiles were covered. They were split into groups of 4 and 5.

Before the actual game, a short presentation about the robot was shown to all groups. It also allowed them to try out how EMYS reacts to applying the tile. The children were very willing to play together and none of them were frightened.

Children responded very positively to the sounds and music, as well as to the pictures on the screen. It can be assumed that these factors allowed them to remember the knowledge gained during the game to a greater extent. Some children were able to combine facts to get points. For example, a group that had a tile with the outline of a country they already had could associate that a tile with an identical contour and a capital city marked on it can also fit to the possessed suitcase. However, this did not work in every case. On average, half of the groups exhibited analytical thinking. Another interesting observation was that the children in the third group were able to remember where the tile, which had been incorrectly chosen by the previous group, was located in case that tile fit in their suitcase.

### 3.2. RESULTS OF DATA ANALYSIS FROM THE CHILDREN'S INTERVIEW

1. Did you like playing with the robot?

This was one of those questions where all the children from all groups answered yes.

2. Would you like to play with the robot again?

Almost every child answered that they would be happy to play with the robot again. There was only one girl, that refused to play with EMYS again, because she felt tired. She said she would play with the robot only after she rested.

3. Did the robot teach you new things?

Most of the children did not remember specific examples but they claimed that the robot taught them new things. One girl from the first group learned the colors of the Italian flag. Another girl from this group remembered the Triumphal Arch is not located in China. Girls from third group mentioned that Paris was the City of Love and The Great Wall of China was made of rice.

4. Do you like how EMYS looks?

Among all groups of children, only one girl answered no. The thing she did not like was the blue eyelids.

5. Did the robot frighten you?

This is another question where all of the kids answered no. Most of the children saw EMYS before and they thought that the robot had a friendly look.

6. Did you find something annoying about the robot?

Among all of the groups only two girls found something annoying about EMYS. The first girl did not like when the robot yawned, and the second one did not like his eyes and blinking.

7. Did the robot speak clearly?

Due to the EMYS speech synthesizer, kids were asked if they understood what the robot said. All the children claimed they understood everything, and it was not too loud or quiet.

8. What did you like most about the robot?

This was an open-ended question where children could answer what they liked about EMYS. Kids typically mentioned songs, pictures on display, the photo at the end of the game, and the voice and way of talking. Some of them liked the construction of the head.

9. Did you want to have EMYS in your house?

All of the children wanted to have EMYS. Most of them would prefer EMYS rather than an iPhone, even more if EMYS had a lot of games to play.

10. Did you like learning with the robot?

All of them answered that they liked the new way of learning with the use RFID cards.

11. Do you have someone to play with you at home?

Most of the children have problems with finding someone to play at home. Their parents do not have much time and their older brothers or sisters want to play different games.

12. What would you like the robot to do?

This was another open-ended question where the children could point out things that they would like to see in a future robot. Most answers were related to the

movement of the robot. They would like to see it fly, drive a car, and have wheels or moving arms and legs. Other suggestions were to make sweets, display cartoons, and produce toys.

### 3.3. RESULTS OF DATA ANALYSIS FROM THE TEACHERS' QUESTIONNAIRE

One of teachers working at the nursery school was also asked questions referring to the questionnaire that was presented in chapter two. The teacher had cooperated before with a similar project. Mrs. Marzena gave her feedback and conclusions on the experiment. She claimed that there was a good amount of prepared information which was interesting for the children. She also said that the images and sound helped with memorization, learning with EMYS was fun for the children, and they were able to stay focused and not get tired. Her suggestion for improvement was an expansion of the robot's travel history.

## 4. CONCLUSIONS

For quite some time we have known that combining learning with play brings better results than standard familiarization of material. Conducted research showed that children reacted very positively to the robot and they were eager to play together because they did not treat this as learning. The use of sounds and pictures helped them assimilate information, and the game with hidden pictures was additionally stimulating memorization. One big advantage of the GeoGame is the fact that it can be used as a base for other areas of science. Going back to the beginning of the article, it is important to emphasize that EMYS is always ready to play whenever the child wants to. You can see here the undeniable advantage over a human who has limited time and energy for many reasons. GeoGame is an effective and enjoyable method of learning for children in preschool, as well as a solution so flexible and versatile that it can be used as a base for something that can be responsible for children of all ages and in different subject areas.

## REFERENCES

- [1] OMAR MUBIN, CATHERINE J. STEVENS, SULEMAN SHAHID, ABDULLAH AL MAHMUD, AND JIAN-JIE DONG *A review of the applicability of robots in education*. Technology for education and learning, 2013
- [2] KORY WESTLUND, J., JEONG, S., PARK, H. W., RONFARD, S., ADHIKARI, A., HARRIS, P. L., DESTENO, D., & BREAZEAL, C. *Flat versus expressive storytelling: young children's learning and retention of a social robot's narrative*. Frontiers in Human Neuroscience, 11, 2017

*Key words:*  
*IoT, Internet of Things, NB-IoT,*  
*3GPP, hardware developing, cellular network, LPWA*

David SZABO<sup>1</sup>

## **NB-IOT TECHNOLOGY AND ITS APPLICATION**

In June of 2016 the 3rd Generation Partnership Project (3GPP) completed the standardization of the Narrowband IoT (NB-IoT). NB-IoT is a Low Power Wide Area Network (LPWAN) radio technology for the Internet of Things using conventional cellular network. Using unexploited LTE resources, narrowband technology does not require new infrastructure to be built. In this article, a universal NB-IoT device design aspects are investigated – which can be equipped with several types of sensors – along with its platform. During the development we put great emphasis on the requirements and benefits of the standard: increased coverage, lower costs, extended battery life, a vast number of connected devices.

### **1. INTRODUCTION**

The fourth industrial revolution is currently underway. We would like our lives to be easier, and our industrial processes to be more optimized and automated. To reach this goal our society has to go through serious societal, economic and technological development. The cyber-physical systems have appeared, and these cyber-physical systems, namely the IT, software technology, mechanic and electronic parts connected into one system. We can only digitalize and automate our processes if the IT system receives enough information from its environment. The measurement is the sensor's task but we also have to relay this data towards central server or towards another sensor module.

We also have to solve the next problems: connecting devices which are not easily accessible into a network, unavailability of the conventional ways of communication or simply their wastefulness in use. In June 2016 the 3<sup>rd</sup> Generation Partnership Project introduced the Narrowband IoT technology, which is a standardized Low Power Wide Area (LPWA) radio technology precisely tuned for the Internet of Things. It puts a large emphasis on indoors signal coverage, low costs, long battery life and it also tolerates a great number of connected devices. The NB-IoT uses the

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already existing LTE network. According to the analysis of Telekom, approximately 3 billion LPWA devices will be connected to the Internet[1] by 2023. It indicates a design of an NB-IoT solution which allows fast and easy device development. The other reason is that there is no comprehensive solution to this problem yet.

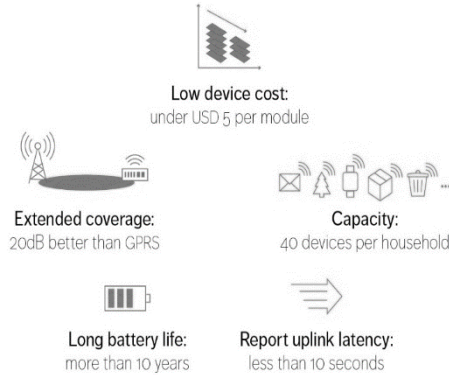


Figure 1. Benefits of NB-IoT[2]

## 2. TECHNICAL OVERVIEW

### 2.1. LOW POWER WIDE AREA

LPWA networks give reasonable range with minimal power consumption. According to Machina’s research this will be the fastest growing IoT technology [3].

These networks have two main aspects:

#### 2.1.1. LOW POWER

Devices designed for LPWA networks are optimized in hardware and software as well, thus they are able to function for many years powered by a single battery. Power consumption is so low that it is comparable to self-discharge of a battery, making it unnecessary to replace the power source ever. Therefore, these devices can be placed in hard-to-reach environments.

#### 2.1.2. WIDE AREA

Technological advances make it possible to have increased transmission power and receiver sensitivity which make obstacles and interference easier to cope with.

Conventional networks, like Bluetooth, Wi-Fi or ZigBee, along with classic cellular technologies, are not efficient enough; they require a considerable amount of investment and power consumption which is a concern as well.

On the other hand, LPWA devices are relatively cheap, use existing infrastructure and require minimal, or no maintenance.

## 2.2. NARROWBAND IOT

Table 1. Technical parameters[4]

Frequency band	NB-IoT (LTE) FDD bands 1, 2, 3, 5, 8, 11, 12, 13, 17, 18, 19, 20, 25, 26, 28, 66, 70
Mode	Half-duplex FDD type B
MIMO	not supported
Bandwidth	180 kHz
Multiple Access	Downlink: OFDMA Uplink: SC-FDMA
Modulation	Downlink: QPSK Uplink: Single Tone: $\pi/4$ -QPSK, $\pi/2$ -BPSK Multi Tone: QPSK
Coverage	164 dB (+20 dB GPRS)
Data rate	~25kbps downlink and ~64 kbps uplink
Propagation	<10 seconds
Power savings	eDRX, Power Saving Mode

### 2.2.1. CHANNEL SCANNING AND CONNECTION ESTABLISHMENT

The key feature of an NB-IoT device is an ability to adapt to changes of the environment. This property is defined in Physical Random Access Channel (PRACH) requirement which ensures sufficient link quality to cells[5].

According to 3GPP Release 13, a device during its power-up scans for available channels and tries to connect to them using one of the three signals[6]:

1. Narrowband Cell Reference Signal (NRS)
2. Narrowband Primary Synchronization Signal (NPSS)
3. Narrowband Secondary Synchronization Signal (NSSS)

NRS signal is used by the User Equipment (UE) to determine the performance of the downlink and is present in every downlink subframe.

NPSS and NSSS estimate (Fig. 2) time and frequency properties with a primary signal in every 5th subframe and a secondary signal in every 9th subframe of frames with even serial numbers.

With these properties at hand, the device is ready to receive Narrowband Physical Broadcast Channel (NPBCH) signal, which conveys Master Information Block (MIB-



NB). The MIB-NB informs the UE, in which mode the cell is operating[7]:

1. Stand-alone (reused GSM frequency band)
2. In-band (inside the LTE spectrum)
3. Guard-band (next to the LTE Physical Resource Block - PRB)

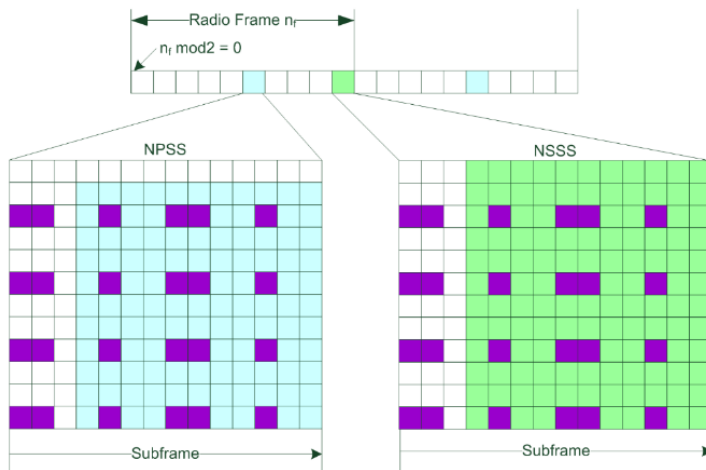


Figure 2. Primary and secondary synchronization signals[8]

Every NB-IoT device should support all modes and configure itself based on the provided information.

Narrowband technology does not require as much resource as standard LTE or GSM, its data rate is lower, handover is not implemented and there is no support for Multiple-Input and Multiple-Output (MIMO)[9].

#### 2.2.2. ENERGY SAVING METHODS

However lifetime of an NB-IoT device still heavily depends on the power source which it uses, therefore it is critical to optimize the power consumption. Optimizations can be done at hardware level, but afterwards a thoroughly designed software is the essence.

3GPP Release 12 defines the Power Saving Mode (PSM), which enables a device to sleep indefinitely. In this state, the UE is unreachable but can be woken up by its internal components, or when the Tracking Area Update (TAU) time is up (Fig. 3).

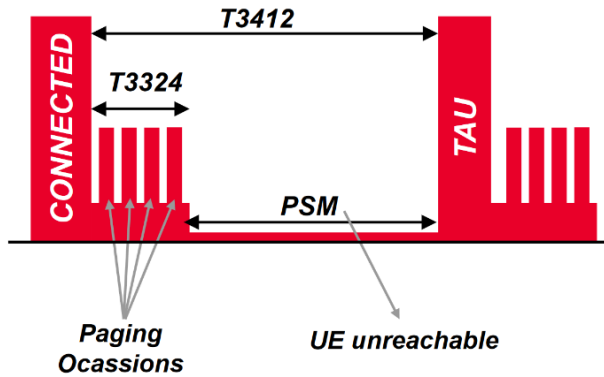


Figure 3. Release 12 Power Saving Mode[4]

3GPP Release 13 defines another power saving technique, the Extended Discontinuous Reception (eDRX), in which the UE can sleep for longer time before it checks back into the network (Fig. 4-5). The UE tells the network how many units of time it would like to sleep and during that time the traffic is queued.

eDRX is useful for applications when frequent downlink is expected.

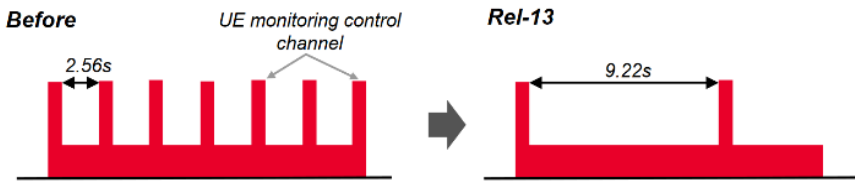


Figure 4. Rel-13 eDRX connected [4]

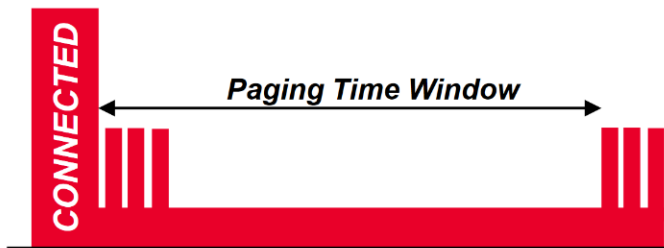


Figure 5. Rel-13 eDRX idle [4]

### 3. DESIGN

#### 3.1. SPECIFICATION AND OBJECTIVES

During the design state, our motivation was to create such NB-IoT device that will make the later adaptations and system integrations significantly easier. The plan was to make a circuit that has the following benefits: minimized size, long life cycle and usability in a lot of applications.

Large variety of sensors can be connected to the device which, thanks to the designed platform, can be used with minimal configuration.

#### 3.2. HARDWARE

We had to choose the components for the hardware in a way that they satisfy the requirements made by current technological trends. The main aspects were functionality, consumption and size.

The complete device consists of the following elements (Fig. 6):

- an NB-IoT enabled module
- a microcontroller
- a power source
- peripherals and extensions

The reason why Quectel's NB-IoT[10] modules were chosen is that they rapidly developed their first NB-IoT enabled module, they have very good support, and they are cooperative.

The 3GPP partner companies have not yet developed an NB-IoT module with integrated MCU that could be used for running user code. This is why we had to use a separate microcontroller unit for handling the modem and the sensor inputs. We have chosen state-of-the-art MCU with low power consumption called STM32L476, manufactured by STMicroelectronics[11]. This MCU can provide sufficient computational capacity while it can reduce its power consumptions in different ways. For example, by reducing its clock rate, sleep mode, shutdown with wake up availability, shutdown with RTC and standby mode.

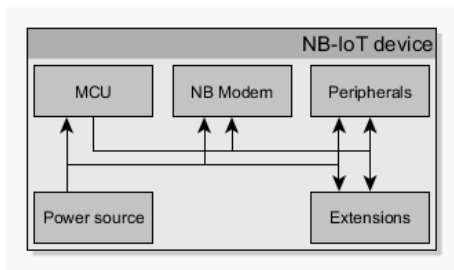


Figure 6. Architecture of the device

The issue of IT security is a continuously reoccurring topic nowadays so this prompted us to choose this MCU. The internal AES-128 crypto module helps us to meet these expectations.

The supply voltage is provided by a Lithium-Ion battery which has capacity scaled according to the application. The MCU has two main states while it is operating:

1. Active state:
  - a. data acquisition, measurements
  - b. processing
  - c. transmission
2. Inactive state

In the active state, the microcontroller gathers data from the environment by reading sensors, processes the acquired data and transmits them through the NB-IoT module. After completion, the whole device enters the inactive state.

While the device is inactive, power consumption is at minimum, the microcontroller is stopped and the NB-IoT module is in PSM or eDRX. If anything happens, the device enters the active state again and performs actions.

Time spent in the states and the actions performed are periodic and almost equal in power consumption, therefore lifetime can be calculated based on the individual power consumption of different processes. Calculations are based on the electrical charge as a resource:

$$Q = \int I(t)dt = I_{avg} * \Delta t \quad (1)$$

Consumption of different states and actions can be summed up to get the amount of charge used in a period of time. Then, the sum of these charges and the duration of the period gives the average consumption.

$$Q_i = I_i * t_i \quad (2)$$

$$Q = \sum_{i=0}^n Q_i = \sum_{i=0}^n I_i * t_i \quad (3)$$

$$Q = \sum_{i=0}^n Q_i = \sum_{i=0}^n I_i * t_i \quad (3)$$

Battery capacity can be calculated from the average current multiplied by the required lifetime and estimated efficiency:

$$Q_{bat} = I_{avg} * t_{lifetime} * \frac{1}{\eta} \quad (5)$$

For example, if a device has an average power consumption of 100mA for 10 seconds, then 10uA for the rest of the time, battery capacity for a 10 years lifetime with 75% efficiency would become:

$$Q_0 = 100mA * 10s = 1As \quad (6)$$

$$Q_1 = 10\mu A * 86390s = 0.8639As \quad (7)$$

$$I_{avg} = \frac{Q_0 + Q_1}{1 \text{ day}} = \frac{1As + 0.8639As}{86390s} = 21.58\mu A \quad (8)$$

$$Q_{bat} = 21.58\mu A * 10 \text{ years} * 75\% = 2520mAh \quad (9)$$

which is not too large considering 10 years of operation. Of course, most of the applications require more active time than 10 seconds per day, but it can be admitted it is possible to operate a device for many years from a single battery cell.

### 3.3. PLATFORM

To come up with a robust solution and to facilitate future development, we decided to create a complex system, which we call platform, to give an abstraction to the hardware, software and web service as a whole. With this abstraction, new applications can be implemented which shortens the time of development.

Aside from minimizing size of the design, we added extension connectors to support connection of common serial interface components, most commonly using I2C, SPI or UART. We dedicated these peripheral signals, as well as some general I/O lines, for control purposes.

For simplifying development of the device, a concept of a complete firmware library was created, in which all the functionality would be implemented and hidden from a programmer in the form of an API. This library would act like an operating system and would guarantee the minimal power levels and robustness of the design. The API would reduce application logic to a few function calls. The library could handle Firmware Over-The-Air (FOTA) and implements failsafe mechanisms.

Data are transmitted to the web in the popular JSON format, which enables flexible usage; different types of data can be enclosed in a single message and almost every web service could handle JSON format.

Transmitted messages always contain unique identifiers, battery voltage level, network statistics and auxiliary flags, so a fleet management solution can be easily built for constant monitoring of the deployed devices, giving notifications about different events.

## 4. CONCLUSION

NB-IoT has a great potential for the world today. Due to using the LTE network, it is cheap to be implemented by operators and can emerge rapidly. It provides good coverage and with proper design it can last for 10 years or more.

With our design, many applications can be implemented by attaching a little extension board to the device and thanks to the platform, it requires minimal

configuration to operate.

According to provisions, vast number of NB-IoT devices will be connected to the internet, which means, Big Data solutions or Artificial Intelligence should be implemented later to handle and process huge amount of data.

Some of the applications are focusing on smart devices used in cities and facilities:

- Smart City

There is no better use of NB-IoT technology, where long-life and maintenance-free solutions are most critical. Smart city is an idea to manage urban assets based on IoT solutions.

- Smart lighting

A city with many street lamps consumes a considerable amount of power. By replacing them with more efficient LED lights and controlling them remotely and individually, lamps could be lit where it is needed, thus minimizing utility costs.

- Smart parking

It is always a challenge to find a parking place in a crowded parking lot. It takes time, consumes fuel and is stressful. If every parking place had a sensor to indicate vacancy and provided connection to the internet with NB-IoT, vehicle owners could get notified about available spots nearby, or they could search them manually on their phone.

- Smart Bin

Cities have their schedules for waste collection. This means excessive waste is not removed before the next collection or there is no need to remove it at all. Therefore, managing waste is not as efficient as it could be. Using NB-IoT, waste collection could be scheduled on demand, saving time and fuel.

The device and its platform significantly accelerate the development of further solutions. We had the opportunity to be one of the first to test the service provider's NB-IoT network. Consequently we were the first to start developing NB-IoT devices in Hungary.

Based on provisions and preliminary calculations, carefully designed NB-IoT devices testify properties stated in 3GPP standards. Narrowband IoT devices can be run maintenance-free throughout their lifetime due to their low power consumption.

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#### REFERENCES

- [1] Telekom, "Narrow-Band IoT: A network designed for the 'simple things' in life." [Online]. Available: <https://www.telekom.com/en/company/details/narrow-band-iot--a-network-designed-for-the--simple-things--in-life-363362>.
- [2] S. Landström, J. Bergström, E. Westerberg, and D. Hammarwall, "NB-IOT: A sustainable technology for connecting billions of devices," *Ericsson Rev.* (English Ed., vol. 93, no. 2, pp. 8–16, 2016).
- [3] GSMA, "GSMA Mobil IoT Initiatives | Low Power Wide Area Technology." [Online]. Available: <https://www.gsma.com/iot/mobile-iot-initiative/>.
- [4] M. Blanco and P. Oloriz, "A cellular technology connecting the Internet Of Things Agenda Why NB-IoT Technical Fundamentals Test Challenges Summary," p. 56, 2016.
- [5] A. D. Zayas and P. Merino, "The 3GPP NB-IoT system architecture for the Internet of Things," 2017 IEEE Int. Conf. Commun. Work. ICC Work. 2017, pp. 277–282, 2017.
- [6] Y. P. E. Wang et al., "A Primer on 3GPP Narrowband Internet of Things," *IEEE Commun. Mag.*, vol. 55, no. 3, pp. 117–123, 2017.
- [7] N. Mangalvedhe, R. Ratasuk, and A. Ghosh, "NB-IoT deployment study for low power wide area cellular IoT," *IEEE Int. Symp. Pers. Indoor Mob. Radio Commun. PIMRC*, no. 1, 2016.
- [8] J. Schlien and D. Raddino, "Narrowband Internet of Things Whitepaper," p. 42, 2016.
- [9] R. Ratasuk, B. Vejlggaard, N. Mangalvedhe, and A. Ghosh, "NB-IoT system for M2M communication," 2016 IEEE Wirel. Commun. Netw. Conf. Work. WCNCW 2016, no. Wd5g, pp. 428–432, 2016.
- [10] Quectel, "Quectel BC95 NB-IoT Specification v1.2," p. 7.
- [11] U. A. Cortex, M. C. U. Fpu, K. B. Sram, and U. S. B. O. T. G. Fs, STM32L476xx, no. March. 2018.

*Key words:*  
*natural language processing, text mining*  
*legal documents, network graph,*  
*data extraction, data visualization*

Adam BOTTKA<sup>1</sup>

## **THE INTELLIGENT EXPLORATION AND VISUALIZATION OF HIDDEN LINKS BASED ON ENTITY RETRIEVAL**

During the overall expansion of computing human language processing has also been improved. The subject of the mining process is to make the texts searchable and to extract data for further processing. In the field of law and law enforcement, the data recovery with the existing methods is sufficient, although the efficiency can be improved. The discovery of connections between entities is not satisfactory, partly due to the linguistic and compositional features and partly due to the low level of social expenditures so far. First of all, without corresponding links the lists of extracted entities are difficult to use. This goal can be achieved and the results can be easily visualized to depict connection nets. From a practical point of view, we can firmly state that a set of documents is considered as processed when the highlighted entities and relationships between them are represented as a network in a way that the user receives an overview of relationships and groups formed by similar entities. A well-known example of such networks is Facebook, a network created from the connections of users' friends, their messages and their likes. In the present study, the body of text is provided by a set of EU and Hungarian legislations and court decisions. Taking advantage of many attributes of these legal documents, a network can be also represented here. The results of this research will be used for the development of Justeus' legal decision-maker developed by the Hungarian Department of Defense

### **1. INTRODUCTION**

In Hungary there is a significant difference between the socio-economical needs and IT opportunities because documents with natural texts (in legal, law enforcement, healthcare, public administration, etc.) have increasingly accrued. The IT provides a wide range of processing options. The artificial intelligence, more precisely the natural language processing and analysis can be a solution to this problem, however, until now most results in this field of IT were achieved only in texts written in English language. The methods and technologies described in this paper were implemented in

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Justeus in a legal decision finding system developed by the Hungarian Ministry of Defense.

## 2. PECULIARITIES OF LEGAL DOCUMENTS

### 2.1. GENERAL STRUCTURE OF LEGAL DOCUMENTS

Legal documents follow a specific set of structures and there are some common habits among jurists, which they frequently use to indicate important information in the text. They are characterized by a very strict format: certain entities (names, dates, IDs, etc.) can only appear in a specific place in the text. For example, it is possible that not all of the judges' names appear in the introduction part of a Constitutional Court document, but in every case all of them must appear in a complete list between the Reasoning and the Justification parts.

In most cases the beginning and the end of several parts of Legal Decisions are marked by certain entities. Such example is the date of creation at the Reasoning. The references to other legal documents, laws, and legislation, cited in the Legal Decisions, are made with a unique identifier, which is sometimes accompanied by the addition of an exact year. In some cases, especially in the case of modifications or overrides, references are used for identification of the paragraphs in a given document.

These can be useful for users, so they are also extracted, but they are not relevant in the entity-search, for establishing relationships and for visualization. They simply provide additional information, which can be interesting for the user.

### 2.2. ENTITY EXTRACTION FOR VISUALIZATION

From the point of view of visualization, the data elements clearly identifying a document, stored in the Justeus' database, are really important. Among the more than 4 million stored documents each one is assigned a Celex-ID, which is not entirely unique, but still clearly identifies the document. The fact that there are multiple Legal Decisions sharing the same identifier does not cause any problem because each document was produced by different organizations. This way the multiple categories can be created and grouped into different subtypes. (Fig. 1.)

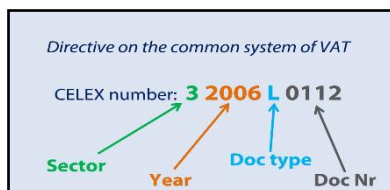


Figure 1. The structure of Celex-ID. [14]

Between the legal documents there is a considerable amount of references types that determine their relationship with the cited entities. This can be detected usually from the direct context, so it is worth extracting a few (3-4) words which are adjacent to the entity. When extracted together, an abbreviation or a seemingly meaningless character string will gain meaning. [5] Indeed, it is possible that concepts of more than one word may occur, which can only be interpreted as a whole. For example, such an entity is "... pursuant to §§ 3 (3) of Avtv." Another good example is: "Cf. Resolution 14/2016 (VII.18) AB".

For the visual representation of links between legal decisions, it is also necessary to determine the method, reason, or type of the reference, which can be extracted directly from the context as well. For example, texts that refer to such links "... modified", "... supplemented". When retrieving documents, it is optimal to query only the relevant group, or type.

The simplest and the best solution is the creation of a hierarchical tree structure: at the first level the documents are distinguished by affiliation (e.g. Hungarian Mansion, European Union, etc.), at the second level by the sector, then by the year, the type, and finally by the serial number. [12] Documents stored in Justeus follow a hierarchy where each element belongs to a given tree structure.

### 3. VISUALIZING THE LEGAL REFERENCE NETWORK

#### 3.1. ENTITY EXTRACTION FOR VISUALIZATION

Most relationship types (such as connections with friends on Facebook) are worth graphing if the number of links between entities to be displayed is not very high. [9] The extracted entities can be displayed as nodes and the links between them as edges. Documents with the same Celex-ID do not cause any problems, because if there is a collision, the user can use other features to select the relevant document, such as the year of issue, organization, or topic.

In Justeus graphs made from legal decisions are always directed from the referring documents to the document that represents the subject of the reference. Different types of nodes (such as Constitutional Court, European Union, Hungarian Mansion, etc.) and edges may occur (e.g. modify, delete, expand) and must be visually represented to users in an easily interpretable way.

#### 3.2. GRAPH READIBILITY FACTORS

The most important factor in graph networks is readability. [3] Nowadays, in the age of the big data the information overload is a much bigger problem than the

demand of it. [4] Without this graph, the user is forced to solve text queries in hundreds of pages.

It is extremely important to avoid the overload in a visualization, so in the first case only the most relevant elements should be displayed. It should be also considered a “small-world” environment, where only documents closely related to the term or attribute sought by the user are shown. [2]

The strength factor of a relationship can be calculated by weighting several components. [8] The two most important of these are the number of the degree and the type of the connection. (Fig.2) If there are numerous edges from one entity to another, then it is clear that this document is linked to more points in the text (e.g. several paragraphs) and it is more closely associated with the content of the selected document. [10]

However, the type of the link is very important because a relation with one or two main links may be much more important in several cases than a dozen of links with inferior types. For example, it can happen that there is a small reference to a document that supersedes the selected document used as reference basis. It is also possible that the selected document, or the most closely related to it does not meet the search criteria formalized by user. Then a more complex search process should be performed. In this case a text-based query should be started on the visual search interface.

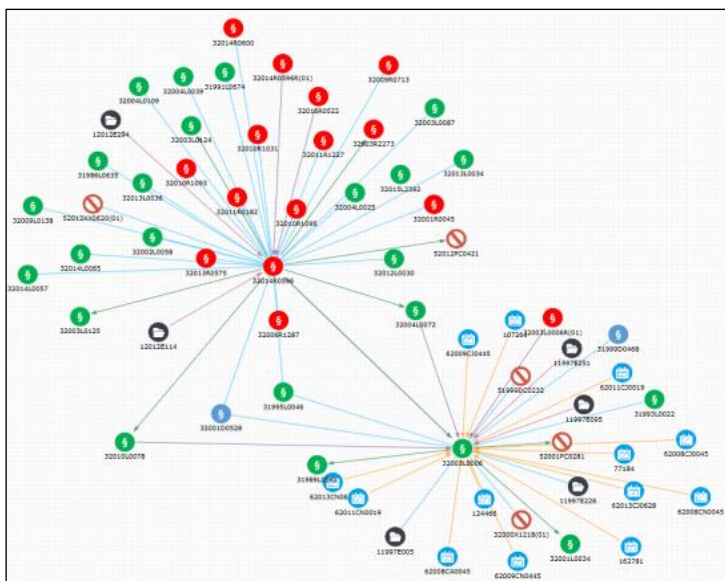


Figure 2. Visualization of links between documents [1]

## 4. VISUAL SEARCH

The visual interface facilitates the searching process for the user and makes it more effective. A similar, "multi-step" investigation in a simple text search platform would be much more difficult. Only after viewing and tracking many possible dead ends, would the user find a track that delivers him the required document. By using text search engines there is no option to look for the chains with the type and quality of the links between the data elements.

Understanding the underlying data structure and the network of connections is an additional work for the legal decision-making users as it does not help in the searching process and unnecessarily consumes their time. Representing relationships between entities as a graph makes data access more effective and intuitive.

To provide visual search, the graphs generated by Justeus will provide a high degree of interactivity enabling users to deal with the related entities. By default, only the most closely related documents will be visible to the user, but the links can be expanded to new branches or closed as desired. Users can select multiple layouts to change the transparency of the given network layout. The ideal choice, of course, may vary depending on the number and type of edges and nodes. [6]

There are several more aesthetic details of the priority entities that can be given to the user by the graph:

- edge and node thickness can represent the degree of relatedness
- color and the variety of nodes and edges can represent different document or reference types
- icons and signs can indicate different organizations
- grouping features such as proximity and similarity [13]

In addition, there are a lot of filtering options that can significantly increase efficiency. For example, if a lawyer needs only the documents that are currently in force, or those that have changed in a given period, the unwanted bundles can be excluded from the graph by filtering. A time-line based display of relation alteration between documents can give a new layer of references for the legislation in force in the given period. [11]

## 5. CONCLUSION

Interactivity can open up a new dimension by exploring the temporal relationships between legal decisions. It is also an abstraction of a kind that cannot be presented in a text search engine as it contains additional information understood only visually by the user. [7] In fact, this information does not exist in a document file, but it can be seen only as a result of the change in the connection network. For example, after a decision has been invalidated, it becomes apparent, which related documents are still awaiting

modification or reinstatement. This has a very great potential in lawmaking and administration management in public administration.

## 6. ACKNOWLEDGMENTS

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## REFERENCES

- [1] dr. Hegedűs András: JUSTEUS Unió Jogkereső <http://www.jogiforum.hu/publikaciok/784>
- [2] Marios Koniaris, Ioannis Anagnostopoulos, Yannis Vassiliou; Network analysis in the legal domain: a complex model for European Union legal sources, *Journal of Complex Networks*, Volume 6, Issue 2, 1 April 2018, Pages 243–268, <https://doi.org/10.1093/comnet/cnx029> (page 18)
- [3] Barabási Albert-László: *A hálózatok tudománya*. Libri Könyvkiadó, 2017
- [4] Thayne Coffman, Seth Greenblatt, and Sherry Marcus. 2004. Graph-based technologies for intelligence analysis. *Commun. ACM* 47, 3 (March 2004), 45-47. DOI=<http://dx.doi.org/10.1145/971617.971643>
- [5] Vadász János Pál: A szemantikus keresés módszerei és alkalmazási lehetőségei a védelmi szférában, a közigazgatásban, illetve a gazdasági életben. NEMZETI KÖZSZOLGÁLATI EGYETEM KATONAI MŰSZAKI DOKTORI ISKOLA 2018. <https://hhk.uni-nke.hu/document/hhk-uni-nke-hu/%C3%A9rtekez%C3%A9s-tervezet%20Vad%C3%A1sz%20P%C3%A1l.pdf>
- [6] Sebastian Schoffel, Johannes Schwank, Achim Ebert (2016) The State of the Art in Empirical User Evaluation of Graph Visualizations 2016 20th International Conference Information Visualisation (IV)
- [7] Nan Cao, Yu-Ru Lin, Liangyue Li, Hanghang Tong. (2015) g-Miner: Interactive Visual Group Mining on Multivariate Graphs. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15 2015*
- [8] J. Heer and D. Boyd, Vizster: Visualizing Online Social Networks, *Proc. IEEE Symposium on Information Visualization*, IEEE Press, Piscataway, NJ, 33-40, 2005
- [9] Fariha Majeed, Dr. Saif-ur-Rahman, Shaheed Zulfikar Ali Bhutto, *Graph Visualization Tools: A Comparative Analysis* (2015) Institute of Science and Technology (SZABIST) Karachi, Pakistan *Journal of Independent Studies and Research – Computing* Volume 13 Issue 1 January 2015
- [10] Daniel Hennessey, Daniel Brooks, Alex Fridman, David Breen (2008) A Simplification Algorithm for Visualizing the Structure of Complex Graphs. Department of Computer Science, Drexel University, Philadelphia, PA, USA 9-11 July 2008
- [11] Raju N. Gottumukkala, Siva R. Venna and Vijay Raghavan. (2015) Visual Analytics of Time Evolving Large-scale Graphs. *IEEE Intelligent Informatics Bulletin* December 2015 Vol.16 No.1
- [12] Amit Tomar, Beena Kumari, Shivam Agarwal, and Jaya Sreevalsan Nair, (2015) A Survey of Visualization Techniques for Network Security Analytics Graphics-Visualization-Computing Lab, Center for Data Sciences, International Institute of Information Technology Bangalore <http://cds.iiitb.ac.in/gvcl> February 15, 2015
- [13] The Aesthetics of Graph Visualization (PDF Download Available). Available from: [https://www.researchgate.net/publication/220795329\\_The\\_Aesthetics\\_of\\_Graph\\_Visualization](https://www.researchgate.net/publication/220795329_The_Aesthetics_of_Graph_Visualization) [accessed May 07, 2018]. Page 5, paragraph
- [14] EUR-Lex. Access to European Union Law. Celex Numbers. Downloaded on 31.05.2018 <https://eur-lex.europa.eu/content/guided-tour/celex-number.html>



**Students'  
Science  
Conference**

**IV**

**MECHANICS  
AND  
MATERIALS ENGINEERING**

*Key words:*  
*polymers, laser interferometry,*  
*contactless measurements, biomedical engineering*

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## **THE ANALYSIS OF SELECTED PROPERTIES OF POLYMERS USED IN BIOMEDICINE BY LASER INTERFEROMETRY**

Nowadays, polymers are among the most commonly used biomaterials. Examination of their properties is not obvious and is difficult with the application of contact methods when the sample is getting destroyed. Based mainly on optical methods, contactless analysis procedures are an alternative. Laser interferometry, which is based on Michelson's interferometer, is one of such contactless methods. Along with proper mathematical formulae, it could be used to examine different parameters of the object in question.

### **1. INTRODUCTION**

The European Society of Biomaterials defines biomaterials as materials intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body. [1]

Polymers are the most significant group of materials used in biomedicine. Their increasing application is related to: easy sterilisation process without changes in the shape or properties of the product; low toxicity; the absence of allergic or immunological reaction; chemical resistance. [2]

Methods used to determine the properties of the materials are divided into two groups: contactual and contactless. The second group is represented by optical measurements and one of them is laser interferometry. The method has been being

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developed since the second half of the 20<sup>th</sup> century. The interferometer based on the wave interference was the most important invention in the field. The most popularized interferometer was created by Albert Abraham Michelson. It was composed of a wave source (O) with determined length, a detector (D), a semi-permeable mirror (P) and two mirrors that reflect the light ( $Z_1$  and  $Z_2$ ). Its general scheme is presented in fig.1. [3, 4]

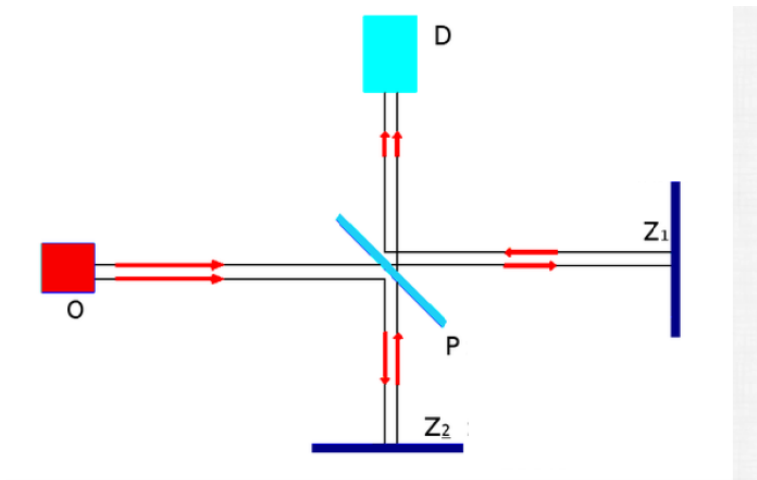


Fig. 1. Michelson's interferometer scheme [3]

Contactless measurements such as the Young's modulus or Kirchhoff's modulus could be applied to determine different properties of the material. [5]

It is universally known that, over the past 30 years, such tests have already been run, mostly on metallic materials. However, the polymer materials, of diversified parameters, are a group of materials which do not have an exactly determined value of the Young's modulus and its range is very wide. [6]

The aim of this research is to estimate the properties of the materials used in bio-medicine with the application of a modified version of Michelson's interferometer and the speckle interferometry, as well as the measurement of uncertainty of the results obtained during the research.

## 2. MATERIALS AND METHODS

### 2.1. MATERIALS

For this study, samples of various polymers of varied filler content were prepared:

- 2, 3, 4 and 5 mm thick PVC samples, 3 of which were made of foamed PVC;
- 4 and 5 mm thick PMMA samples;
- 3 mm thick PC samples;



- 2 mm thick thermoplastic PE samples. [Fig.2]

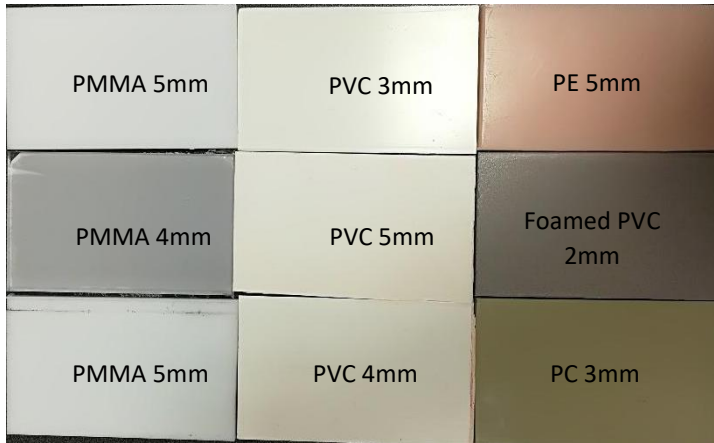


Fig. 2. Samples used for the study

Polymer materials were cut using guillotine in order to obtain rectangular samples of the size of 60x100 mm.

### 2.3. METHODS

The main principle of the experiment depended on bending a one-side loaded bar and the layout of speckles on the sample during the process. Force  $P$  is located at the edge of the beam with the active length  $l$  and its bow  $f_a$ .

The appearance of dark speckle informs that the bell was bent on a half of the wave's length applied for the study. The Total length of the bending line is the result of multiplication between the quantity of dark speckles on the sample surface and the half of wavelength. The general idea of the method was presented in figure (Fig.3.).

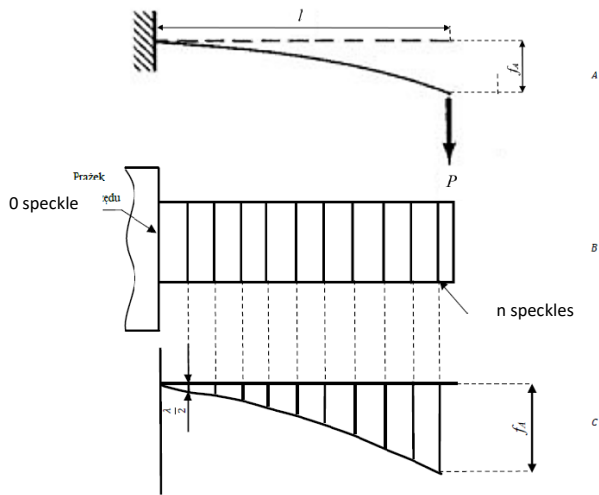


Fig. 3: Bending of one-side immobilised bar with the general idea of its bent length calculation related to speckle interferometry

Figure 4 represents the stand which was used to receive all necessary data. It consist on the modified Michelson's interferometer where one of the mirrors had been replaced by the polymer plate (7) which had been folded by the small bur-den chosen accordingly to the used material (8). Laser (2) was plugged into the feeder. The light come across two lenses (3) and it was divided by semi-permeable mirror [6]. The half of light's beam reflect on the measured material (7) and the other on the referential plane (5). After reflection, the two beams overlap and are recorded by the detector (4) in the form of an interference image (Fig.5.).

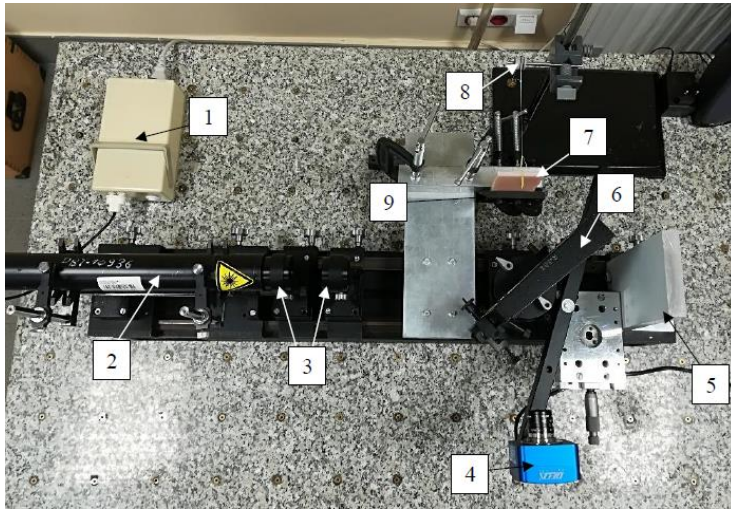


Fig. 4. Research office applied for the study with interferometry laser

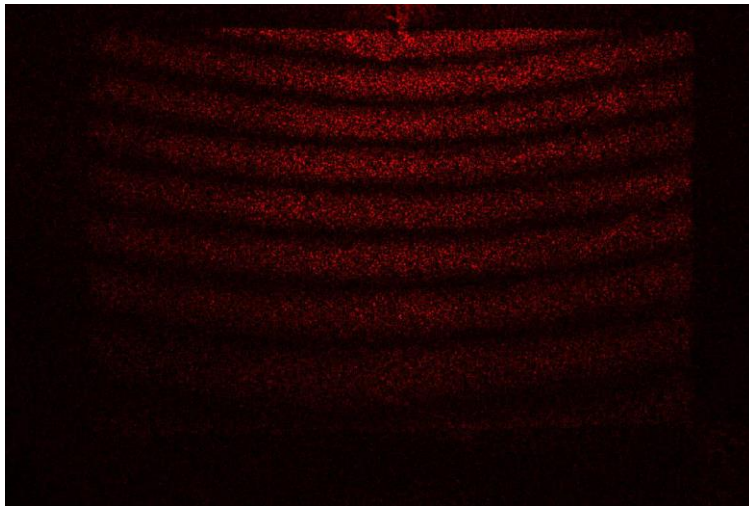


Fig. 5. Example of reference image obtained from the test

At first the geometrical moment of inertia was calculated along with the forces applied during the study. After that the bent length was determined using the quantity of speckles seen over each of the polymer samples and the half of wave length used for this study. During the last step, Castigliano's method was transformed to receive the Young's modulus value for each of the examined materials. This transformation is presented below.

$$f_A = \frac{\partial U}{\partial P} = \frac{1}{EI} \int_L M(x) \frac{\partial M(x)}{\partial P} dx = \frac{1}{EI} \int_0^l px * x dx = \frac{P}{EI} \int_L x^2 dx = \frac{Pl^3}{3EI} \quad (1)$$

$$f_A = \frac{Pl^3}{3EI} \rightarrow E = \frac{Pl^3}{3f_A I} \rightarrow E = \frac{Pl^3}{\frac{3ql}{2} I} \quad (2)$$

Where:

$f_A$ - deflection

$\frac{\partial U}{\partial P}$ - Partial Derivatives for deflection

$M(x)$ - moment applied

$P$ - force at a certain point

$x$ - displacement

$E$ - material's Young's Modulus

$I$ -moment of inertia

$l$ -length

Measurement error was calculate based on exact differential method.

Finding the measurement error Young's Modulus is determining complex measurement error.

$$E = f(P, l, I, f_A) = \frac{Pl^3}{3f_A I} \quad (3)$$

Partial Derivatives Young's Modulus after force P:

$$\frac{\partial f}{\partial P} = \frac{l^3}{3f_A I} \quad (4)$$

Partial Derivatives Young's Modulus for length l:

$$\frac{\partial f}{\partial l} = \frac{Pl^2}{If_A} \quad (5)$$

Partial Derivatives Young's Modulus after deflection:

$$\frac{\partial f}{\partial f_A} = \frac{Pl^3}{3If_A^2} \quad (6)$$

Partial Derivatives Young's Modulus after Moment of Inertia:

$$\frac{\partial f}{\partial I} = \frac{Pl^3}{3I^2 f_A} \quad (7)$$

$$I = \frac{h*b^3}{12} \quad (8)$$

$$\Delta I = \frac{\partial I}{\partial h} \Delta h + \frac{\partial I}{\partial b} \Delta b = \frac{b^3}{12} * \Delta h + \frac{hb^2}{4} * \Delta b \quad (9)$$

### 3. RESULTS

All sizes had been measured with calliper.

In table 1 there are all necessary dimensions of the tested materials (length and thickness) there are also numbers of the perceived stripes and deflection.

Table 1. Summary of tested materials with their dimensions and deflection

ID	Name of swatch	Length $l$ [m]	Thickness $b$ [m]	Number of stripes	Deflection [m]
1	PVC	0,0719	0,004	10	$3,48*10^{-6}$
2	PMMA	0,0694	0,005	12	$4,11*10^{-6}$
3	PE	0,0749	0,003	13	$4,43*10^{-6}$
4	PVC (foamed)	0,051	0,005	11	$3,80*10^{-6}$
5	PVC	0,0737	0,003	14	$4,75*10^{-6}$
6	PC	0,0740	0,003	16	$5,06*10^{-6}$
7	PMMA	0,0675	0,004	13	$4,43*10^{-6}$
8	PVC	0,0722	0,002	10	$3,48*10^{-6}$

There is an example of scheduled Young's Modulus for first swatch.

$$E = \frac{0,04905N*(0,0719m)^3}{3*\frac{10*632,8*10^{-9}}{2}*3,259*10^{-10}m^4} = 5,90 * 10^9 Pa \quad (10)$$

All results are in table 2.

Finding the measurement error of Young's Modulus is determination complex measurement error.

Table 2. Comparison of Young's Modulus, attained Moment of Inertia and Measurement error

ID	Young's Modulus		Moment Of Inertia	Measurement error of Young's Modulus
	scheduled	literary		
1	$5,90*10^9$	$2,5\div 3,2*10^9$	$3,259*10^{-10}$	6%
2	$1,99*10^9$	$2,7\div 3,0*10^9$	$7,217*10^{-10}$	5%
3	$1,19*10^9$	$7,5\div 1,06*10^9$	$1,400*10^{-10}$	5%
4	$1,22*10^9$	$92,43*10^6$	$6,541*10^{-10}$	5%
5	$4,26*10^9$	$2,5\div 3,2*10^9$	$1,386*10^{-10}$	5%
6	$4,04*10^9$	$1,8\div 2,2*10^9$	$1,379*10^{-10}$	4%
7	$3,69*10^9$	$2,7\div 3,0*10^9$	$3,317*10^{-10}$	5%
8	$9,43*10^9$	$2,5\div 3,2*10^9$	$4,128*10^{-10}$	7%

The results of this experiment are relatively accurate. Values of Measurement error don't exceed 7%.

#### 4. DISCUSSION

The values of Young's modulus are similar to the information presented in literature. As it had been presented by Konnerth [7] those materials show an excellent correlation for the elastic modulus even if for some of them the measurement error seems to be more significant.

The PVC samples experimental modulus represent certain variety within the literature's values and it could be affected by polymers' modifiers applied by producers. This variety could be also caused by the chemical composition, the temperature difference between the material and environment or any specific sounds.

The temperature and undesirable sounds caused certain number of problems during the research, which was done in complete darkness. The influence of both factors was relatively visible on the speckle images and hindered their analysis. Due to that there was an obligatory buffer time before the installation of the samples and image's registration.

The study had been limited due to unknown chemical composition. As it had been proved by Sharma [8] the quantity of pure polymer had significant meaning for its mechanical properties.

## 5. SUMMARY

Studies using speckle interferometry to determine the properties of materials give results with low measurement uncertainty. Regardless of the tested polymer type, it was possible to carry out the experiment on all tested samples with the quality of its surface. For polymers visible differences between the literature data and the results of the experiment are the effect of modifiers used by the materials' producers. During the tests, polymers showed high sensitivity to even small changes in temperature, so it was important to stabilize the environment before registering images. Attempts carried out with the use of speckle interferometry also confirm the reduction of the time necessary to conduct the examination of the material properties of selected materials and their lack of influence on the condition of the used sample. Each of the samples prepared for testing could be re-used for the same or another test.

## REFERENCES

- [1] LEALI, P. Tranquilli; MEROLLI, Antonio. Fundamentals of biomaterials. In: Biomaterials in Hand Surgery. Springer, Milano, 2009. p. 1-11.
- [2] SEK, Danuta; WŁOCHOWICZ, Andrzej. Chemia polimerów i polimery biodegradowalne. Wydaw. Politechniki Łódzkiej Filii w Bielsku-Białej, 1996.
- [3] GÅSVIK, Kjell J. Optical metrology. John Wiley & Sons, 2003.
- [4] ERF, R. K. Speckle Metrology (New York: Academic). 1978.
- [5] Shelton J.C., Orr J.F., Optical Measurement Methods in Biomechanics, Chapman & Hall, 1997
- [6] Rabek, J. F. (2009). Współczesna wiedza o polimerach: wybrane zagadnienia. Wydawnictwo Naukowe PWN.
- [7] Konnerth, J., Gindl, W., & Müller, U. (2007). Elastic properties of adhesive polymers. I. Polymer films by means of electronic speckle pattern interferometry. Journal of applied polymer science, 103(6), 3936-3939.
- [8] Sharma, U., Concagh, D., Core, L., Kuang, Y., You, C., Pham, Q., & Langer, R. (2018). The development of bioresorbable composite polymeric implants with high mechanical strength. Nature materials, 17(1), 96

*Key words:*  
*transition metal dichalcogenides,*  
*hBN encapsulation, interference effect*

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## **THE INTERFERENCE EFFECT ON THE RAMAN AND PHOTOLUMINESCENCE EMISSION OF MONOLAYER WSe<sub>2</sub> EXFOLIATED ON hBN/SiO<sub>2</sub>/SI SUBSTRATES\***

Thin layers of hexagonal boron nitride (hBN) are widely used in studies of optical properties of transition metal dichalcogenides (TMDs) due to their ability to reduce the influence of the environment on material properties. It has been shown that heterostructures consisting of monolayers of TMD and hBN are characterized by much more homogeneous optical properties compared to their counterparts without layers of hBN. The goal of this work is to study the impact of dielectric stacking in this kind of heterostructures on interference enhancement of emitted Raman and PL signal. We performed photoluminescence (PL) and Raman scattering measurements of monolayer WSe<sub>2</sub> exfoliated on hBN/SiO<sub>2</sub>/Si heterostructures with more than 20 different thicknesses of hBN and SiO<sub>2</sub> thicknesses equal 200 nm and 300 nm. Enhancement factors of those signals, resulting from interference effects, have been modelled theoretically using effective medium approach. Calculated enhancement factors can be used to adjust thickness of hBN on specific SiO<sub>2</sub> thickness and under fixed excitation wavelength in order to obtain the highest emission intensity in the wavelength region of interest.

### 1. INTRODUCTION

Semiconducting transition metal dichalcogenides (TMDs) of chemical formula MX<sub>2</sub> (such as WSe<sub>2</sub>, WS<sub>2</sub>, MoSe<sub>2</sub> and MoS<sub>2</sub>) have attracted great interest from the scientific community due to the underlying physics and promising applications in photonics, optoelectronics and the development of valleytronics [1–3]. When these materials are exfoliated on SiO<sub>2</sub> substrate, the PL linewidth is typically exceeds 10

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meV at low temperatures [4–7]. Recently, it has been shown that encapsulating monolayers (ML) of the TMDCs in hexagonal boron nitride (hBN) can efficiently suppress inhomogeneous broadening of the exciton linewidth on account of reduction of

influence of the environment on material properties [8,9]. In this work we focus on the impact of dielectric stacking in vertical heterostructure of  $\text{WSe}_2/\text{hBN}/\text{SiO}_2/\text{Si}$  on interference enhancement of emitted Raman and PL signal.

Most of previous studies concerning interference effects in thin films of transition metal dichalcogenides focused on improvement of monolayer identification by optical microscopy [10,11]. In this work we demonstrate that a far more important aspect to designing dielectric stack is increasing the intensity of outgoing signal in the wavelength region of interest. We focus on optical properties of monolayer  $\text{WSe}_2$  because PL and Raman response of this material is in different wavelengths under excitation of 532 nm laser line. We performed studies of monolayer  $\text{WSe}_2$  flakes exfoliated on thin layers of hBN placed on  $\text{SiO}_2/\text{Si}$  substrates with  $\text{SiO}_2$  thickness close (300 nm) and far away (200 nm) from previously reported thicknesses of constructive interference [10,11]. We measured Raman and photoluminescence emission for two excitation energies. In addition, we numerically simulated interference effect of dielectric stack consisted of  $\text{WSe}_2/\text{hBN}/\text{SiO}_2/\text{Si}$  employing multiple reflection model [12,13]. Obtained dependence of emission intensity on hBN thickness is in a very good agreement with experimental results, demonstrating that applying hBN layer of specific thickness allow to enhance emitted signal even in case of  $\text{SiO}_2$  substrate with destructive interference thickness condition. Such manipulation is very important because interference amplification condition changes for different emission wavelengths. To maximize intensity of emitted signal e.g. for Raman and PL range of wavelengths, different conditions have to be fulfilled.

## 2. EXPERIMENTAL DETAILS

We prepared  $\text{WSe}_2/\text{hBN}/\text{SiO}_2/\text{Si}$  structures from bulk crystals of  $\text{WSe}_2$  grown by chemical vapour transport technique and hBN purchased from 2D Semiconductors.  $\text{WSe}_2$  monolayers and hBN flakes with different thicknesses were mechanically exfoliated and then stacked using deterministic all-dry stamping method, according to ref. [14], onto two Si substrates with 200 nm and 300 nm  $\text{SiO}_2$  layer, respectively. On each of those substrates we studied optical properties of  $\text{WSe}_2$  monolayers placed directly on  $\text{SiO}_2$  and compared them with properties of those transferred on over 20 different hBN thicknesses in each case. Typical size of flakes exceeded  $4 \times 4 \mu\text{m}$ . Monolayer character of  $\text{WSe}_2$  flakes was determined by their different optical contrast



and has been confirmed by Raman and PL measurements on PDMS (to ensure the same experimental conditions) and, after transfer on target substrate, by atomic force microscopy (AFM) imaging.

Room temperature Raman and PL spectra were measured by micro-Raman spectrometer (Renishaw inVia Raman Microscope) in backscattering configuration with excitations provided by 532 nm and 633 nm laser lines. The power was kept on the order of 250  $\mu$ W to avoid heating effects.

### 3. RESULTS

We studied the effect of substrate thickness and composition on PL and Raman response of monolayer WSe<sub>2</sub>. Our research constitutes an essential step towards improvement of light extraction from dielectric stack consisted of monolayer transition metal dichalcogenides in relatively easy way. Example of optical micrograph and the characteristic PL and Raman spectra recorded under excitations of 532 nm and 633 nm laser line are presented in fig. 1.

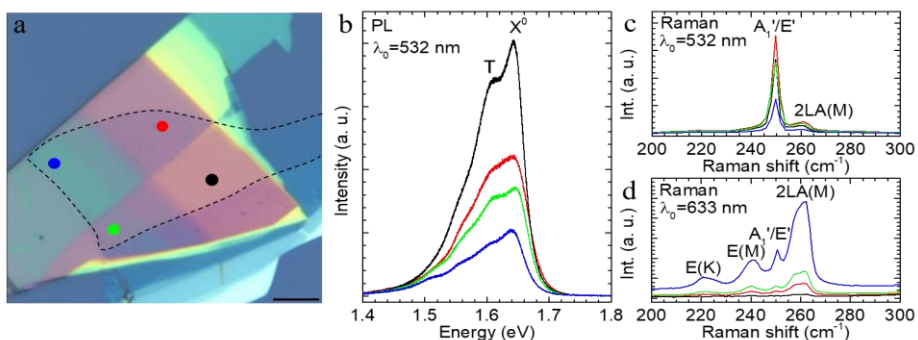


Figure 1. Optical, photoluminescence and Raman characterization of 1L-WSe<sub>2</sub> on hBN flake with different thicknesses on 300nm-SiO<sub>2</sub>/Si substrate. (a) Optical micrograph of example heterostructure under study. Colour dots indicate regions with hBN thicknesses equal to: 100 nm (black), 115 nm (red), 120 nm (green) and 135 nm (blue) analysed in this work. The contours of 1L-WSe<sub>2</sub> are outlined for clarity. Scale bar is 10  $\mu$ m. (b) Photoluminescence and (c) Raman spectra measured under excitation at 532 nm, (d) Raman spectrum measured under excitation at 633 nm. Colours correspond to dots in part (a). Visible different order in intensity increase is due to the interference effect

At room temperature in PL spectra of monolayer WSe<sub>2</sub> we can resolve at least two lines, attributed to neutral ( $X^0$ ) and charge ( $X^-$ ) exciton emission, with energies equal to 1.64 eV and 1.61 eV, respectively. Raman spectra, depending on excitation energy reveal several vibrational frequencies. In our studies we focus only on the mixture of  $A_1'$  and  $E'$ -mode (at frequency  $\sim 250$   $\text{cm}^{-1}$ ) dependence on substrate thickness and

composition, since this mixture of Raman modes is visible in spectra under whole range of excitation energies.

In order to study substrate-induced light interference we employed the multiple reflection model presented in ref. [12,13]. Increasing number of layers in heterostructure complicates the geometry of the optical path (fig. 2), because differences in thicknesses and the optical constants give rise to the optical interference in the incoming and outgoing signal.

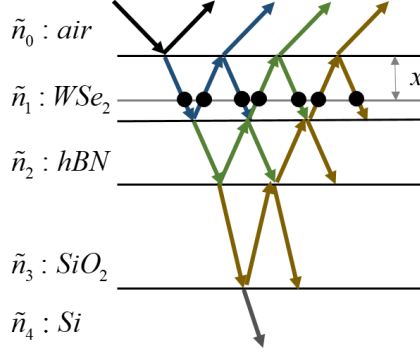


Figure 2. Schematics of trajectories of the incident excitation laser light in the five media: (0) air, (1) WSe<sub>2</sub>, (2) hBN, (3) SiO<sub>2</sub> and (4) Si

The interference have an influence on the absorption of the excitation light as well as the Raman and PL intensity. In this work we consider the following stacking order: air, WSe<sub>2</sub>, hBN, SiO<sub>2</sub>, Si denoted  $i = 0, 1, \dots, 4$ , where air and Si layers are considered to be semi-infinite. Considering both absorption and emission in the active layer of transition metal dichalcogenide, the intensity of the light coming out of the heterostructure can be calculated using the formula:

$$I(\lambda) = \int_0^d \left| E_{abs}(\lambda_0, x) \cdot E_{em}(\lambda, x) \right|^2 dx \quad (1)$$

where  $d$  denotes thickness of the flake of transition metal dichalcogenide,  $E_{abs}$  and  $E_{em}$  are the electric field amplitudes of the light within and emitted out of the flake, respectively. We assume normal incidence in all equations, because according to previous reports the oblique incidence caused by the objective with numerical aperture 0.9 lead only to minute changes in the spectral response [12]. On the basis of derived model we can calculate dependence of the intensity of light coming out of the heterostructure as a function of emission wavelength or layer thicknesses for specific excitation wavelengths.

Fig. 3 presents comparison of measured and calculated intensities of emitted PL

and Raman signal as a function of hBN thickness for different excitation and emission wavelengths on two considered substrates with SiO<sub>2</sub> layer thickness equal to 200 nm and 300 nm. For PL spectra excited at 532 nm we considered intensity of the neutral exciton (X<sup>0</sup>) observed at 755 nm, whereas for Raman scattering spectra we focus on Raman active A<sub>1</sub>'&E' mode observed at 539 nm and 643 nm under illumination of 532 nm and 633 nm laser line, respectively. Changing hBN thickness and excitation wavelength lead to dramatic change of the intensity of emitted light. We clearly observe that maximum interference reinforcement of emitted signal for PL and Raman spectra is fulfilled for different hBN and SiO<sub>2</sub> thicknesses. Hence, in order to achieve the highest interference enhancement of emitted signal from monolayer transition metal dichalcogenides there is a need to adjust dielectric stack composition, depending on the excitation and emission wavelength region of interest.

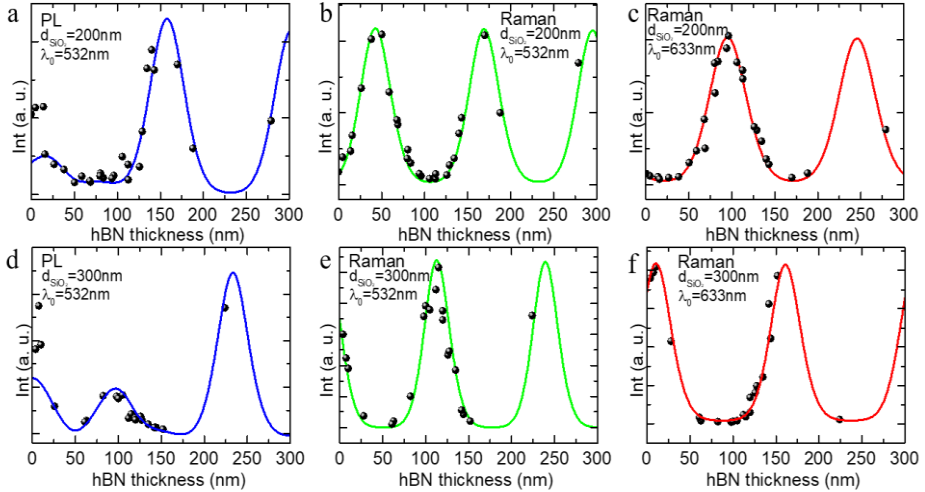


Figure 3. Comparison of measured (dots) and calculated (straight line) intensities as a function of hBN thickness. (a) PL (at 755 nm) and (b) Raman (at 539 nm) intensities under excitation at 532 nm on 200 nm-SiO<sub>2</sub>/Si substrate. (c) Raman (at 643 nm) intensities under excitation at 633 nm on 200 nm-SiO<sub>2</sub>/Si substrate. (d)-(f) corresponding plots on 300 nm-SiO<sub>2</sub>/Si substrate

#### 4. CONCLUSIONS

To conclude, we studied interference effect in WSe<sub>2</sub>/hBN/SiO<sub>2</sub>/Si heterostructures with different hBN and SiO<sub>2</sub> thicknesses. We demonstrated that application of hBN layer with specific thickness allows to increase intensity of emitted signal even in case of SiO<sub>2</sub> substrate with thickness fulfilling destructive interference condition. Obtained results can be used to design the dielectric stack order and composition in order to

achieve the highest intensity of emitted signal in the wavelength region of interest depending on excitation wavelength.

#### REFERENCES

- [1] K.F. Mak, C. Lee, J. Hone, J. Shan, T.F. Heinz, Atomically Thin MoS<sub>2</sub>: A New Direct-Gap Semiconductor, *Physical Review Letters*, Vol. 105, 2010, 136805.
- [2] D. Xiao, G.-B. Liu, W. Feng, X. Xu, W. Yao, Coupled spin and valley physics in monolayers of MoS<sub>2</sub> and other group-VI dichalcogenides, *Physical Review Letters*, Vol. 108, 2012, 196802.
- [3] B. Radisavljevic, A. Radenovic, J. Brivio, V. Giacometti, A. Kis, Single-layer MoS<sub>2</sub> transistors, *Nature Nanotechnology*, Vol. 6, 2011, 147–150.
- [4] A.M. Jones, H. Yu, N.J. Ghimire, S. Wu, G. Aivazian, J.S. Ross, B. Zhao, J. Yan, D.G. Mandrus, D. Xiao, W. Yao, X. Xu, Optical generation of excitonic valley coherence in monolayer WSe<sub>2</sub>, *Nature Nanotechnology*, Vol. 8, 2013, 634–8.
- [5] J.S. Ross, S. Wu, H. Yu, N.J. Ghimire, A.M. Jones, G. Aivazian, J. Yan, D.G. Mandrus, D. Xiao, W. Yao, X. Xu, Electrical control of neutral and charged excitons in a monolayer semiconductor, *Nature Communications*, Vol. 4, 2013, 1474.
- [6] A.T. Hanbicki, G. Kioseoglou, M. Currie, C.S. Hellberg, K.M. McCreary, A.L. Friedman, B.T. Jonker, Anomalous temperature-dependent spin-valley polarization in monolayer WS<sub>2</sub>, *Scientific Reports*, Vol. 6, 2016, 18885.
- [7] D. Sercombe, S. Schwarz, O. Del Pozo-Zamudio, F. Liu, B.J. Robinson, E. a Chekhovich, I.I. Tartakovskii, O. Kolosov, a I. Tartakovskii, Optical investigation of the natural electron doping in thin MoS<sub>2</sub> films deposited on dielectric substrates., *Scientific Reports*, Vol. 3, 2013, 3489.
- [8] F. Cadiz, E. Courtade, C. Robert, G. Wang, Y. Shen, H. Cai, T. Taniguchi, K. Watanabe, H. Carrere, D. Lagarde, M. Manca, T. Amand, P. Renucci, S. Tongay, X. Marie, B. Urbaszek, Excitonic Linewidth Approaching the Homogeneous Limit in MoS<sub>2</sub> -Based van der Waals Heterostructures, *Physical Review X*, Vol. 7, 2017, 021026.
- [9] O.A. Ajayi, J. V Ardelean, G.D. Shepard, J. Wang, A. Antony, T. Taniguchi, K. Watanabe, T.F. Heinz, S. Strauf, X.-Y. Zhu, J.C. Hone, Approaching the intrinsic photoluminescence linewidth in transition metal dichalcogenide monolayers, *2D Materials*, Vol. 4, 2017, 031011.
- [10] A. Castellanos-Gomez, N. Agrat, G. Rubio-Bollinger, Optical identification of atomically thin dichalcogenide crystals, *Applied Physics Letters*, Vol. 96, 2010, 2010–2012.
- [11] G. Rubio-Bollinger, R. Guerrero, D. de Lara, J. Quereda, L. Vaquero-Garzon, N. Agraït, R. Bratschitsch, A. Castellanos-Gomez, Enhanced Visibility of MoS<sub>2</sub>, MoSe<sub>2</sub>, WSe<sub>2</sub> and Black-Phosphorus: Making Optical Identification of 2D Semiconductors Easier, *Electronics*, Vol. 4, 2015, 847–856.
- [12] S.L. Li, H. Miyazaki, H. Song, H. Kuramochi, S. Nakaharai, K. Tsukagoshi, Quantitative raman spectrum and reliable thickness identification for atomic layers on insulating substrates, *ACS Nano*, Vol. 6, 2012, 7381–7388.
- [13] D.H. Lien, J.S. Kang, M. Amani, K. Chen, M. Tosun, H.P. Wang, T. Roy, M.S. Eggleston, M.C. Wu, M. Dubey, S.C. Lee, J.H. He, A. Javey, Engineering light outcoupling in 2D materials, *Nano Letters*, Vol. 15, 2015, 1356–1361.
- [14] A. Castellanos-Gomez, M. Buscema, R. Molenaar, V. Singh, L. Janssen, H.S.J. van der Zant, G. a Steele, Deterministic transfer of two-dimensional materials by all-dry viscoelastic stamping, *2D Materials*, Vol. 1, 2014, 011002.

*Key words:*  
*composite materials, motorcycle,*  
*FEM analysis, strength analysis*

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## **EXPERIMENTAL AND NUMERICAL ANALYSIS OF MOTORCYCLE'S SUBFRAME MADE OF COMPOSITE MATERIALS\***

The aim of the work was to present a project of the composite motorcycle's subframe made of composite material. The current knowledge about this element concentrates mostly on the technology of the injection moulding of plastics. Therefore, fibre reinforced plastic composites were investigated. Firstly, a strength pre-analysis using FEM method was conducted. Next, when a prototype was prepared, a strength experiment was conducted. Thanks to this test a diagram of force displacement was obtained. The force value expressed the reaction force of the subframe. The maximum obtained force was 35 kN. After this value, a crack occurred. In order to obtain the real layout of the composite, material investigation was conducted. Thanks to this, the thicknesses of the specific layers were known. The next step of the work was to conduct a FEM simulation reflecting the experiment. A model was created and the simulation was set in Abaqus CAE software. Two layouts were used in the simulation: with the theoretical layers' thicknesses and the real ones taken from the material investigation. Then the FEM and experiment results were compared. The character of the subframe behaviour under load was fairly reflected in the simulation. However, there occurred some differences between the results. The main factors that could have influence were the material data without the damage character introduced. Also, some imperfections in the real model and the digital model occurred.

### 1. INTRODUCTION

The investigated motorcycle's subframe is a part of the electric motorcycle called LEM Falcon. The two-wheeler is one of the main projects run in The Scientific Association of Vehicles and Mobile Robots. It is a group of students and PhD students

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\* Paper awarded in the Best Paper Contest.

concentrated around a project of constructing and building an electric motorcycle. LEM Falcon is an off-road electric motorcycle designed in accordance with the rules of the students' competition in SmartMoto Challenge Barcelona [1]. According to the rules, the maximum constant power is set to 8 kW, the voltage of the battery at the level of 60 V. The figure 1 shows the motorcycle – LEM Falcon.



Fig. 1 LEM Falcon

The model of the subframe is shown in the figure 2. It was designed to support the seat of the motorcycle. Moreover, it works as a rear fairing and as a mounting of the rear light. The subframe is mounted to the main aluminum alloy frame by means of 6 screws. As a technology for that element, a vacuum infusion process and manual lamination were used. The final product can be seen in the figure 3.



Fig. 2 The model of the motorcycle's subframe



Fig. 3 Motorcycle's subframe

## 2. EXPERIMENTAL INVESTIGATION

After the subframe had been manufactured, the microscopic investigation was conducted. The purpose was to reveal the real thickness of the composite structure. In the figure 4, the theoretical and real layups are displayed. The theoretical one was based on the thicknesses given by the woven producer [2]. The real one was based on the microscopic investigation.

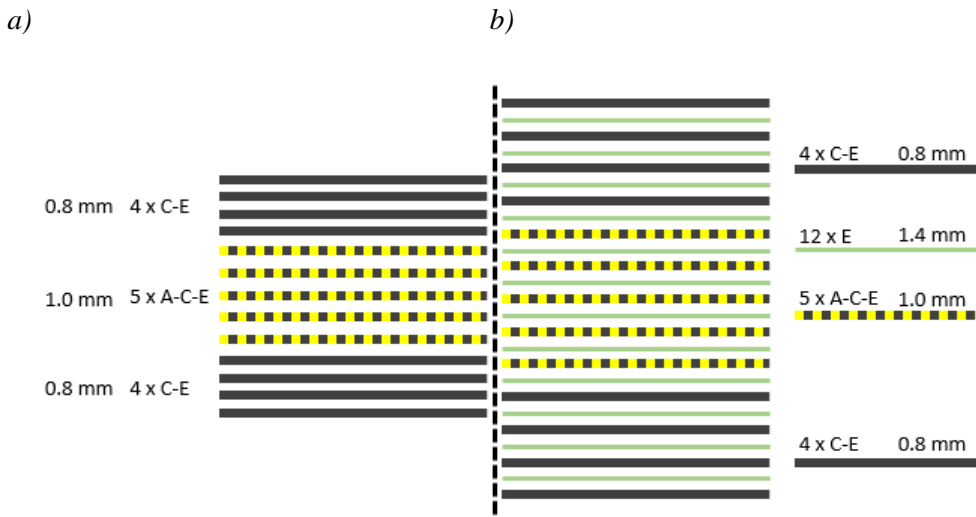


Fig. 4 Composite layups: theoretical 2,6 mm (a) and real (b) 4,0 mm

The subframe was subjected to a strength experiment using an MTS testing machine in the Department of Mechanics, Materials Science and Engineering,

Wrocław University of Science and Technology. The assembly of the experiment equipment and the specimen is shown in the figure 5.

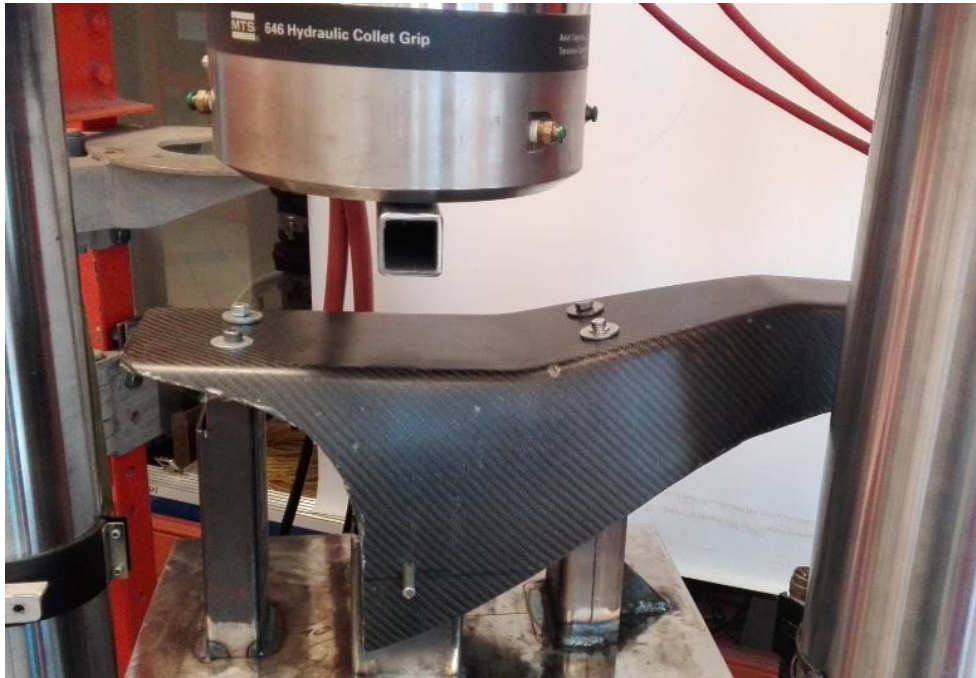


Fig. 5 The subframe in the experiment equipment

### 3. FEM ANALYSIS

After the experiment, a numerical analysis was conducted. The model of the subframe was a shell model [3]. Static analysis was set with geometrical nonlinearity. The particular laminas of the composite were divided into two separate unidirectional laminas in order to reflect the woven structure.

Thanks to the analysis, the diagram of the force and displacement was obtained. The force read from the simulation was the reaction force from the rigid loading pin. Moreover, values of the strain of laminas with  $0^\circ$  and  $90^\circ$  were obtained. They can be seen in the figure 6. The highest values can be noticed for the external layers, whereas in the middle of the subframe the strain is very low. In the figure 7 the displacement fields of the subframe are presented.



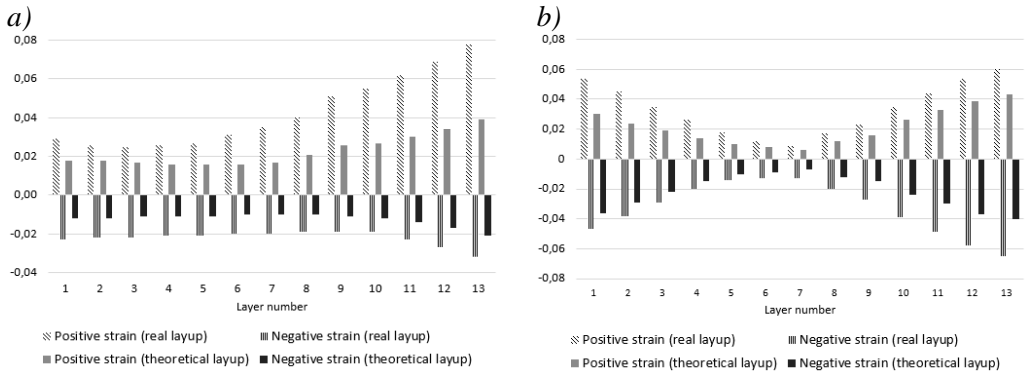


Fig. 6 Strain comparison for both layups for 0° (a) and 90° (b) fibre orientation

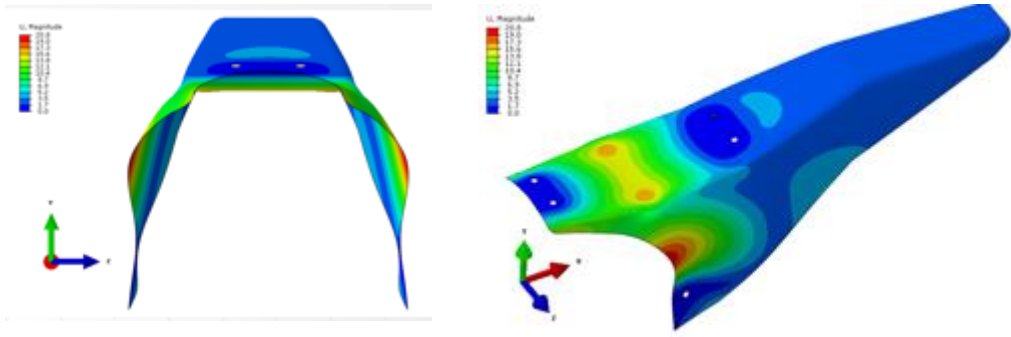


Fig. 7 Fields of displacement from the numerical analysis

#### 4. RESULTS AND CONCLUSIONS

Both from the experiment and the FEM analysis curves of force – displacement was obtained. They are presented in the figure 8. It can be noticed that for the theoretical layup curve the values of the force are quite similar to the experiment.

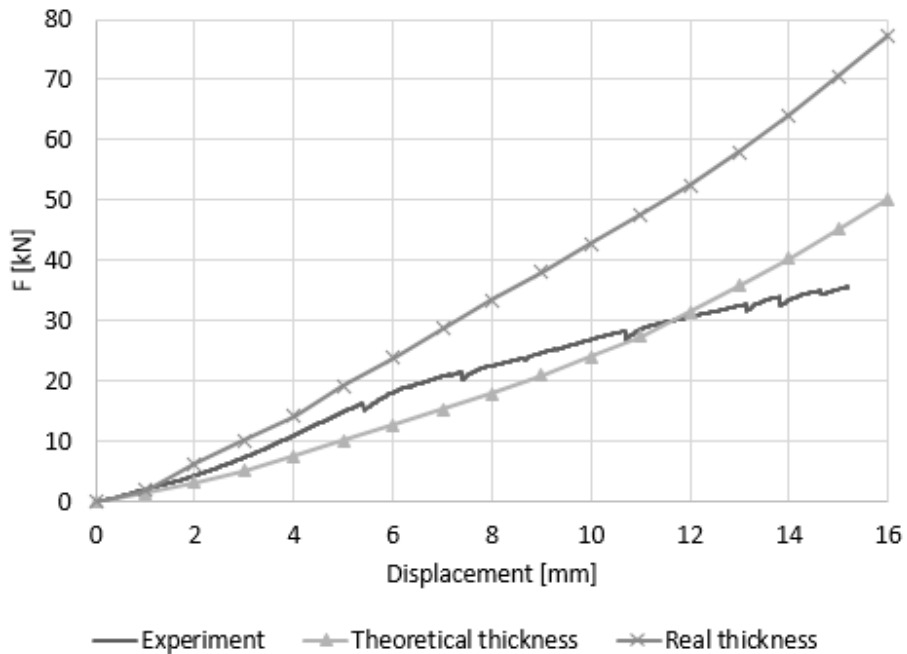


Fig. 8 The curves of force – displacement for the experiment and analyses

Although the curves of the experiment and the FEM simulation are not identical, the work is claimed to be successful. The experiment was conducted properly and the data was gathered successfully. The displacement fields obtained from FEM analysis faithfully reflect the real deformation of the specimen. Although the results of the reaction forces for both the experiment and the simulation are fairly similar and satisfactory, a set of improvements may be introduced. The material data could be derived from an experiment, instead of the product card. The destruction model in the composite could be introduced to take into account the real behaviour of the material over the elastic limit of the fibres. Moreover, the lamination technology would be developed so that the porosity of the composite would be lower. The experiment equipment could also be manufactured using prices cutting and welding machine to maintain better precision of the element.

#### REFERENCES

- [1] SMARTMOTO CHALLENGE (SMC) ASSOCIATION., SMARTMOTO CHALLENGE 2017 Rules 8.0\*
- [2] <http://primson-composites.pl/tkaniny-hybrydowe-i-inne/>. [Online]
- [3] Barbero E.J. *Finite Element Analysis of Composite Materials Using Abaqus*. New York : CRC Press, 2013. ISBN 978-1-4665-1661-8.

*Key words:*  
*Motorcycle shock arm, linkage system, force transmission ratio, FEM*

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## **CONCEPTION OF MOTORCYCLE SHOCK ARM CAPABLE OF VARIOUS TRANSMISSION FORCE RATIO**

The article presents the idea of creating a shock arm for the Light Electric Motorcycle - LEM Thunder. Nowadays, linkage systems used in motorcycles do not offer various transmission force ratios. The only way to change forces in the rear suspension in motorcycles consists of changing the parameters of a damper – stiffness, damping factor or preload. The main focus of the article was to create more than one point of attachment of the damper to the shock arm, which will enable various transmission force ratio of rear suspension. It will also allow to adapt rear suspension behavior proper for different types of roads. The article shows a kinematic model of linkage system created in MSC Adams 2016 software, attained characteristics of force transmission in different shock-damper configurations and FEM calculations for determined points of damper attachment in Abaqus CAE.

### **1. INTRODUCTION**

#### **1.1. LEM THUNDER**

LEM Thunder is the sixth motorcycle project of the Students' Association of Vehicles and Mobile Robots. The whole project consists of: designing the motorcycle, doing construction calculations, producing the parts, assembly and taking part in SmartMoto Challenge in Barcelona. LEM Thunder is a cross – type motorcycle designed to withstand the conditions similar to those of Dakar Rally competitions. The motorcycle's visualization is shown in the Fig.1 below.

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Fig. 1. Visualization of LEM Thunder

### 1.2 SHOCK ARM, MAIN ASSUMPTIONS

Fig. 2 below shows the linkage system of LEM Thunder with the shock arm. The whole system was created by students to attain value- and direction-wise optimal forces transferred from the rear wheel by the swingarm-link-shock and the damper to the chassis frame. Also, the transmission – force ratio in this system can be only changed by adjusting the preload and stiffness of the spring in the damper.

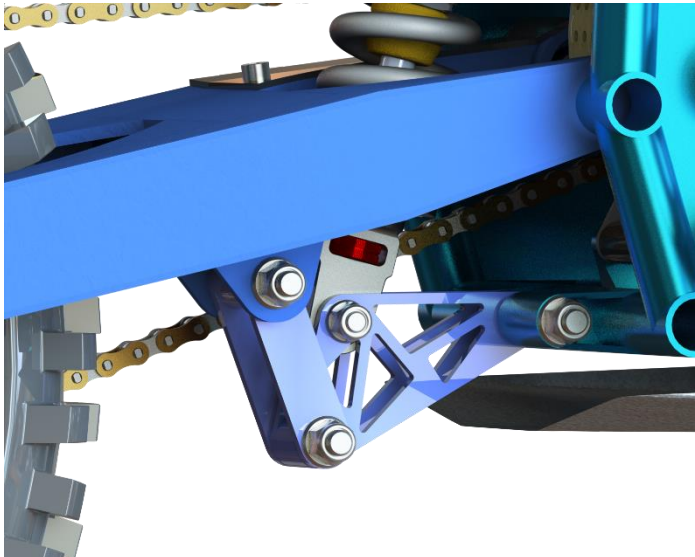


Fig. 2. Linkage system in LEM Thunder

To allow a wider range of changes in transmission forces and shock arm behavior, the idea of creating a shock arm with more attachment points occurs appeared. Changing the points adjusts the stiffness of the whole system, making the motorcycle more comfortable to ride on different types of roads. For example, a stiff suspension could be used on city roads, and a more flexible one on rough terrain. The main assumptions of this shock arm project are:

- to create a shock arm which withstands 4g acceleration force acting on a rear wheel,
- to create an area of attachment points which lets the whole system work without colliding with another,
- to achieve various force transmission ratio in attachment points.

The proposition of such shock arm conception is shown in the Fig. 3 below.

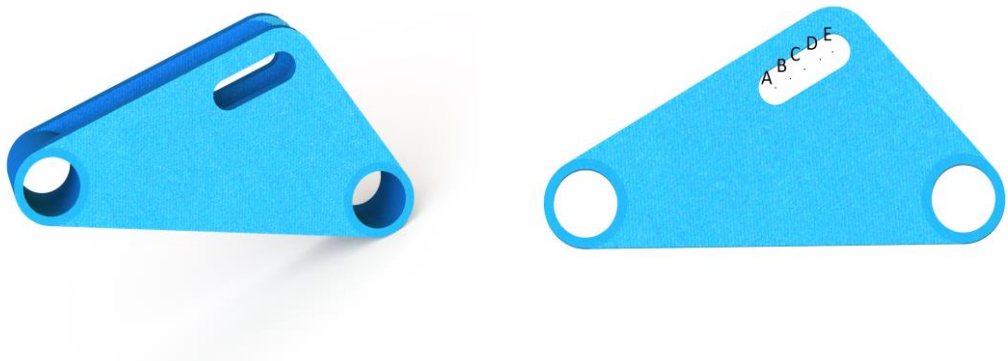


Fig. 3. Proposition of shock arm with five mounting points

## 2. CALCULATIONS

### 2.1. DYNAMIC MODEL IN MSC ADAMS

The first step in linkage system movement simulation was creating a functional assembly in the MSC Adams 2016 software. The components were uploaded and the kinematic pairs were added between them. The chassis frame of motorcycle was locked to the ground. For the spring, the stiffness of 210 N/mm was added. The influence of stiffness coefficient was removed – the examination was conducted in

quasi-static behavior. The force acting from the mounting points of the wheel was rising at the velocity of 850 N/s. The preload value on the spring was different in each case and was set to keep the same angle on the swingarm when the g acceleration starts. The whole system, as it is seen in MSC Adams, is presented in the Fig. 4 below. The linkage system was examined in 5 points: A-E with the acting force ranging from 1 to 4 times gravity acting on rear wheel. The maximum force was calculated using the following formula:

$$F_{max} = 4 * g * (m_1 + m_2) * \%r_m = 3380 N, \quad (1)$$

where g is earth gravity,  $m_1 = 70$  kg – mass of a driver,  $m_2 = 120$  kg - assumed mass of the motorcycle and  $\%r_m = 0.46$  - percentage division of motorcycle-driver mass onto front and rear wheel.

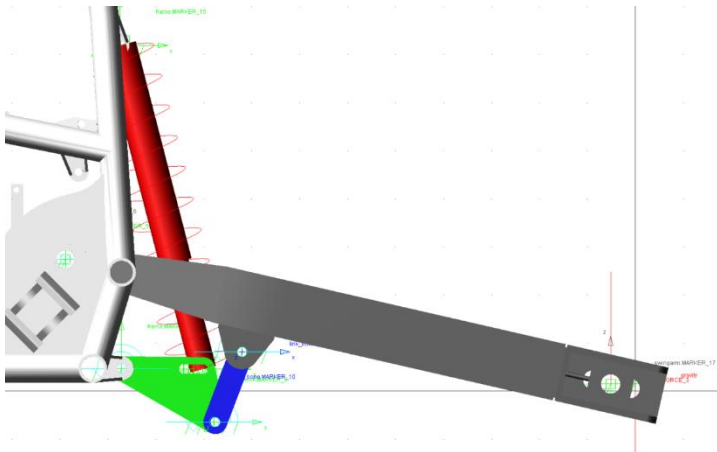


Fig. 4. Linkage system in LEM Thunder

The Fig.5-7 below show the differences in rear wheel travel, force in spring and transmission ratio between the A-E points of attachment in the shock arm.

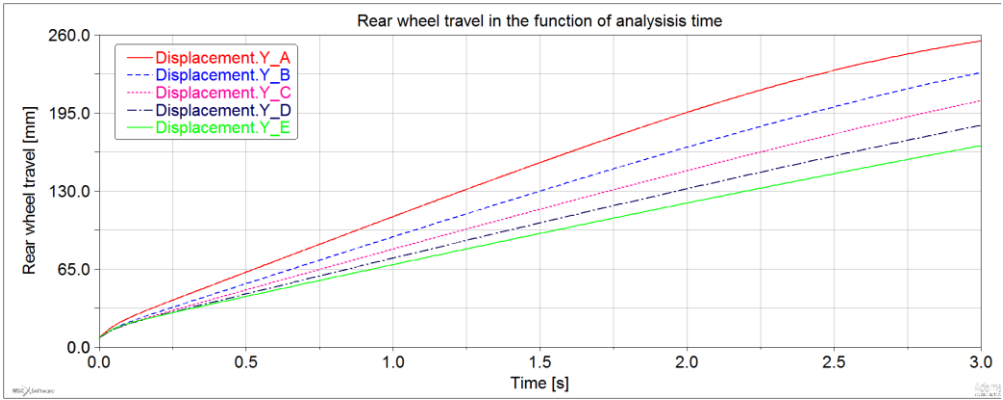


Fig. 5. Rear wheel travel [mm] in the function of time [s]

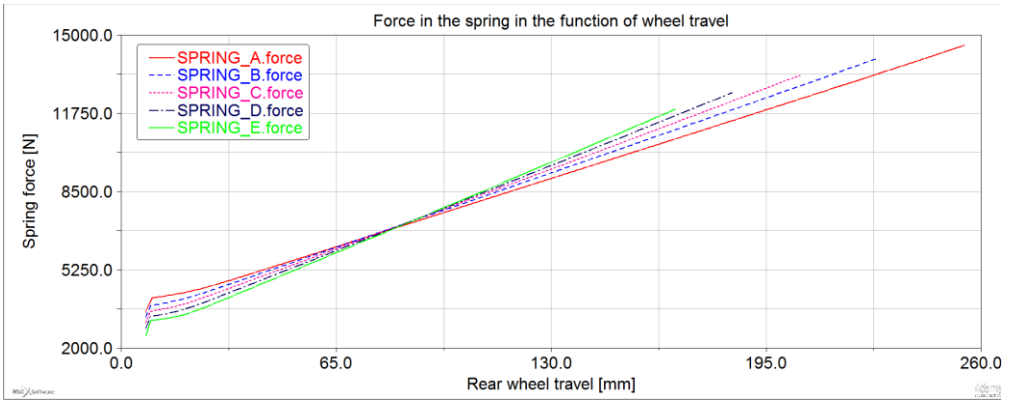


Fig. 6. Force in the spring [N] in the function of wheel travel [mm]

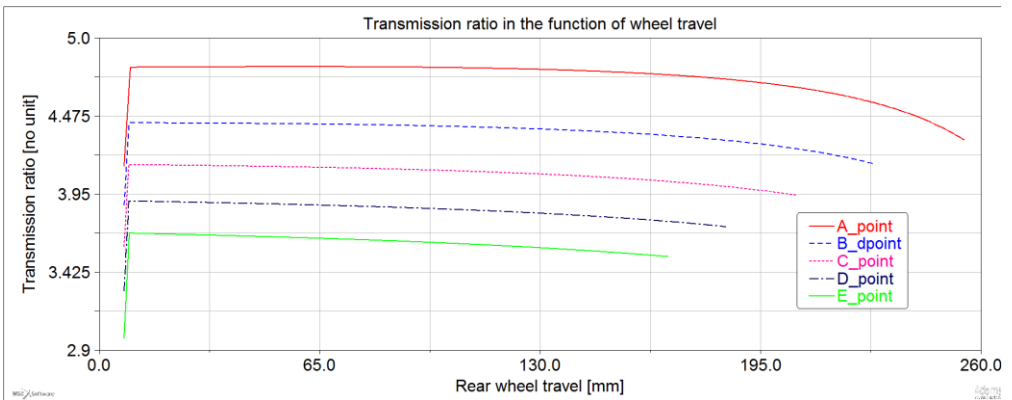


Fig. 7. Transmission ratio in the function of wheel travel [mm]

## 2.2. STRENGTH ASSESTMENT IN ABAQUS CAE

The last step of the project was to check the static strength of the system. For that, the linkage system was created in the Abaqus CAE software. The swingarm and the link were modeled as link-connections, a spring – spring connection with a stiffness of 210 N/mm and a shell model of the shock arm. In the attachment points in the frame, boundary-fixed conditions were added. The force was acting like in the Adams software. The examination of strength assessment was conducted in 3 points: A,C and E. The S355 material properties and assumed coefficient of safety for the material, construction and load factors for the shock arm are shown in Table 1 below. Also, the linkage system from Abaqus software is shown in Fig. 8 below. Results of the Huber-Mises simulation are also shown in the Table 2 below.

Table 1. Mechanical properties and safety coefficient for steel S355 [1]

	$R_m$ [MPa]	$R_e$ [Mpa]	$E$ [GPa]	$k$	$\mu$
S355	470	355	210	0.3	1.5

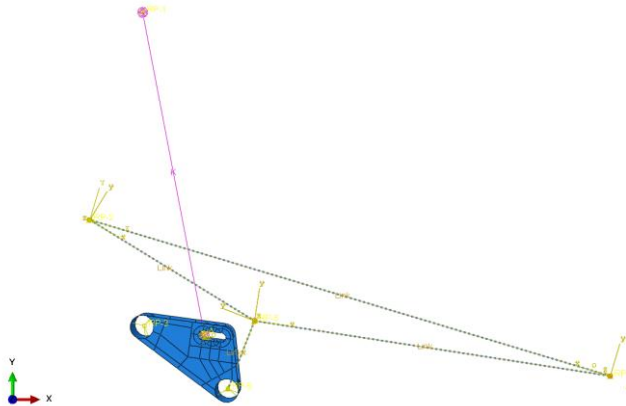


Fig. 8. Linkage system in Abaqus CAE

Table 2. Huber – Mises stresses for cases

	Case point A	Case point C	Case point E
$\sigma_{max}$ [Mpa]	245.0	232.4	219.3

## 3. CONCLUSIONS

- A proposition of various force ratio shock arm for rear linkage system in motorcycle was created.



- For five points of mounting A-E, the changes of transmission force ratio values vary from 3.7 to 4.8. Regressive behavior of rear suspension linkage system in each point was observed as well.
- In the Fig.6 all the functions cross in one point. It is a linkage system position situation in which the width dimension of the hole is perpendicular to the spring.
- In attachment points A to E, the rear wheel travel, maximum force on the spring and the force ratio decrease. Also because of that, an excess of maximum assumed Huber-Mises stresses occurs in the case of point A.

#### REFERENCES

[1] [https://www.steelconstruction.info/Steel\\_material\\_properties](https://www.steelconstruction.info/Steel_material_properties)

*Key words:*  
*CNC, milling machine, project, construction*

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## **PROJECT AND CONSTRUCTION OF A SMALL CNC MILLING MACHINE**

This article describes design problems of a small CNC milling machine which is build/being built building by students from the Association of Mobile Robots and Vehicles affiliated with Wrocław University of Technology. The paper describes the process of designing the device and includes the FEM analysis which helps with constructing the components of the machine. The article presents how to choose and arrange the parts, and describes the problems concerning stiffness and control system of this machine, and the solutions to these problems.

### **1. INTRODUCTION**

The project of CNC milling machine presented in this paper aims to supply the workshop of student scientific association KN PIRM which is affiliated with Wrocław University of Technology. We aim to present certain ideas which were discussed during the construction of the prototype of this machine. The project phase was finished in April 2018 and the final product is to be constructed this year. The construction of this machine is modeled on ready-made solutions which are available on the market. There are numerous blueprints available on the Internet, which helped to find solutions to the problems we have encountered.

The goal of this project is to create a machine with a relatively big working field. The dimensions of the device are about 700x700x400mm. The main application of the machine is machining aluminium, mild steel and plastics. Such application is important for our association, as it provides independence from external workshops and shortens the time spent on waiting for the order completion. It also saves money which would top up the project budget.

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## 2. PROJECT PHASE

In the project phase we created several conceptual models, from the prototype which shows a number of mistakes to the final model with reinforcements.

Presented in Fig. 1 is the basic model which lacks some elements. The parts of the machine are connected in the least complicated way. This one was presented at the beginning for the purpose of finding errors in the project and analysing future constructions. There are no reinforcements in this model, and there is a large risk that this movable gate will be deformed after several minutes of milling. Another factor creating tension during the machine's work is the table with legs. This concept also has construction errors in the frame of axle Z, as it is too long, which generates additional moments and forces.

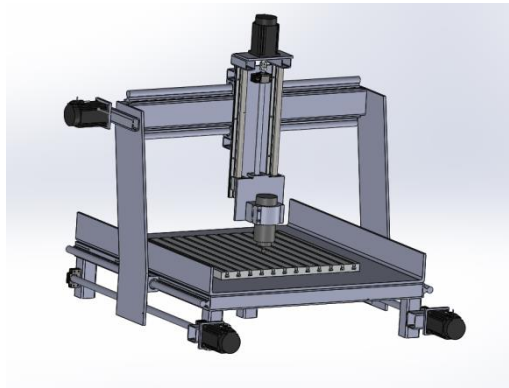


Fig.1. First conception of CNC milling machine

After some research and analysis of forces and methods of creating these devices, we decided to add frames from profiles which would reinforce the movable gate and the Z axis positioning frame, as seen in Fig.2. It was necessary to create a durable construction. To reduce gate mass, there are some notches. Their placement was selected thanks to FEM analysis. However, this conception has the same flaw as the first one, which is a too long Z axis positioning frame. It was connected with a higher movable gate and it has different gradient of moment connected with higher of electrospindle.

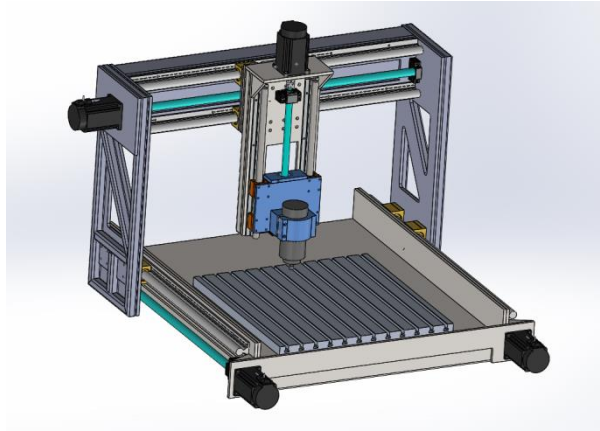


Fig.2. Second conception of CNC milling machine

The final conception of CNC milling machine has a different way of positioning in the Z axis, which is the only difference between the two concepts presented.. The main advantage of this idea is a working field increase and creating a stable frame for the Z axis movement. The shape of metal plates and profiles is designed to make them easier to weld and to obtain high accuracy.

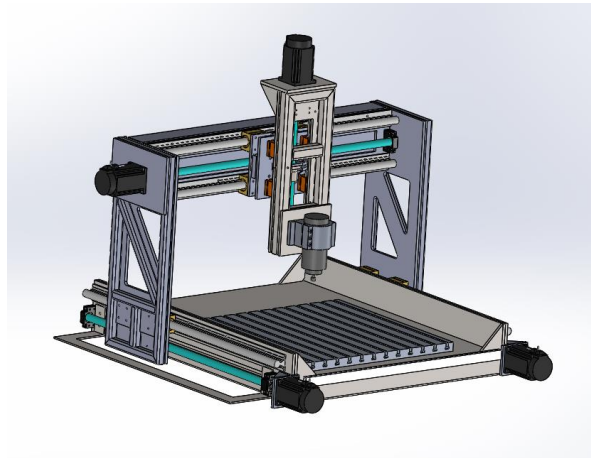


Fig.3. Final conception of CNC milling machine

### 3. LIST OF COMPONENTS

In order to assemble the CNC milling machine, it is necessary to divide components into ready-made and custom-built parts. Table 1 presents a list of ready parts and cost of steel parts after laser cutting.

Table. 1. List of components

List of components			
Name	Quantity	Price per item	Total price of items
Electrospindle ER11 1,5kW	1	889zł	889,00zł
Inverter HNC HV950-1R5G1	1	599zł	599,00zł
Stepper servo motor 8,7Nm	4	998zł	3992,00zł
Transformer 50V 400W 8A	4	265zł	1060,00zł
Electro casing	1	168,52zł	168,52zł
Linear bearing SME20LGUU	4	60,00zł	240,00zł
Linear guide SA20 500mm	2	60,00zł	120,00zł
Ball screw HIWIN R20-05-427-500	1	440,00zł	440,00zł
Bearing block BK15	4	150,00zł	600,00zł
Bearing block BF15	4	70,00zł	280,00zł
Linear bearing SME25GUU	8	47,00zł	376,00zł
Linear guide SA25 1000mm	4	180,00zł	720,00zł
Ball screw HIWIN R25-05-927-1000	3	560,00zł	1680,00zł
Aluminium T-Table	1	1700,00zł	1700,00zł
Steel + laser cutting	1	2176,37zł	2176,37zł
Tools	1	700,00zł	700,00zł
Arduino Uno Rev3 + components	1	319,75zł	319,75zł
Wires and accessories	1	330,70zł	330,70zł
			16391,34zł

#### 4. TECHNOLOGY OF EXECUTION

The best and the most precise method of cutting and preparing metal parts is laser cutting. This technology provides high quality of edges without the need for further adjustments. Waterjet cutting should also be taken into account; it may, however,

result in steel rusting and, consequently, lower edge quality. cutting prices are similar for both methods. These methods are necessary to consider, as there are many screws and joints which require folding. Without a high performance accuracy the frame which provides movement in Y and Z axis (which are connected to the gantry) would perceive motion and the control system would not obtain real information in real time [3].

To connect the metal parts of profiles and plates the best method would be laser welding or robot welding, but in workshop conditions the most suitable method would be TIG or MAG method welding. The difference between these methods is that MAG is faster than TIG. However, TIG welding provides welds of higher quality and more satisfying mechanical properties, with no splashes and with precise control of the process. To obtain higher performance, the TIG method is sufficient [1].

After machining and welding, surface layer of metal parts should be secured by cleaning from oxides and covering with primer and paint [2,3].

## 5. FEM ANALYSIS

The most important way to prove that this machine will be durable and safe in use is the FEM Analysis. The results of this analysis show how to reduce mass and project reinforcements. Such analysis requires data concerning the cutting force. To obtain approximate value, Taylor equation was applied:

$$F_c = k_c * A$$

$F_c$  – cutting force,

$k_c$  – cutting resistance,

$A$  – cross-sectional area of the cutting layer [4,5,6].

Table. 2.  $k_c$  parameter for different materials [4]

Material	$k_c$ [N/mm <sup>2</sup> ]
Aluminium	500 – 900
Steel	1400 – 3200
Stainless steel	1800 – 2900
Cast iron	1000 – 1500
Heat resistant alloys	2600 – 3300
Hardened steel	2800 – 4900

After calculations, obtained values were used in FEM analysis. Shown below are several analyses for aluminium, steel and cast iron.

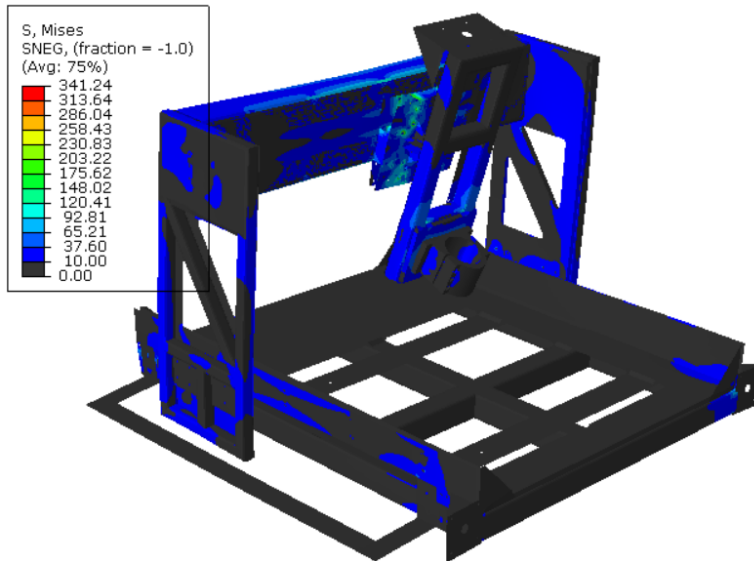


Fig.4. Analysis for steel  $k_c = 2000 \text{ N/mm}^2$  – model with deformations

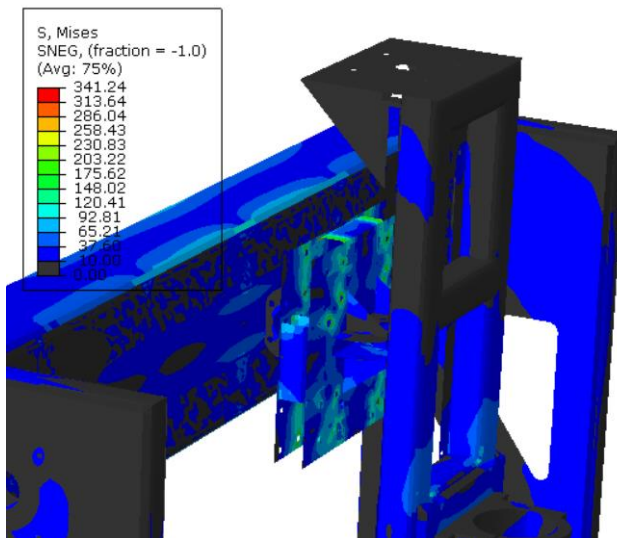


Fig.5. Analysis for steel  $k_c = 2000 \text{ N/mm}^2$  – the most loaded area

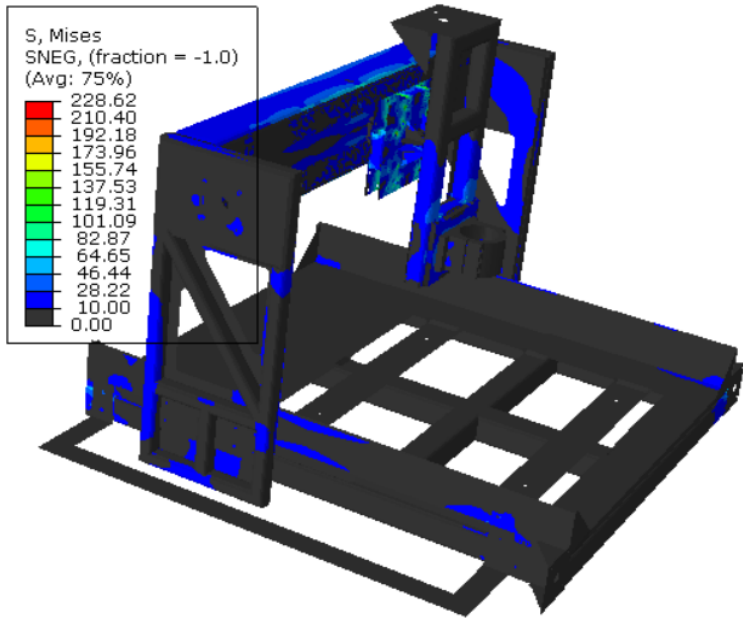


Fig.6. Analysis for cast iron  $k_c = 1500 \text{ N/mm}^2$

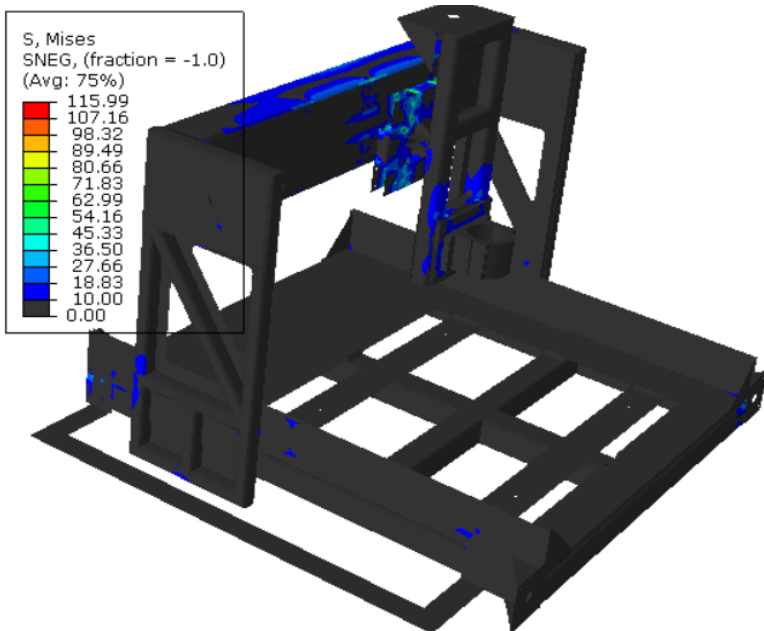


Fig.7. Analysis for aluminium  $k_c = 900 \text{ N/mm}^2$



Figures above present the results of simulations for steel, cast iron and aluminium. The figures presented above show that this CNC machine is suitable for materials presented, excluding some types of steel. It was prepared for tools diameter of 10mm, but the tools which were included with the electrospindle are 7mm in diameter at most (ER11). Fig.4. presents a model with deformations, which shows how the device would be damaged when provided with incorrect cutting parameters. Taylor equation provides only approximate data, so it should be taken into account to make some test in laboratory or apply force to a similar object. There are also problems connected with machine vibration. Such problems are typical for the industry and the field of laboratory research. The configuration of the machine is also an important factor, but the device would be most loaded with the electrospindle close to table surface.

Fig.5. shows tensions in the scope. The most loaded part is the plate which connects the movable gate to the axis Z positioning frame. This indicates that this element should be redesigned. Other figures demonstrate a simulation for aluminium and cast iron for comparison. For aluminium, the security factor is close to three.

These models include such loads as moments of 8700 Nmm on each servo motor and cutting force on electrospindle position which is placed perpendicularly to the table. As boundary condition, the bottom surface of the frame is connected to the ground. All degrees of freedom were taken. Mesh has quadratic-shaped elements with medial axis.

## 6. SUMMARY

The main idea behind creating this machine was machining aluminium, mild steel and plastics. As presented on figures the most important connection in this machine is between Z axis and the movable gate. The device will be subjected to considerable forces, which it is capable of withstanding.

There are also processes like welding and machining parts which are important because the material may be susceptible to deformation under the influence of heating and machining. There is also high risk during the positioning of the elements. Bevelled frame may not fit other elements, which would create some difficulties during the motion of each axis.

## REFERENCES

- [1]. A.Ambroziak - Techniki wytwarzania spawalnictwo, laboratorium, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2010.
- [2]. M.Feld - Podstawy projektowania procesów technologicznych typowych części maszyn, WN1 Warszawa 2007, Wyd III
- [3]. P. Cichosz – Techniki wytwarzania – obróbka ubytkowa, laboratorium części I i II. Oficyna Wydawnicza PWr Wrocław 2002

- [4]. <https://www.cnc.info.pl/sily-opory-skrawania-aluminium-a-dobor-silnika-t6000.html> [8.07.2018]
- [5]. [https://www.sandvik.coromant.com/pl-pl/knowledge/materials/workpiece\\_materials/the\\_specific\\_cutting\\_force/pages/default.aspx](https://www.sandvik.coromant.com/pl-pl/knowledge/materials/workpiece_materials/the_specific_cutting_force/pages/default.aspx) [8.07.2018]
- [6]. <https://www.sandvik.coromant.com/pl-pl/knowledge/machining-formulas-definitions/pages/milling.aspx> [8.07.2018]

*Key words:*  
*Vlasov theory, MES, finite element method,*  
*thin-walled bar, buckling.*

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## BUCKLING OF THIN-WALLED BAR – VLASOV THEORY VERSUS FINITE ELEMENT ANALYSIS

Nowadays, thin-walled constructions are widely used in civil engineering. There is a need to design those constructions economically and safely. It is very important to take into account the phenomenon of buckling. The article presents the results of a comparative thin-walled bar buckling analysis using the Vlasov theory and the finite element method (FEM). In the beginning, the basic assumptions of the thin-walled Vlasov theory and methods of deriving basic cross-section characteristics are presented. Subsequently, the one-dimensional finite element with 7 degrees of freedom has been created. Results obtained by using the described finite element and analytic solution for chosen boundary conditions and loads have been presented and compared. In the last part, the numerical model of thin-walled bar is made by using shell elements. The model shows the accuracy of the finite element obtained.

### 1. THE BASICS OF VLASOV THEORY

Vlasov theory can be used only when a bar is considered to be thin-walled. A bar is thin-walled when its dimensions fulfill conditions [1]:

$$\frac{g}{h} \leq 0.1 \text{ and } \frac{h}{L} \leq 0.1, \quad (1)$$

where:

$g$  [m] – thickness of cross-section,

$h$  [m] – characteristic dimension of cross-section,

$L$ [m] – length of the bar

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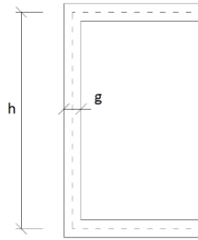


Fig. 1. Explanation of thin-walled bars' dimensions

In Vlasov theory, there are two important assumptions [2]:

1. Non-deformability of the cross-section area. This assumption is equivalent to *Saint-Venant's* rule for non-thin-walled bars in torsion theory [6].
2. Hypothesis of null shear strain of the bar's middle surface [6].

## 2. ANALYTICAL SOLUTION FOR SIMPLY STATIC SCHEME

### 2.1. STATIC SCHEME

In this part, an analytical solution for I-beam loaded with a constant bending moment along its length was derived using the minimum total potential energy principle. The end supports of the beam comply with the fork support condition. It prevents lateral displacement of the cross-section at supports and warping of the open thin-walled cross-section can develop freely [3]. The static scheme and I-beam cross section dimensions (in millimeters) were shown on Fig. 2.

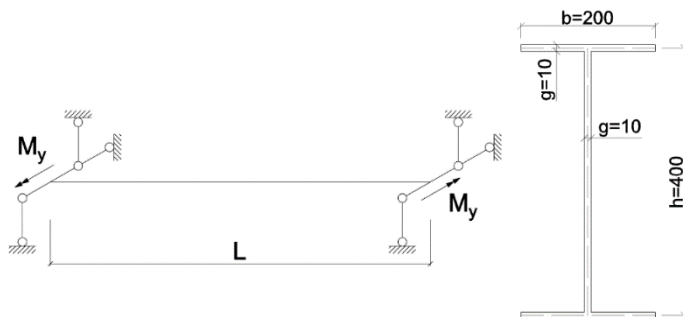


Fig. 2. Beam static scheme and I-beam cross section dimensions

## 2.2. ANALYTICAL SOLUTION

According to Lagrange theorem the first variation of the total energy of the system is equal to zero [5]:

$$\delta V = \delta U - \delta W = \delta \left( \frac{1}{2} \int_V C_{ijkl} \varepsilon_{ij}^L \varepsilon_{kl}^N dV + \int_V C_{ijkl} \sigma_{ij}^L \sigma_{kl}^N dV \right) - \delta W = 0 \quad (2)$$

Where:

- $V$  – total energy of the system,
- $U$  – total potential energy of the system,
- $W$  – total work of external forces,
- $C$  – stiffness tensor
- $\varepsilon, \sigma$  – deformation and stress tensors.

The following system of equations was obtained from formula (2):

$$\begin{cases} EI_z v_s^{IV}(x) + M_y \psi^{II}(x) = 0 \\ EI_\omega \psi^{IV}(x) - GI_s \psi^{II}(x) + M_y v_s^{II}(x) = 0 \end{cases} \quad (3)$$

With boundary conditions:

$$\begin{cases} \psi^{II}(0) = 0, & \psi^{II}(L) = 0, \\ \psi(0) = 0, & \psi(L) = 0, \\ v_s(0) = 0, & v_s(L) = 0, \\ w_s(0) = 0, & w_s(L) = 0. \end{cases} \quad (4)$$

Where:

- $E$  [GPa] – Young's modulus,
- $G$  [GPa] – Kirchoff's modulus,
- $I_z$  [m<sup>4</sup>] - moment of inertia with respect to the  $z$  axis,
- $I_s$  [m<sup>4</sup>] – torsion cross-section constant,
- $\psi$  [rad] – the angle of twist,
- $x$  [m] – coordinate along the axis of the bar.

The solution of following equation system has been obtained using Mathematica program:

$$\left\{ \begin{aligned}
 v_s(\xi) &= \frac{1}{2\beta^2\gamma\omega\sqrt{-\alpha-\omega}\sqrt{\omega-\alpha}} \left( \sqrt{2} (\sqrt{\omega-\alpha} \sinh\left(\frac{\xi\sqrt{-\alpha-\omega}}{\sqrt{2}}\right) (C_4(-\alpha^2 + \alpha\omega - 2\beta^2\gamma) + \right. \\
 &+ \beta\gamma C_8(\alpha - \omega)) + \sqrt{-\alpha-\omega} \sinh\left(\frac{\xi\sqrt{\omega-\alpha}}{\sqrt{2}}\right) (C_4(\alpha(\alpha + \omega) + 2\beta^2\gamma) - \beta\gamma C_8(\alpha + \omega)) ) + \\
 &+ \sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} \cosh\left(\frac{\xi\sqrt{-\alpha-\omega}}{\sqrt{2}}\right) (C_3(-\alpha^2 + \alpha\omega - 2\beta^2\gamma) + \beta\gamma C_7(\alpha - \omega)) + \\
 &+ 2\omega\sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} (-\alpha(C_4\xi + C_3) + \beta^2\gamma(C_2\xi + C_1) + \beta\gamma(C_8\xi + C_7)) + \\
 &+ \sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} \cosh\left(\frac{\xi\sqrt{\omega-\alpha}}{\sqrt{2}}\right) (C_3(\alpha(\alpha + \omega) + 2\beta^2\gamma) - \beta\gamma C_7(\alpha + \omega)) \Big) \\
 \psi(\xi) &= \frac{1}{2\beta\gamma\omega\sqrt{-\alpha-\omega}\sqrt{\omega-\alpha}} \left( 2\omega\sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} (\beta\gamma C_5 + \beta\gamma C_6\xi + C_4\xi + C_3) + \right. \\
 &+ \sqrt{2} (\sqrt{\omega-\alpha} \sinh\left(\frac{\xi\sqrt{-\alpha-\omega}}{\sqrt{2}}\right) (C_4(\alpha - \omega) - 2\beta\gamma C_8) - \sqrt{-\alpha-\omega} \sinh\left(\frac{\xi\sqrt{\omega-\alpha}}{\sqrt{2}}\right) \\
 &(C_4(\alpha + \omega) - 2\beta\gamma C_8)) + \sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} \cosh\left(\frac{\xi\sqrt{-\alpha-\omega}}{\sqrt{2}}\right) (C_3(\alpha - \omega) - 2\beta\gamma C_7) - \\
 &\left. - \sqrt{-\alpha-\omega}\sqrt{\omega-\alpha} \cosh\left(\frac{\xi\sqrt{\omega-\alpha}}{\sqrt{2}}\right) (C_3(\alpha + \omega) - 2\beta\gamma C_7) \right)
 \end{aligned} \right. \quad (5)$$

Where:

$$\xi = \frac{x}{L}, \quad \xi \in [0, L], \quad \alpha = -\frac{GI_s L^2}{EI_\omega}, \quad \beta = \frac{M_y L^2}{EI_\omega}, \quad \gamma = \frac{I_\omega}{I_z}, \quad \omega = \alpha^2 + 4\beta^2\gamma.$$

The boundary conditions (4) can be now presented in the form:

$$\mathbf{AC} = \mathbf{0} \quad (6)$$

Where:

$\mathbf{A}$  – matrix 8 x 8, obtained from (4) and (5),

$\mathbf{C}$  – column vector of constants  $C_i, i = 1, 2, 3, \dots, 8$ .

Non-zero solution to the above equation system can be obtained only if  $\det \mathbf{A} \neq 0$ . The figure below shows the dependence  $\det \mathbf{A}$  from bending moment  $M_y$ :

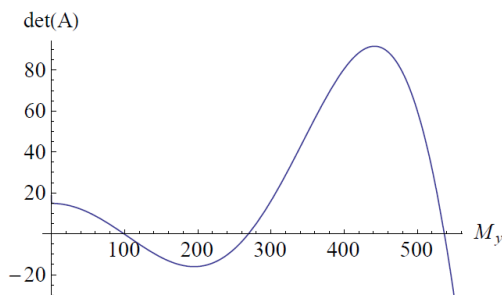


Fig. 3. Graph of dependence  $\det \mathbf{A}$  from bending moment  $M_y$

The first three critical moments  $M_y$  were received (see Table 1.).

Table 1. First three critical moments  $M_y$  gained using analytical method

	$(M_y)_{cr1}$	$(M_y)_{cr2}$	$(M_y)_{cr3}$
Critical load value [kNm]	99.06	269.4	537.0

According to Timoshenko, the formula for the first critical value is equal to [4]:

$$(M_y)_{cr1} = \frac{\pi}{L} \sqrt{EI_z GI_s \left(1 + \frac{EI_\omega}{GI_s} \frac{\pi^2}{L^2}\right)} \quad (7)$$

The first critical value  $M_{y,cr1}$  obtained by the two methods described is identical.

### 3. ONE-DIMENSIONAL FINITE ELEMENT ACCORDING TO VLASOV THEORY

#### 3.1. STIFFNESS MATRIX OF ELEMENT

Stiffness matrix of element has been derived using minimum total potential energy principle [5]:

$$\begin{bmatrix} \frac{AE}{L_e} & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{AE}{L_e} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{12EI_z}{L_e^3} & 0 & 0 & 0 & \frac{6EI_z}{L_e^2} & 0 & 0 & -\frac{12EI_z}{L_e^3} & 0 & 0 & 0 & \frac{6EI_z}{L_e^2} & 0 \\ 0 & 0 & \frac{12EI_y}{L_e^3} & 0 & -\frac{6EI_y}{L_e^2} & 0 & 0 & 0 & 0 & -\frac{12EI_y}{L_e^3} & 0 & -\frac{6EI_y}{L_e^2} & 0 & 0 \\ 0 & 0 & 0 & \frac{6GI_s + 12EI_\omega}{5L_e} & \frac{12EI_\omega}{L_e^2} & 0 & \frac{GI_s}{10} + \frac{6EI_\omega}{L_e^2} & 0 & 0 & 0 & -\frac{6GI_s}{5L_e} - \frac{12EI_\omega}{L_e^2} & 0 & 0 & \frac{GI_s}{10} + \frac{6EI_\omega}{L_e^2} \\ 0 & 0 & -\frac{6EI_y}{L_e^2} & 0 & \frac{AEI_y}{L_e} & 0 & 0 & 0 & 0 & \frac{6EI_y}{L_e^2} & 0 & \frac{2EI_y}{L_e} & 0 & 0 \\ 0 & \frac{6EI_z}{L_e^2} & 0 & 0 & 0 & \frac{AEI_z}{L_e} & 0 & 0 & -\frac{6EI_z}{L_e^2} & 0 & 0 & 0 & \frac{2EI_z}{L_e} & 0 \\ 0 & 0 & 0 & \frac{GI_s}{10} + \frac{6EI_\omega}{5L_e} & 0 & 0 & \frac{AEI_\omega}{L_e} + \frac{2GI_sL_e}{15} & 0 & 0 & -\frac{GI_s}{10} - \frac{6EI_\omega}{L_e^2} & 0 & 0 & -\frac{2EI_\omega}{L_e} - \frac{GI_sL_e}{30} & 0 \\ -\frac{AE}{L_e} & 0 & 0 & 0 & 0 & 0 & 0 & \frac{AE}{L_e} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -\frac{12EI_z}{L_e^3} & 0 & 0 & 0 & -\frac{6EI_z}{L_e^2} & 0 & 0 & \frac{12EI_z}{L_e^3} & 0 & 0 & 0 & -\frac{6EI_z}{L_e^2} & 0 \\ 0 & 0 & -\frac{12EI_y}{L_e^3} & 0 & \frac{6EI_y}{L_e^2} & 0 & 0 & 0 & 0 & -\frac{12EI_y}{L_e^3} & 0 & \frac{6EI_y}{L_e^2} & 0 & 0 \\ 0 & 0 & 0 & -\frac{6GI_s}{5L_e} - \frac{12EI_\omega}{L_e^2} & 0 & 0 & -\frac{GI_s}{10} - \frac{6EI_\omega}{L_e^2} & 0 & 0 & \frac{6GI_s}{5L_e} + \frac{12EI_\omega}{L_e^2} & 0 & 0 & -\frac{GI_s}{10} - \frac{6EI_\omega}{L_e^2} & 0 \\ 0 & 0 & -\frac{6EI_y}{L_e^2} & 0 & \frac{2EI_y}{L_e} & 0 & 0 & 0 & 0 & \frac{6EI_y}{L_e^2} & 0 & \frac{4EI_y}{L_e} & 0 & 0 \\ 0 & \frac{6EI_z}{L_e^2} & 0 & 0 & \frac{2EI_z}{L_e} & 0 & 0 & 0 & -\frac{6EI_z}{L_e^2} & 0 & 0 & 0 & \frac{4EI_z}{L_e} & 0 \\ 0 & 0 & 0 & \frac{GI_s}{10} + \frac{6EI_\omega}{L_e^2} & 0 & 0 & \frac{2EI_\omega}{L_e} - \frac{GI_sL_e}{30} & 0 & 0 & -\frac{GI_s}{10} - \frac{6EI_\omega}{L_e^2} & 0 & 0 & \frac{4EI_\omega}{L_e} + \frac{2GI_sL_e}{15} & 0 \end{bmatrix} \quad (8)$$

Where  $L_e$  is length of the beam element.

To find a critical load value using FEM (finite element method), the generalized eigenproblem should be solved:

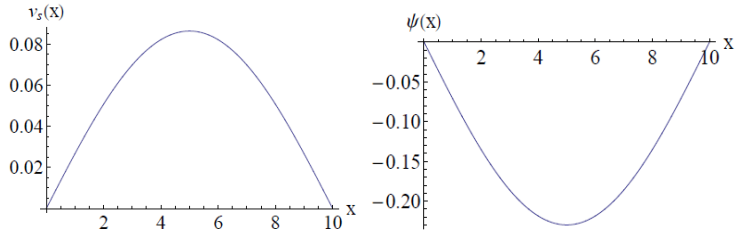
$$(\mathbf{K} + \lambda \mathbf{K}_{\sigma 0})\mathbf{q} = 0 \quad (9)$$

Where:

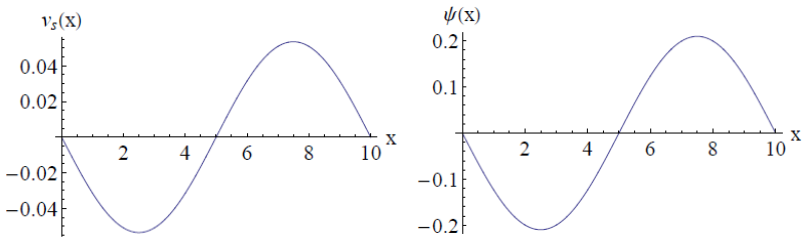
$\mathbf{K}$  – global stiffness matrix,

$K_{\sigma 0}$  – global initial stress matrix  
 $q$  – displacement vector

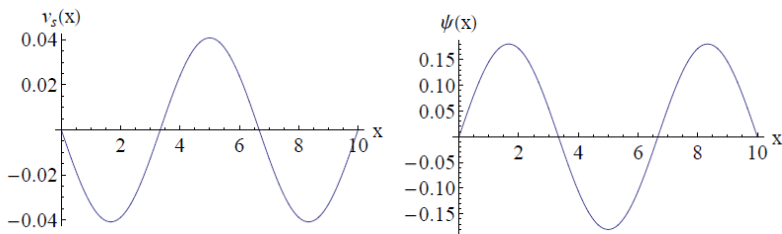
The results (displacements in the direction of the z axis  $v_z$  [m] and the angle of twist  $\psi$ [rad]) obtained by using created beam finite element are presented below.



a) The first form of loss of stability  $M_{y,cr1} = 99.06 \text{ kNm}$



b) The second form of loss of stability  $M_{y,cr2} = 269.4 \text{ kNm}$



c) The third form of loss of stability  $M_{y,cr3} = 537.0 \text{ kNm}$

Fig. 4. The first three forms of loss of stability obtained by using created finite element

### 3.2. ANALYSIS OF CORRECTNESS OF VLASOV THEORY USING ABAQUS PROGRAM

In this part the numerical model of thin-walled bar is made by using shell finite



elements. Fig. 5 shows the created numerical model and adopted static schema.

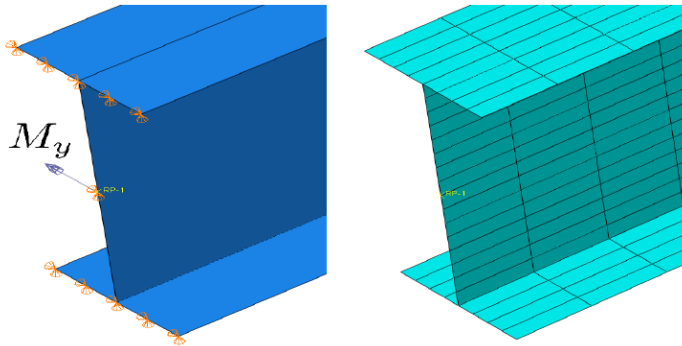


Fig. 5. Numerical model created in Abaqus

Fig. 6 shows results obtained by using shell elements in Abaqus.

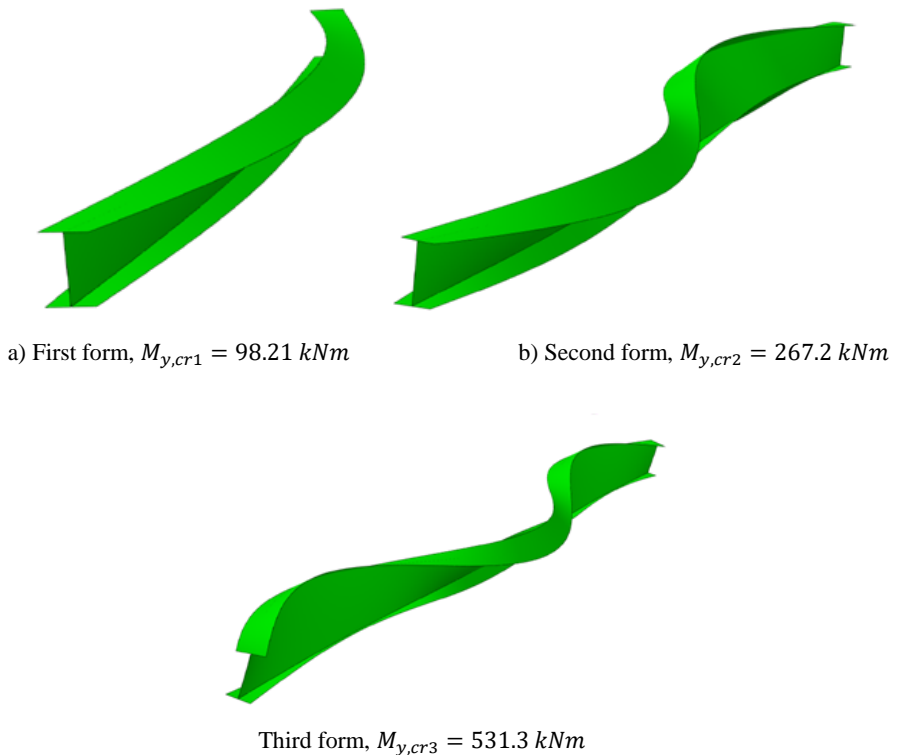


Fig. 6. The first three forms of loss of stability obtained by using Abaqus shell finite elements

### 3. SUMMARY AND CONCLUSIONS

Below in Table 2. results obtained by using created finite element and Abaqus shell elements are compared.

Table 2. Comparison of results obtained by using created beam finite element and Abaqus shell elements

	$(M_y)_{cr1}$ [kNm]	$(M_y)_{cr2}$ [kNm]	$(M_y)_{cr3}$ [kNm]
Created beam elements	99.06	269.4	537.0
Abaqus shell elements	98.21	267.2	531.3
Relative error [%]	0.87	0.82	1.07

For the purpose of checking the correctness of Vlasov theory a numerical model of an I-shaped, thin-walled beam was created. Results obtained by using the created beam finite element are very similar to results gained by shell elements. By analysing obtained results it can be concluded that the one-dimensional element discussed can be already effective for a small amount of used elements and it can be used with success to solve simple engineering problems.

#### REFERENCES

- [1] GAWĘCKI A., Mechanika materiałów i konstrukcji prętowych. ALMA MATER, POZNAŃ 2003.
- [2] OBREŃBSKI J., Cienkościenne sprężyste pręty proste. OFICYNA WYDAWNICZA POLITECHNIKI WARSZAWSKIEJ, WARSZAWA 1999.
- [3] IVAN BALÁZS, JINDŘICH MELCHER, Lateral Torsional Buckling of Steel Thin-Walled Beams with Lateral Restraints, WORLD ACADEMY OF SCIENCE, ENGINEERING AND TECHNOLOGY INTERNATIONAL JOURNAL OF STRUCTURAL AND CONSTRUCTION ENGINEERING VOL:9, NO:6, 2015
- [4] N. GOODIER S. TIMOSHENKO, Teoria sprężystości, 1951.
- [5] J. N. REDDY, An Introduction to the Finite Element Method, Department of Mechanical Engineering Texas A&M University College Station, Texas, USA 77943
- [6] RUTECKI J., Wytrzymałość konstrukcji cienkościennych. WARSZAWA: PAŃSTWOWE WYDAWNICTWO NAUKOWE, 1957

*Key words:*  
*SiC, silicon carbide, SiC waste, disintegrator, grinding*

Elina BARONE<sup>1</sup>

## **SILICON CARBIDE POWDER FROM WASTE USING A DISINTEGRATOR**

Silicon carbide (SiC) is a non-oxidizing high hardness ceramic material that possesses high technological properties such as high corrosion resistance and heat resistance. It is chemically inert to all alkalis and acids and highly abrasive. SiC is used as abrasive material, refractory material, and in ceramics. Sil.SiC are obtained through the silicidation process to improve the mechanical, thermal, and chemical properties of the material samples. SiC and sil.SiC ceramic materials from residues were ground for the first time. In this paper a method to produce fine SiC micro powder with determined particle size from heating element waste has been presented. These details were ground in several stages in a laboratory disintegrator. The mechanism of disintegration, the relationship between spent energy for disintegration and the degree of grinding SiC and sil.SiC powder are described. The dependence of grindability (decrease in particle size) on the specific energy of treatment was studied. The application of SiC powder material is to create lightweight temperature-resistant concrete.

### **1. INTRODUCTION**

Silicon carbide (70.05% silicon and 29.95% carbide) is a non-oxidizing ceramic material that possesses high technological properties, such as high corrosion resistance and heat resistance (up to 2000°C). It is chemically inert to all alkalis and acids and highly abrasive [8]. SiC is used as an abrasive material, refractory material, and in ceramics. Sil.SiC are obtained through the silicidation process to improve the mechanical, thermal and chemical properties of the material samples. A disadvantage of this material is its fragility but for the disintegrator grinding mode this is a positive aspect.

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High hardness SiC and sil.SiC ceramic materials from residues were ground for the first time. The sample is saturated with high temperature silicon, which greatly increases the strength of the sample. [1] For the object of research, the technological wastes of SiC in the solid forms (Fig 2a, 2b) obtained at the stage of their production and application have been used as insulation of heating in furnaces and kilns. Raw material comes from a furnace heat element – a pipe with wall thickness 8–9 mm and length 1100–1300 mm (Fig. 1a). Before grinding, heat elements were crushed to size 10–15 mm by hammer mill (Fig. 1b).

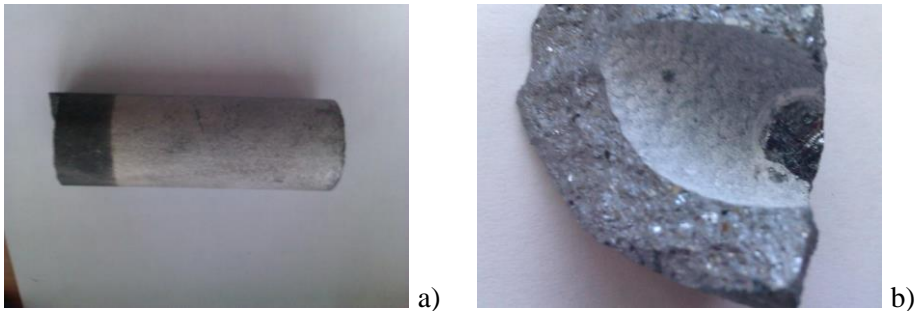


Fig. 1. Technological wastes of SiC a) as supplied (fragment); b) crushed in the hammer mill

Effective crushing process of the residue SiC material is performed by grinding mills called disintegrators (Fig. 2 a,b). The advantages of this technique are that this type of grinding allows to reduce the price of the fraction material and, at the same time, to reuse waste, which saves natural and energy resources. Through grinding, selected material particles can gain a certain size. In this work the system of disintegrators DS-Series in Tallinn University of Technology in Estonia was used. [2-7]

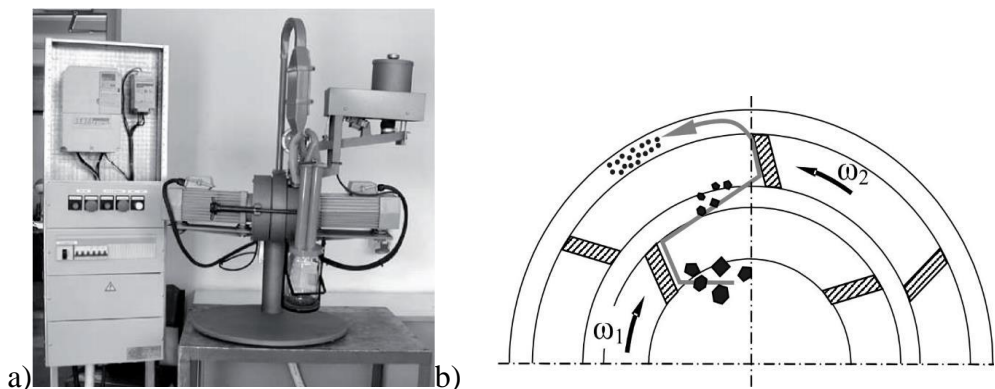


Fig. 2 a) laboratory disintegrator system DSL-175; b) schematic representation of the disintegrator equipment: where  $\omega_1$ ,  $\omega_2$  – radial velocity of disintegrator wheels [1]

## 2. EXPERIMENTAL PART

The grindability of SiC and sil.SiC using milling by collision in a high speed laboratory disintegrator (up to 12000 rpm) was studied and the dependence of article size reduction on specific energy of treatment was determined. The illustration of the grindability of SiC and sil.SiC at different stages of grinding, depending on the specific energy of treatment (lower specific energy is achieved by pre-crushing and direct grinding, higher specific energy by using the separative grinding system) is shown in figures 3–5.

An important factor in researching acquisition process of powder material by waste grinding is the disperser consumed specific energy depending on the final particle size. The parameter of grinding – specific treatment energy  $E_s$  – was used to estimate grindability. The results of grading curves of grained SiC for various grinding modes are shown in Figure 3 (in case SiC grinding) and in Figure 4 for sil.SiC grinding.

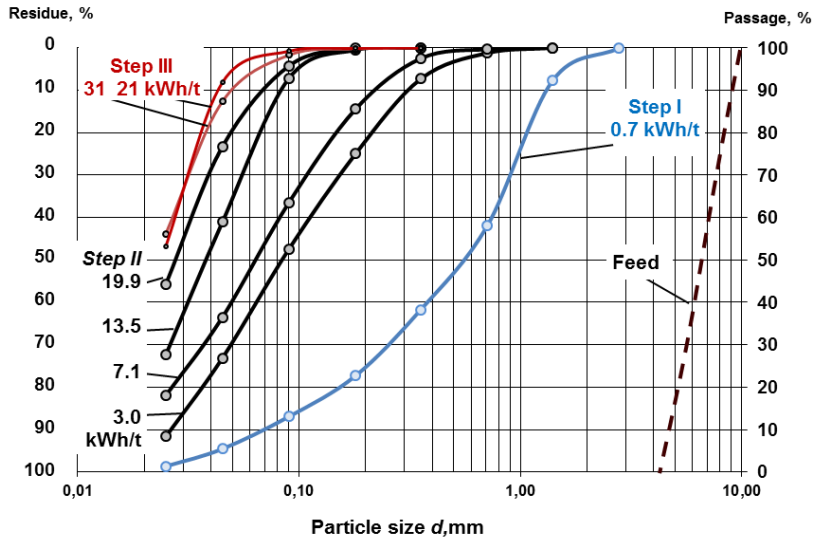


Fig. 3. Grading curves of ground SiC for various grinding modes. Feed – raw material granularity; Step I – preliminary crushing by roller mill; Step II – Intermediate direct multi-stage grinding; Step III – separative final grinding with an inertial air classifier

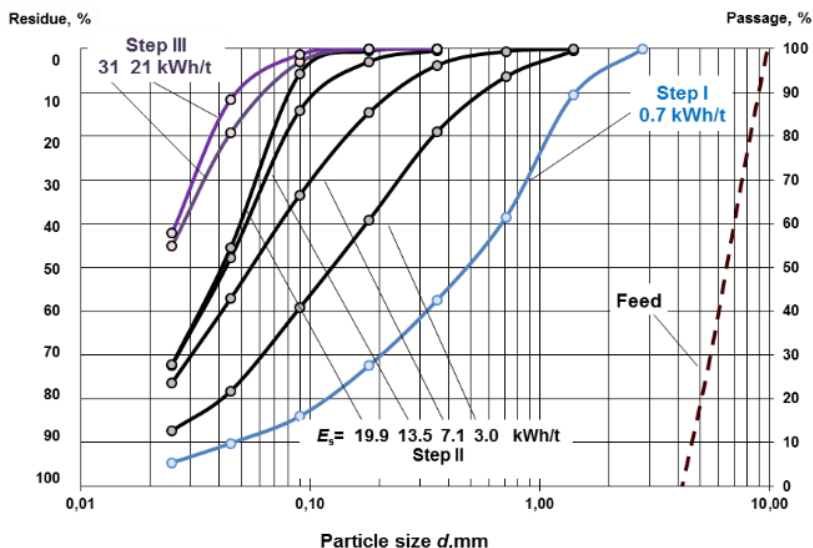


Fig. 4. Grading curves of milled sil.SiC for various milling modes. Feed – raw material granularity; Step I – preliminary crushing by roller mill; Step II – Intermediate direct multi-stage grinding; Step III – separative final grinding with an inertial air classifier

### 3. RESULTS AND DISCUSSION

The shape of a particle depends on the duration of grinding with increase in time. Examined grinding process of SiC and sil.SiC depending on the specific energy consumed determined the optimum energy consumption mode (20-31 kWh/t) that allows to save ten times more energy than other grinding devices (ball, hammer mills, etc.). With increasing energy expended in grinding particles, sphericity also increases. At the same time, the angularity of fine particles, mainly the product of direct fracture, does not always decrease. Particles of sil.SiC are more spherical and similar to each other than SiC. This can be explained by higher brittleness of SiC. Silicon impregnation allows strengthening the structure of material. Therefore, in the beginning size reduction happens a little slower, but it does not affect grinding significantly.

Particles size reduction has rapid nature and therefore it does not need much energy and is very effective. The shape of grindability curves shows that both materials can be very well ground by disintegrators.

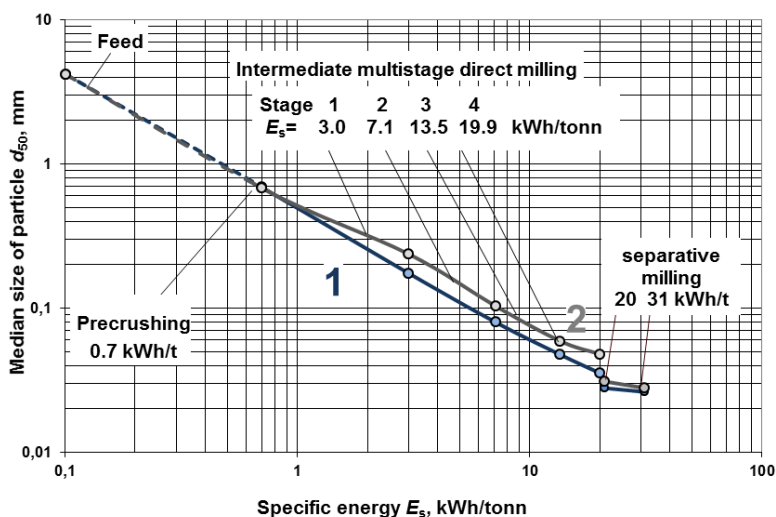


Fig.5. Dependence of the median particle size  $d_{50}$  on the specific energy  $E_s$  of grinding. Grindability curves of materials: 1 – (SiC); 2 – (sil.SiC)

Comparing both materials, a silicidated silicon carbide sil.SiC showed slightly lower grindability. Silicidated silicon carbide sil.SiC showed approximately 36% lower decrease in the mean particle size after one step direct grinding by disintegrator in comparison with non-silicidated sil.SiC. After the second grinding, this difference was approximately 30% and after the third – about 23%. At the same time, results after multiple grinding did not differ (sil.SiC and SiC after separative grinding in Fig. 5).

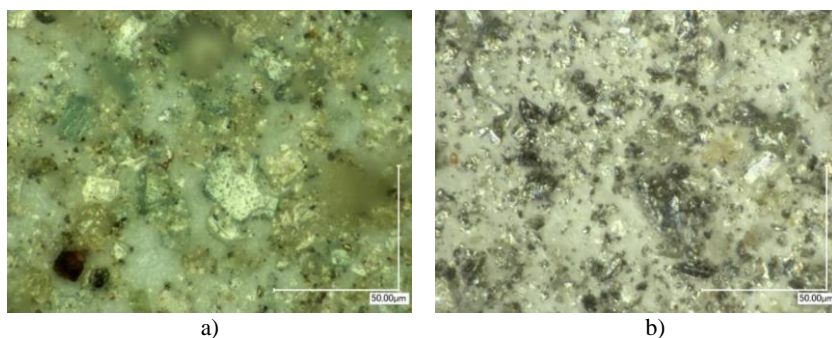


Fig. 6. Morphology (a, b) of ground products after final separative grinding by laboratory disintegrator system DSL-175: a – (SiC); b – (sil.SiC)

The technology of producing powders from used (recycled) silicidated and non-silicidated silicon carbides sil.SiC and SiC consisted of the preliminary crushing of initial raw material and the final grinding of pre-treated product by collision in the

disintegrator mill with direct or separative mode. The dependence of grindability (decrease in particle size) on the specific energy of treatment was studied. SiC and sil.SiC powders production with a desired particle size is available. Silicon impregnation allows strengthening the structure of material. Therefore, at the beginning size reduction happens slower but it does not affect grinding significantly. To obtain fine powders it is recommended to use disintegrator grinding with inertial separative system, which allows to obtain fine powder in one cycle with lower energy consumption (20–31 kWh/t). This is achieved by constant removal of fine material from the grinding zone using inertial separator. Obtained results can be used in future evaluations for industrial grinding facility design.

#### 4. CONCLUSION

To obtain fine SiC and sil.SiC powders with an optimal particle size (10-15  $\mu\text{m}$ ) from waste details it is recommended to use disintegrator system DSL-175 grinding with inertial separative system, which allows to obtain fine powder in one cycle with lower energy consumption (20-31 kWh/t) saving ten times more energy than other grinding devices (ball, hammer mills, etc.).

#### REFERENCES

- [1] INDRIKSONE E. *SiC Ceramics, Characteristics and Uses*, Master Thesis, RTU, Riga, Latvia, 2013 69 p.
- [2] GOLJANDIN D., KULU P., PEETSALU P. *Ultrafine Metal Powder Produced by Grinding from the Industrial Wastes* Proc. TMS 2002 Recycling and Waste Treatment in Mineral and Metal Processing: Technical and Economic Aspects, Sweden, Vol. 1 2002: pp. 277 – 284.
- [3] TUMANOK A., KULU P., GOLJANDIN D., ROSHTSHIN P. *Disintegrator as a machine for utilizing of metal chips to metal powder*, In Proc. III ASM International Conference and Exhibition. The Recycling of Metals. Barcelona, 1997, pp. 513-522.
- [4] SHISHKIN A., MIRONOV V., GOLJANDIN D., LAPKOVSKY V. *Recycling of Al-W-B Composite Material*. Key Eng. Mater., vol. 527, pp. 143–147, Nov. 2012.
- [5] SHISHKIN A., MIRONOV V., GOLJANDIN D., LAPKOVSKY V. *Mechanical Disintegration of Al-W-B Waste Material*. PM2010 World Congress, 2010, vol. 2, pp. 597–601.
- [6] TUMANOK A., KULU P. *Treatment of different materials by disintegrator systems*. In Proc. Estonian Acad. Sci. Eng., 5, 3 (1999), pp. 222-242.
- [7] GOLJANDIN D. *Disintegrator Milling System Development and Milling Technologies of Different Materials*. Doctoral Thesis of Tallinn University of Technology, Tallinn, Estonia, 2013
- [8] KUMAR P. V., GUPTA G. S. *Study of Formation of Silicon Carbide in the Acheson Process*, India, 2001, 21p



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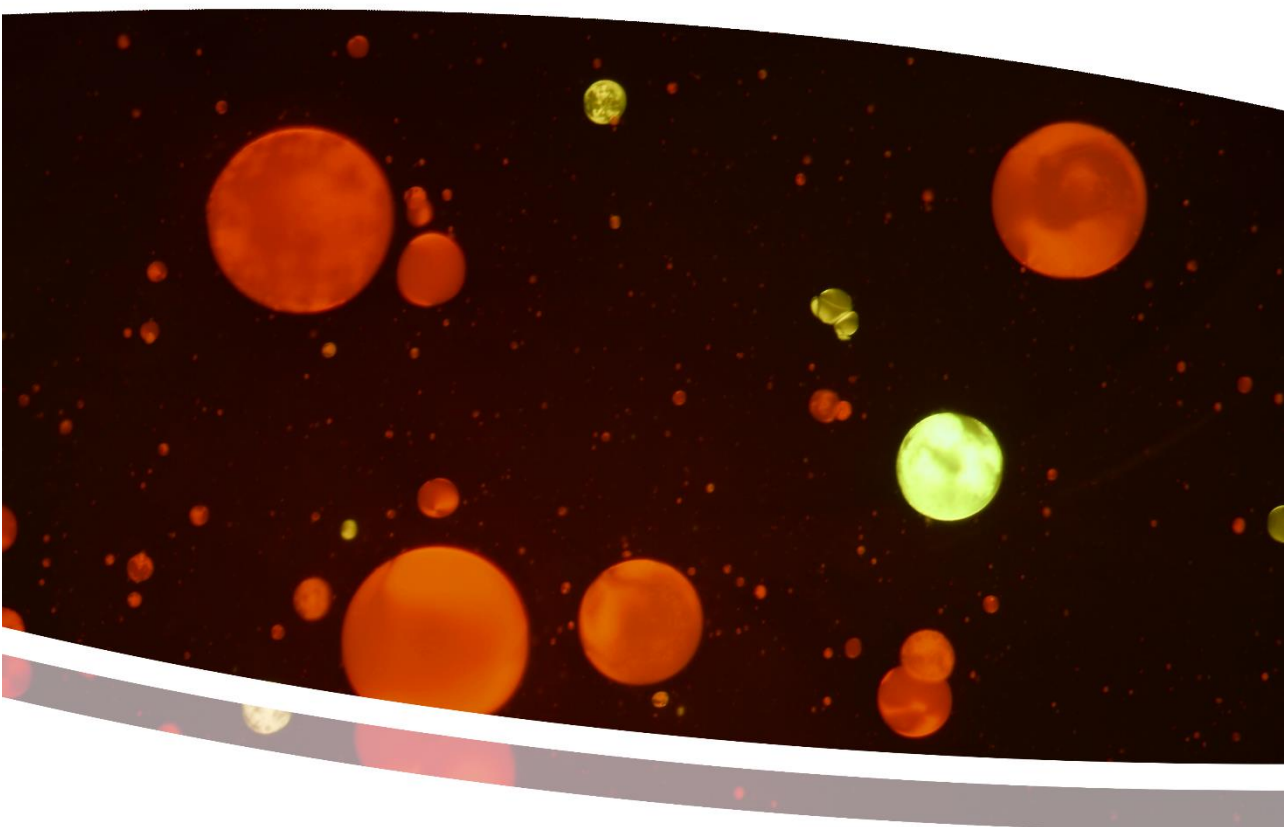
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