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# Integrated design for large-scale opto-mechanical structure

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An integrated design method is discussed which thoroughly considers related parameters of the various subsystems in order to optimize the overall system that mainly consists of opto-mechanical structure CAD, CAE and the integrated information platform PDM. Based on the parameter drive of the virtual main model, the method focuses on the model transformation and data share among different design and analysis steps, and so the concurrent simulation and design optimization are carried out. As an example of application, the integrated design for a large-scale opto-mechanical structure is introduced, including optical design, structure design and analysis, which further validates the advantages of the method. Due to comprehensive consideration of the design and analysis process by CAD and CAE based on PDM, the integrated design well attains the structure optimization with high efficiency.

Keywords: integrated design, CAD/CAE, large-scale structure, optical instrument.

## 1. Introduction

Large-scale optical instruments, such as large telescopes and laser communication terminals, belong to the optical-mechanical-electric integrated systems, which are characterized by a large-scale clear aperture and high precision [1, 2]. Development of such instruments involves many key techniques, for instance, large mirror mounting design, high-accuracy special base frame, large precision shafting, high-accuracy driving technique, ultrathin optical component support, active control for thin mirror surface deformation, new material and machine technique, and so on.

In the early design of large-scale optical instruments, due to the lack of design experience, sufficient tolerances are usually scheduled for initial design parameters [3].

After the engineering prototype is completed, its actual test results are contrasted to the design indexes to evaluate the design quality, and some structures and parameters may in turn be modified till the instrument design is in agreement with the design requirements. At present, this method is not encouraged for heavy task, high expense, long cycle, and especially unattainable optimization of the design results.

With the wide application of computer techniques in various engineering fields, the techniques of CAD and CAE have rapidly developed and led to the innovation in design methods of modern optical instrument structure. In 1980, Jacob M. Miller, American researcher at Honeywell Electro-Optical Systems Center, firstly proposed the concepts and steps of optical-mechanical-electric integrated design method, and enumerated the software used [4]. Meanwhile he successfully analyzed the optical-electric sensor by using the method. Based on CAD/CAE techniques, the optical-mechanical-electric integrated method is used to analyze and simulate the geometry model and finite element model corresponding to the virtual prototype of the instrument, and overall, considers mutual actions and constraints of various subsystems so that the structure parameters are systemically, consistently and dynamically balanced to finally optimize the whole system parameters.

In the paper, we further discuss an integrated design method, which fully considers the model transformation and optimization of the parameters during the entire design process, mainly including opto-mechanical structure design and analysis by CAD, CAE and especially the integrated information share through product data management (PDM). As an example, a large-scale optical instrument structure is developed by this method. The integrated design and simulation are carried out for the overall system.

## 2. Opto-mechanical structure CAD model

The mechanical structure as the mounting supports the optics system and ensures the optics performance and the system reliability. The constraints of mechanical structure are generally divided into two types according to their effectiveness in optics system and application environment, the auxiliary parts of optics system and the mounting mechanisms of optics components. The opto-mechanical structures include two aspects of static structure and dynamical one, and both of them collaboratively realize the optics performance under the different application conditions. Therefore, the structure design needs to correspondingly consider static stiffness and motion reliability [5]. As regards a large mechanical structure, especially used in special environment such as space conditions, the weight, volume and power consumption become the main factors to be considered, and some special structure, material and technology are to be adopted to optimize the system design.

Figure 1 shows the opto-mechanical structure ACD flow. Firstly, according to the optics system requirements, a concept of structure design is put forward and preliminary calculation is carried out. Then, a virtual prototype of the whole structure is built, including all parts, all components and overall assembly. Finally, after the geometry dimensions and materials are set, the character parameters and structure

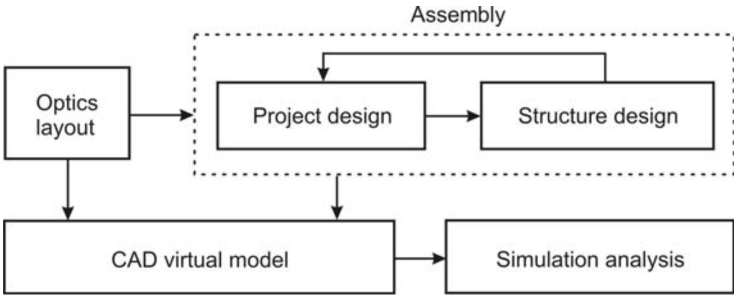


Fig. 1. Opto-mechanical structure ACD design flow.

rationality can be tested and modified in turn. Together with the dynamical performance simulation based on virtual motion model, we can fully check the feasibility of the design project and decide whether or not to change the design details or even the project. Moreover, we can either import the CAD model into FEA software by format transformation such as IGES, STEP, DFX, *etc*., or transfer the CAD model to FEA software through the interface processing program processor.

## 3. Opto-mechanical structure CAE analysis

Due to the large structure and high precision in a large-scale optical instrument, it is necessary to evaluate the design by finite element analysis method, including structure analysis, thermal analysis and optical analysis [6]. In order to realize the integrated design and system optimization, collaborative simulation and analysis must cover the whole process including project selection, structure design, motion simulation, thermal design, assembly analysis and machining process.

Generally, the steps of FEA method consist of solid modeling, generating meshes, setting conditions, solving and post-processing. The structure statics analysis is intended for research into the structure response shown by strain and stress. For a large-scale structure, the gravity effect must be considered, which usually induces the elastic deformation, especially serious in space environment. The dynamics analysis mainly resolves the vibration mode and gains the dynamic rigidity. In other words, the structure weakness as well as the resisting fracture capability can be found through the vibration mode analysis. Conduction, convection and radiation as three heat transfer modes widely exist in large-scale instruments, including steady and transient temperature field [7, 8]. Through the thermal analysis to get thermal performance, the thermal control project of optical instrument can be implemented, which will guide the structure design to meet the requirements of optics performance.

However, no mater which project of the mechanical structure is used, it must center the optics system, and the final analysis is to improve the optical performance. Figure 2 gives relations of the various analysis processes, which can be realized by the data interchange and integration among different software. The Zernike fitting method is usually employed to evaluate the optics performance such as wavefront

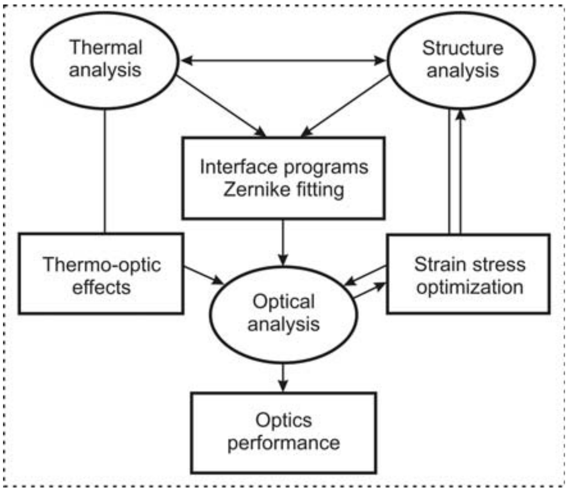


Fig. 2. Relations among different FEA processes.

analysis, transformation function, and so on. In Figure 3, an example of our prior FEA on a large-scale opto-mechanical structure is shown [9].

## 4. PDM information integration

PDM as the integrated platform bridges the design and analysis process, and shares data based on the virtual main model, which approaches the parameter drive and real time modification during the whole design [10].

PDM generally includes CAD model data, technology and file data, FEA analysis and simulation data, *etc*. Different CAD and CAE subsystems all can share data information by PDM. For instance, in CIMS (computer integrated manufacturing system) based on concurrent engineering, PDM plays a key role for different subsystems with high efficiency. Moreover, with the development of network technology, PDM relies on the CAN (controller area network) and client-server system structure will efficiently build the collaborative and integrated work environment, including project design, system simulation and analysis, product management over the whole lifecycle, and even all the production and service process in the market. Figure 4 shows PDM application in optical instrument design and analysis.

## 5. A design example of a large-scale optical structure

We develop a Fizeau interferometer with a 360 mm clear aperture by the integrated design method. Figure 5 shows the design and optimization flow of the reference mirror and mounting structure in the interferometer. We use Windchill PDMLink to solve the distributed product data management problem, including file management, model data management, information saving and opening. CAD and CAE software include optics design software of CODE V, 2D and 3D design software of AutoCAD and Pro/Engineer, FEA software of Ansys, calculation software of Matlab, *etc*.

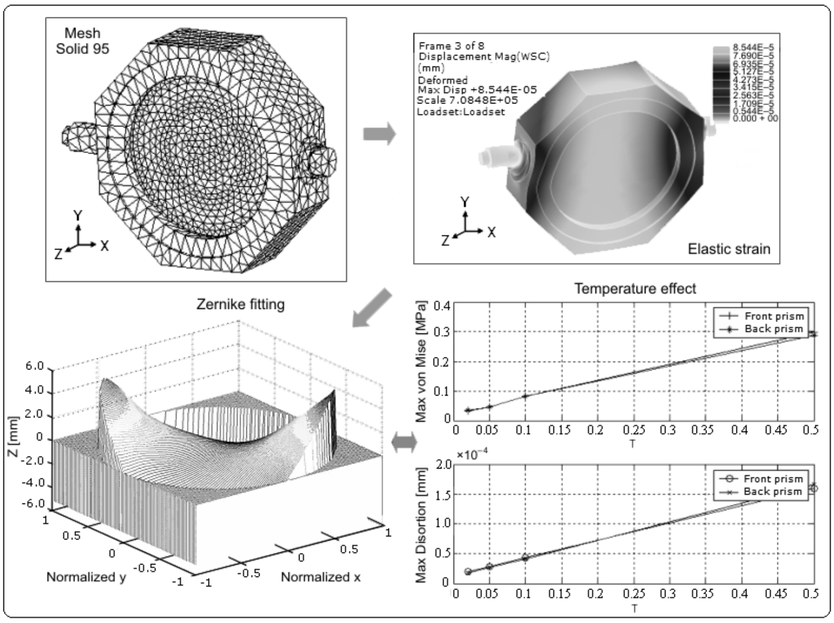


Fig. 3. FEA process of a prism assembly.

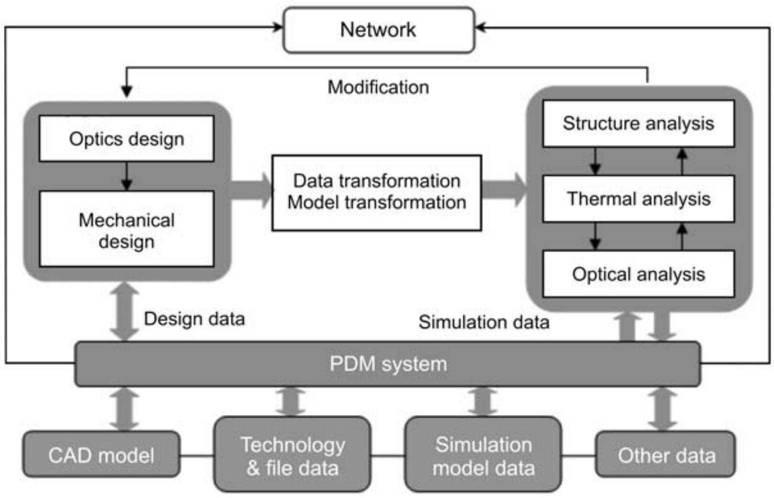


Fig. 4. Design and simulation based on PDM system.

In Figure 5 the arrows show the data flow between different design modules. Firstly, the virtual model of the optical instrument is conceptually designed by Pro/Engineering and CODE V. Then the finite element method is taken for the static and dynamical analysis, as well as the temperature field analysis, by CAE software of Ansys1.0. Thirdly, the structure and thermal control project is further analyzed and

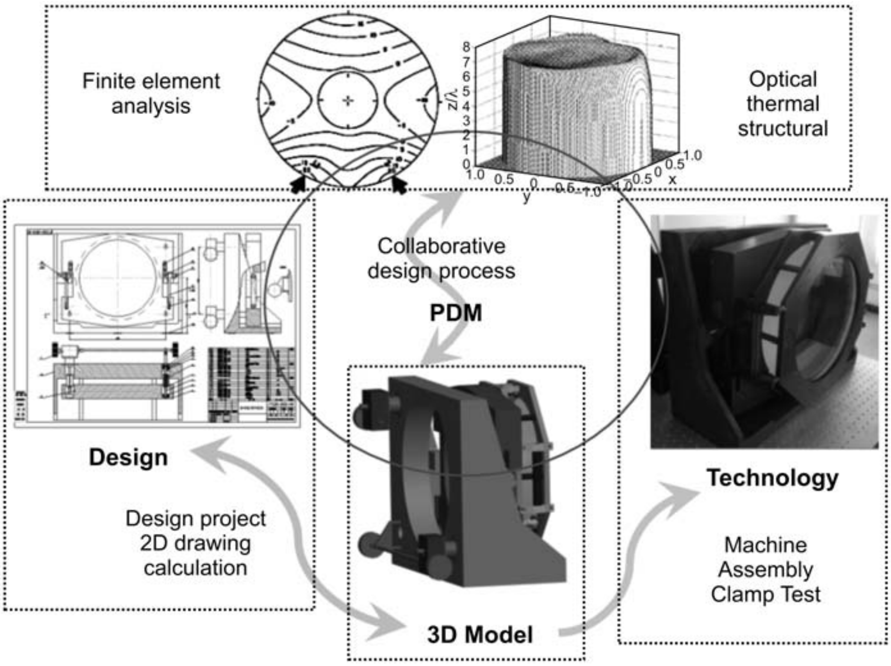


Fig. 5. An example of design process: integrated design of reference mirror structure of the Fizeau interferometer with a 360 mm clear aperture.

optimized through the CAE result again and again, and various optical aberrations are solved and corrected. Finally, the whole process is based on PDM, and related data between CAD and CAE model share each other till realizing the overall design optimization. The whole design process is under the integrated framework, and the integrated design method through dynamical data interaction highly improves the design efficiency and quality.

## 6. Conclusions

In order to overcome the disadvantages of the traditional design of large-scale optical instruments, the integrated design method is introduced for complete consideration of the design process to attain the overall system optimization, which mainly consists of three aspects, including opto-mechanical structure CAD, opto-mechanical structure CAE and PDM information integration. With the developments in network and software techniques, the future large-scale optical instrument design will mainly tend towards two aspects. On the one hand, the integrated design based on Web PDM will play an important role in complicated and dynamical data treatment. On the other hand, the Opto-CAD software emerging will better facilitate the visualization and parameterization design in the optical instrument field, which will well improve the design quality and efficiency.

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