Environment Protection Engineering

Vol. 32 2006 No. 1

ŁUKASZ ZIELIŃSKI*

BIOETHANOL AS A COMPONENT OF LIQUID FUELS AFFECTING ENVIRONMENTAL PROTECTION

Government programmes of blending bioethanol with petrol are presented. The results of numerical simulation of real plant conditions are discussed.

1. INTRODUCTION

Ethanol as a fuel was first used on a large scale in the early 1900's when petroleum in Europe was in short supply. In America, Henry Ford's Model T and other early 1920's automobiles were originally designed to run on alcohol fuels. Germany and the U.S. relied on ethanol to power their armies during World War II. After World War II, oil prices dropped, which decreased the use of ethanol. The limited use of ethanol continued until the oil crisis developed in the 1970's. An increased use of ethanol as a fuel has developed since the late l970's. It was first used as a product extender because of gasoline shortages.

Ethanol is widely used as a component of liquid fuels. Ethanol is a renewable product so its combustion does not intensify the "greenhouse effect". Plants absorb the product of its combustion, i.e., carbon dioxide, which makes them a raw material in production (fermentation) of bioethanol. Bioethanol addition to fuel increases the octane number and decreases harmful gases emission such as carbon monoxide, nitric oxide, and toxic and cancerogenic VOC (volatile organic compound).

Economic aspects of using bioethanol as petrol are as follows: small distillery will continue to operate, utilisation of agricultural yield surplus, unemployment reduction (industry in the rural areas) and waste land management.

* Institute of Chemical and Process Engineering, Cracow University of Technology, ul. Warszawska 24, 31-155 Kraków, Poland.

2. NET ENERGY BALANCE OF ETHANOL PRODUCTION

The net energy value (NEV) is the difference between the energy in the fuel product (output energy) and the energy needed to produce the product (input energy). In the 1980's it was thought that the ethanol energy balance was neutral to negative: the amount of energy that went into producing ethanol was less than or equal to the energy contained in the ethanol. Since then the advances in the farming community as well as technological advances in the production of ethanol have led to positive returns in the energy balance of ethanol.

Many advances have led to the surge in ethanol production efficiency. One key issue is the ability to produce more litres of ethanol per volume of bio-product. Another element to ethanol's increased efficiency is the advances in agricultural production. Another key factor in farming efficiency is that of yield. Yield plays a major role in determining net energy value in the energy balance.

3. VAST POTENTIAL OF FUEL ETHANOL

Every government in countries all around the world has been criticised for the lack of an energy policy. Brazil is a good example of how a commitment by government can help realise goals for ethanol production and use.

In 1975, Brazil began an ambitious, three-stage, national alcohol fuel programme designed to reduce its dependence on imported oil. This program [1] has created a market where Brazilian petrol-powered vehicles operate on 20–25% (by vol.) ethanol. It created a market with 4.3 million vehicles using hydrated ethanol (95.5 vol%) and another 17 million cars utilising blends of ethanol for a combined fleet equivalent of 7.25 million cars. It created 640000 direct jobs and approximately 9 million indirect jobs, reduced oil imports by nearly 70% between 1979 and 1992. An increased manufacturing of ethanol-powered vehicles to 96% of domestic vehicle production improved the Brazilian trade balance from US $ 3.5 million in 1975 to over US $ 14.9 million in 1992. It reduced Brazil's reliance on imported oil from 43.3% in 1985 to 21.7% in 1992, it increased ethanol production to the level of 16 million litres per year. And now 18000 of 22000 Brazilian fuel stations sell fuel ethanol.

The current European fuel standard DIN EN 228 specifies 15% ETBE (ethyl tertiary butyl ether), or 5% (by vol.) ethanol. The objectives of the EU biofuel directive for 2010, however, require a higher proportion of up to roughly 9% ethanol by volume in petrol. Volkswagen is therefore actively supporting the drafting of a suitable European standard for the future E10 fuel.

Venezuela plans to invest US $ 900 million over the next five years to plant sugar cane and build processing plants to produce ethanol. Venezuela's government aims to produce all the ethanol it needs so it will no longer have to import it. The programme is projected to create about 500000 jobs in the country of 25 million people [2].

The French government is accelerating its efforts to develop alternative energies in order to reduce national oil consumption and to limit France's energy dependence. The key elements of the plan are [3]: France's target of 5.75% biofuel content by 2008, the support in a direct blending of ethanol in gasoline, a pilot project for direct ethanol blending in Rouen that will incorporate 5% ethanol into 300,000 tons of gasoline beginning from February 2006, trial support for E85 (85% ethanol, 15% gasoline) flex-fuel vehicles.

The Chinese government planned expansion of the use of ethanol in fuel [4]. With government support of US $ 222 for every ton of ethanol sold, nine provinces planned to begin trials of ethanol blends by the end of year 2005. It has set a clear goal of ethanol development for the next few years, with the total annual output to be controlled at about 5–7 million tons.

The largest integrated sugar refinery in India is doubling its current ethanol production output from 18 million litres per year to 36 million litres per year by setting up a new 60000 litres/day ethanol plant [5]. Financing for the project is partly through the loan of US $ 2.8 million from ICICI Bank. Production will begin in June 2006. The company has identified ethanol production as a key future business driver.

Cyprus's Commerce Ministry is poised to announce a pilot project to introduce biofuels in an attempt to cut down the cost of petroleum imports and the emissions from fossil-fuel use [6]. The island will set an initial biofuel target of one per cent (6,000 metric tons) of annual transport fuel consumption. There will be an initial focus on ethanol derived from grapes and grape residues from the Cypriot wineries, as well as from grain, potatoes and other fruits.

Japan expects to introduce more vehicle fuels containing ethanol, and will pursue ongoing talks with Brazil [7]. Japan is turning to ethanol as a fuel additive as one measure to help it meet its goal for reducing emissions of greenhouse gases under the Kyoto Protocol. Japan has committed to reducing greenhouse gases emissions by 6 per cent from the 1990 level between 2008 and 2012. Six Japanese prefectures are running tests with ethanol. Currently, petrol in Japan may contain up to 3% ethanol.

The public transport operator in Stockholm has purchased another 123 ethanol buses for its fleet from Scania [8]. Scania, which was the world's largest maker of buses running on E95 (95% ethanol, 5% ignition-enhancing additive), ceased production of its ethanol-adapted engine in 2003. Stockholm already has the world's largest fleet of ethanol buses, which operate mainly in the inner city. The new buses were put into suburban operation during autumn 2005. When deliveries are concluded in early 2006, around 350 ethanol buses will be operating in the Stockholm fleet. Since 1990, Scania has supplied around 450 ethanol buses to Swedish cities, of which more than 200 are rolling in the inner city of Stockholm. The ethanol buses use Scania's 230 hp, 9-liter diesel engine adapted for ethanol. Exhaust emissions meet Euro 4 standards.

Ethanol buses were the subject of a variety of studies in the 1990's, including trials by Los Angeles and tests by NREL. The high operating costs of using ethanol buses dampened enthusiasm at the time.

The Philippine Department of Energy is supporting pending legislation allowing the use of ethanol as an alternative blending product for petrol [9]. The target is a 10% ethanol blend for vehicles by 2007, increasing to 25% in 2010.

The main problem concerning bioethanol production is dehydration process. The water amount in ethanol must be negligible [10]. Ethanol–water mixtures cannot be separated in a traditional way, i.e., by using distillation, so other dehydration methods such as azeotropic distillation, extraction, pervaporation as well as adsorption on bio-adsorbents or molecular sieves must be applied.

Ethanol purity, i.e., water amount in ethanol, is significant during petrol blending and must be strictly obeyed, especially in the winter to avoid stratifying of the fuel with bioethanol addition.

Modern bioethanol separation techniques are highly efficient and produce no waste. The most popular is the dehydration on molecular sieves and pervaporation.

4. RESULTS OF NUMERICAL SIMULATION OF ETHANOL DEHYDRATION PROCESS

Many mathematical models simulating pressure swing adsorption (PSA) have been developed over the last 30 years [11].

In recent papers, ethanol dehydration study by PSA method was described [12]–[16] and the numerical simulation of real plant conditions was performed [17]. An analysis of the effect of bed height on both the ethanol purity and the ethanol recovery ratio was performed [17].

The ethanol purity is a mean mole fraction of ethanol obtained in adsorption step over adsorption step length. The recovery ratio of product (Reco) is defined as follows:

$$\text{Reco} = \frac{\text{ethanol amount in dehydrated product}}{\text{ethanol amount in feed stream}} .$$

In figure 1, the influence of bed height on ethanol purity is presented. The higher the bed, the higher the water amount adsorbed in the bed. However, there is no ethanol purity change in bed above 2 m height. The influence of the bed height on recovery ratio is shown in figure 2. The higher the bed, the higher the volume of the gas that contains ethanol after adsorption step. During regeneration step the ethanol amount is lost because it is removed from the column and transported to the regeneration zone. The higher the bed, the more ethanol we lose, so recovery ratio will be smaller.

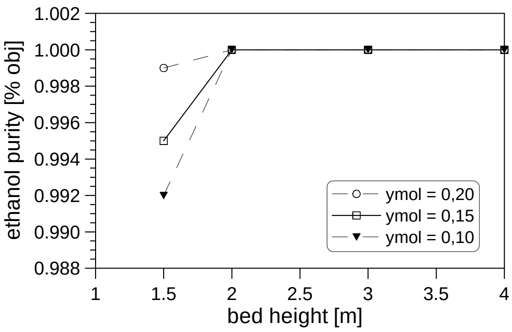

Fig. 1. Influence of bed height on ethanol purity

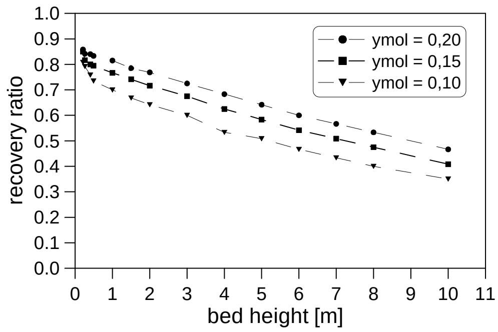

Fig. 2. Influence of bed height on recovery ratio

On the other hand, if the bed height is insufficient, breakthrough could occur. It causes product pollution and is unacceptable. Numerical methods can be used in order to specify the optimum bed height. Then the loss of ethanol will be minimal and there will not be any product pollution.

5. CONCLUSIONS

- An increase in biofuels production in highly developed countries has been observed. An increase in crude oil prices causes search for fuels from alternate sources.
- National biofuel programmes have been introduced in many countries around the world.
- Technology improvements in production agriculture and ethanol production can help significantly reduce Poland's demand for foreign oil and help to create a cleaner environment.
- Dehydration is the most expensive stage in the whole process of bioethanol production. So it demands improvement. The analysis of the influence of bed height on real plant conditions can also include other factors, for instance: feed composition, mass flow rates and pressure changes. This way the optimum conditions will be achieved.

REFERENCES

[1] http://www.cleanfuelsdc.org/issues/2003EthanolFactBook.pdf
[2] http://www.baynews9.com/content/9/2005/9/22/119678.html
[3] http://www.industrie.gouv.fr/infopres/presse/tableronde.html
[4] http://news.xinhuanet.com/english/2005-09/30/content_3565158.htm
[5] http://sify.com/finance/fullstory.php?id=13957908
[6] http://www.simerini.com.cy/nqcontent.cfm?a_id=208542

[7] http://www.bloomberg.com/apps/news?pid=10000086&sid=arwpoaBbjzGI&refer =latin_america
[8] http://www.scania.com/news/press_releases/n05012en.asp
[9] http://www.philstar.com/philstar/News200412260703.htm
[10] Etanol absolutny PN-A-79521 (1999).
[11] RUTHVEN D., FAROOQ S., KNAEBEL K., *Pressure Swing Adsorption*, VCH, 1994.
[12] KUPIEC K., RAKOCZY J., ZIELIŃSKI Ł., *Badanie kinetyki adsorpcji wody na zeolitach z gazowych mieszanin etanol–woda*, Inż. i Ap. Chem., 2004, 3S, 87–88.
[13] KUPIEC K., RAKOCZY J., MIREK R., GEORGIOU A., ZIELIŃSKI Ł., *Wyznaczanie i analiza krzywych przebicia w adsorpcyjnym odwadnianiu etanolu na zeolitach*, Inż. Chem. i Proc., 2003, 24, 293–310.
[14] KUPIEC K., ZIELIŃSKI Ł., GEORGIOU A., *Odwadnianie etanolu na zeolitach*, Inż. i Ap. Chem., 2003, Nr 4, 63–65.
[15] KUPIEC K., ZIELIŃSKI Ł., *Component Concentration in Bed for Adsorption System with Non-linear Equilibrium*, 14 Seminarium Inżynieria Procesowa i Budowa Aparatury Chemicznej, Berlin, 2002, 134–145.
[16] ZIELIŃSKI Ł., KUPIEC K., *Study of dehydration of (bio)ethanol by PSA method*, Czasopismo Techniczne – Mechanika, 2004, z. 4-M/2004, 309–317.
[17] ZIELIŃSKI Ł., *Ethanol dehydration by PSA method – theoretical and experimental analysis of the process* (in Polish), PhD Thesis, Kraków, 2005.

BIOETANOL JAKO DODATEK DO CIEKŁYCH PALIW
I JEGO WPŁYW NA OCHRONĘ ŚRODOWISKA

Przedstawiono zagadnienia związane z programami rządowymi wspierającymi stosowanie bioetanolu jako dodatku do paliw. Omówiono także wyniki symulacji numerycznej procesu adsorpcyjno-desorpcyjnego w warunkach instalacji przemysłowej.