Application of Modern Simulation Technology in Mechanical Outstanding Engineer Training

http://dx.doi.org/10.3991/ijet.v9i2.3406

Gongfa Li, Jia Liu, Yin Sun, Guozhang Jiang, Jianyi Kong, Hegen Xiong
Wuhan University of Science and Technology, Wuhan, People's Republic of China

***Abstract*—The paper describes the relationship between an outstanding engineering training and modern simulation technology and recommends the characteristics for an outstanding mechanical engineer in detail. Aiming at the importance of the teaching practice link to courses on the theory of mechanics, mechanical design and mechanical signal analysis has expanded the function of modern simulation technology in outstanding mechanical engineer training. The training has had the advantage of economizing the teaching costs, overcoming the hardware constraints and model prediction, and promoting students' innovation and manipulative abilities.**

***Index Terms*—Simulation technology, Mechanical outstanding engineer, Mechanism innovation, Theory of mechanics, Mechanical design, Labview**

I. INTRODUCTION

A large number of applied engineering and technical personnel with innovative spirit and ability are being cultivated through engineering education. It offers a strong practical perspective and develops ability for engineering design, comprehensive application, and scientific research to analyze and solve problems. It is impossible to achieve all of these capabilities by theoretical teaching alone, but they can be achieved through engineering practice and production. Using computer simulation technology to analyze and solve problems, including geometric modeling, model analysis, optimization of control parameters, models and methods of optimization, simulation analysis, and five basic modules, it also has a structure analysis and motion control module[1]. The virtual prototype technology on which it is based has become a relatively independent industrial technology that will continue to have a profound impact on the manufacturing industry. Simulation science and technology involve the use of a computer and special experimental equipment as the tools and the experimental model of the physical system as the basis through the combination of numerical calculation methods, professional theory knowledge and computer interaction, data processing, strong display function, mature software and hardware technology for analysis, and research and design of the existing or not existing [2]. It has many advantage, including being forward-looking, providing visualization of the systematic process and results, low costs, and convenient changes of the system parameter. With the computer technology changing rapidly, simulation science and technology have been widely applied in various engineering projects and have achieved wide success and economic benefits.

II. THE CHARACTERISTICS OF MECHANICAL OUTSTANDING ENGINEER

The "Outstanding engineering education program" is a major reform project of the Chinese Ministry of Education to implement the "National long-term education reform and development plan (2010-2020)" and "National long-term talent development plan outline (2010-2020)." The project was planned to take 10 years to cultivate millions of diverse and highly talented engineering technology personnel for our country as well as establish good human resources for building an innovation-oriented country and to realize industrialization and modernization[3]. Technical characteristics of excellent engineers include (1) having rational and broad knowledge and solid professional skills as well as design and development skills to participate in the project and put forward technical professional opinions and propose and solve problems; (2) having strong innovative ability, paying close attention to the development of frontier science and technology and industry dynamics, being forward-looking and advanced in the specialty, and having strong competitiveness and creative ability; (3) having abundant knowledge of the society, economic management and humanistic knowledge as well as comprehensive competitive ability; (4) presenting good teamwork, interpersonal, and communication skills; (5) exhibiting good ideological and moral qualities[4]. The project quality is based on the ability of the engineering and technical personnel in the process of decision-making and implementation[5]. Technical personnel with excellent engineering quality not only have technical knowledge and rich experience in this field, but also have abilities in marketing, management, quality, safety, economics, and law. An engineering education environment should be close to the market and enterprise so the students can learn all aspects of engineering through corresponding engineering conditions and background.

The "Excellence initiative" aims to cultivate high quality engineering and technical personnel with innovative abilities that are adaptable to the needs of economic and social development and that match the emphasis on ability and all-round development of talent cultivation in higher education engineering in China. The point is reforming the talent cultivation mode of engineering education; innovating the joint cultivation mechanism of the University and industry, and enterprise; and enhancing students' practical ability, innovation ability, and international competitiveness [6].

III. APPLICATION OF SIMULATION TECHNOLOGY IN THEORY OF MECHANICS

The mechanical principle course researched general common problems among institutions and the machine, such as the theory of mechanisms, kinematics, mechanical dynamics, etc. and researched the movement and the dynamic performance of a common machine and the design method for all kinds of machines. The course objective was to improve the students' comprehensive design ability, innovative ability and engineering practice through cultivating students' ways of thinking in an innovative design for a mechanical system scheme as well as the ability for autonomous learning. For this course, students need to have basic knowledge of agency selection and dimension design according to technical requirements, have the preliminary ability of mechanical system scheme innovative design, and lay a solid foundation for subsequent specialized courses in engineering machinery and engineering machinery design.

The mechanical principle teaching model of the "five horizontal five longitudinal" matrix solved the problem of the singularity of ability training and isolation of the teaching link. The pattern refines the training goal of teaching into five basic abilities: knowledge mastery ability, engineering practice ability, analysis and calculation ability, software application ability, and innovation ability ("five horizontal"). The teaching process is divided into five key links: classroom teaching, experiment teaching, course design, homework, and innovation design competition ("five longitudinal"), as shown in Figure 1. The new model explores the inner connection between teaching and ability training, and studies the relationship of primary and secondary between the teaching link and cultivating ability. The implementation of guiding the teaching content and teaching process is based on the matrix teaching mode, which solves the problem of the singularity of ability training and isolation of teaching link.

In the new teaching mode of the matrix type mechanical principle, each teaching link is summarized as follows: the foundation is classroom teaching, the key is experimental teaching, the breakthrough is curriculum design, the big homework is the bridge, and the sublimation is the innovation competition. The ability training and each element of the teaching link is closely linked through the establishment of the "five horizontal five longitudinal" matrix teaching mode. Ability training is stressed, and the organization teaching process of innovation is kept according to the design of the main line. As shown in Figure 1, (A) basic knowledge and skills training are strengthened; (B) the theory and application are implemented based on the combination of an existing big institution for the process design; (C) the innovation ability is trained through the new organization design; and (D) the innovation ability is improved through practice to achieve innovation. The Cultivate main line is composed of a series of training processes, such as the basis to the application, theory to practice, and shift from a single ability to comprehensive ability. The teaching mode of the classroom as the centre and design for the centre are changed thoroughly.

Using computer simulation technology, such as the combination of a VC OpenGL corresponding program, students can easily see the mechanism motion information in the 3D scene to verify whether the institutions designed

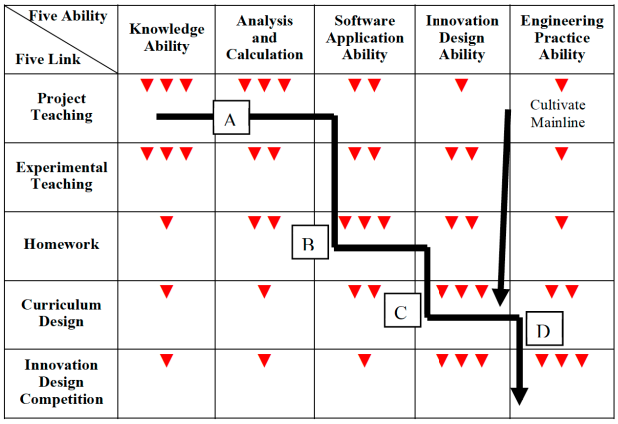


Figure 1. Matrix type teaching mode of mechanical principle

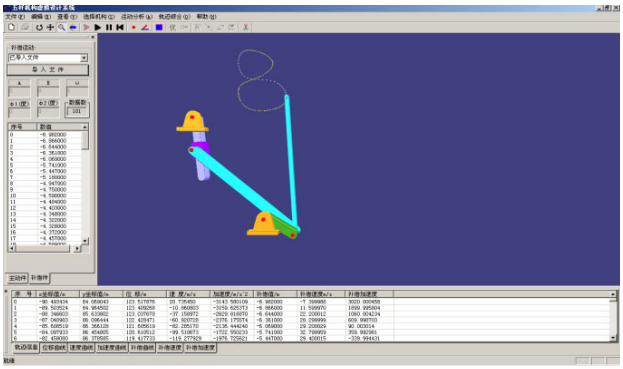


Figure 2. Mechanism of virtual machine system

meet the design requirements. So no matter whether from the point of view of the hardware and the requirement of the experiment content, it is necessary to use computer simulation technology applied to mechanical principle experiment teaching.

In addition to the extracurricular making of the science, technology is a very important part of training innovative and applied talents in the teaching system. Mechanical professional students in the process of physical production tend to be concentrated on the development of a robot to perform a certain action, perform some function of a special machine, and meet the specific needs of local parts for the prescribed actions in the pre-design of the physical model from design to performance as well as the displacement, velocity and acceleration. Computer simulation technology is a good method to meet these requirements; simulation technology can easily modify the organization's size, observe the operating status, and obtain satisfactory output parameters that greatly shorten the development cycle and cost. Combining knowledge of curriculum theory and using computer simulation technology to solve some problems can stimulate the students' pride and sense of achievement. But it can also train students' creative thinking and practical skills as well as overcome the shortage of school hardware facilities; it has a positive effect in many aspects. So the application research of computer simulation technology in the course of teachers' education is worth concerning.

As the simplest multi-degree mechanism, a controlled five-bar mechanism is becoming the hot spot. A controlled five-bar mechanism has two parts, with one part constantly in motion and the other controlled by a computer to give compensating motion so the required track will be

generated by one or more links on the mechanism[1]. Study of the five-bar shifts from structure analysis to kinematics analysis, so developing software with motion analysis and path synthesis of the controlled five-bar has a positive significance for the development of the contemporary mechanism. A controlled five-bar platform (CFDP) is designed for structure, dynamic simulation and path synthesis of all thirteen five-bar basic types. Therefore, the platform can achieve parameterization of the structure, dynamic selection of the point generating path, motion analysis of the path and coordinate controlling of the driving links, path synthesis based on GA, etc. Designed as auxiliary software for the mechanism design, professionalism and versatility should be considered. Thus functions should be well arranged, well planned, and embodied without too many details revealed to avoid increasing the complexity of the operation. Figure 3 is the function tree of the platform. As can be seen in the figure, the functions are intensive in the two modules of motion analysis and path synthesis. Functions included in the motion analysis module are intuitionist and have more interactive operations with the operator. The path synthesis module involves more professional knowledge and less detail function, so this module mainly presents the intellectualization of the platform. The following parts will provide an explanation of the detail functions of the two modules [7].

The goal of the motion analysis is to complete the simulation of the five-bar basic type and provide the results. The user should form a particular five-bar basic type through a pair of similar Ⅱ groups according to the Table.1 and then initialize each parameter (by hand or input the dimension file). Since the five-bar has two degrees, driving parts including the initiative part and the compensative part, should be controlled correctly. In order to ensure input coordination of the two parts, the numbers of position data must be equivalent and the index should coincide. To complete the motion analysis of the special position, an added bar is required (of course the point can be directly selected on the mechanism body). Then the simulation can start, and results, including curve and data, will be given in the end. To display the state of the mechanism in a more vivid way, CFDP introduces a virtual 3D environment with OpenGL in the motion analysis model. Therefore, there are several operations on the view – for example, scaling, rotating and translating. Figure 4 is the interface of motion analysis of RRRRP [8].

To integrate the two function modules, the results of the path synthesis will return to the view of motion analysis for modeling and simulation and check the effects by comparing the generated path and the ideal path.

The basis of the combination of computer technology is provided by an analytic method, guiding the students to accomplish the 2D simulation and 3D motion by use of the virtual design and kinematic analysis mechanism, stimulating the students' interest in learning, and training students' comprehensive ability to use modern technology. In the example of scientific computing and software programming ability, the proportion of software analysis organized by the students increased from the initial 10% to about 60%, and many have been applied to the teaching practice – for instance cam motion simulation software, gear generating dynamic simulation software, the typical mechanism motion analysis software have access to software copyright – and are widely used in the classroom.

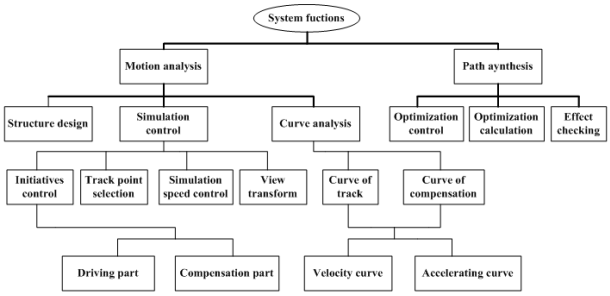


Figure 3. Function tree of CFDP

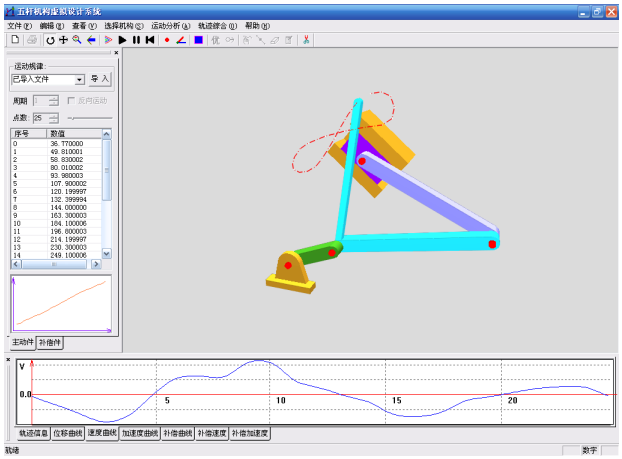


Figure 4. Motion analysis interface of RRRRP

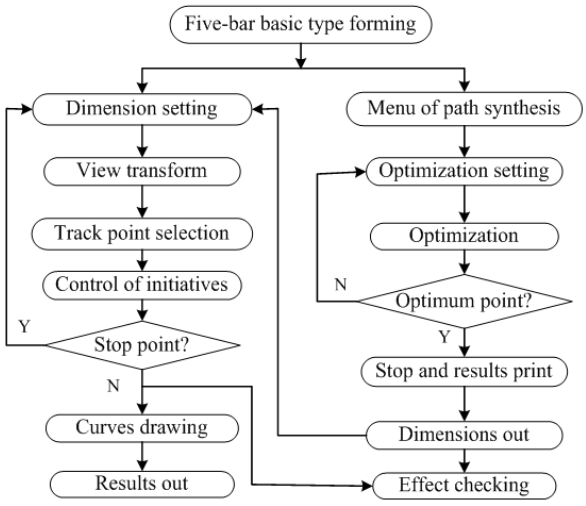
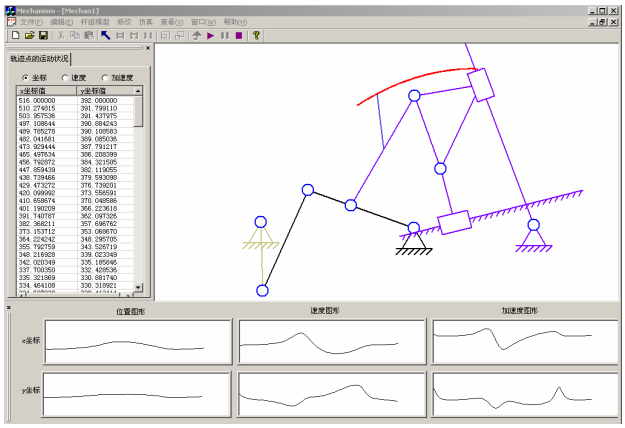
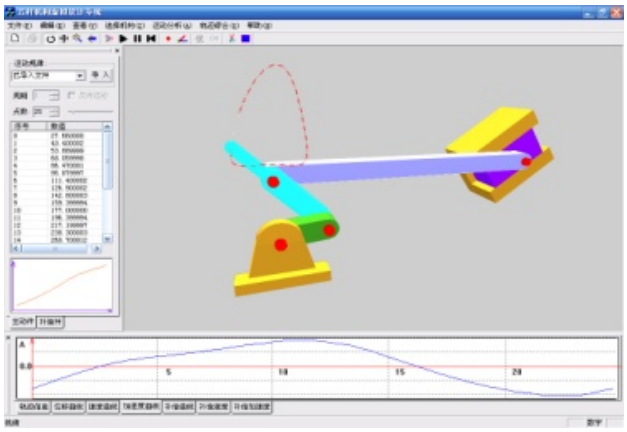


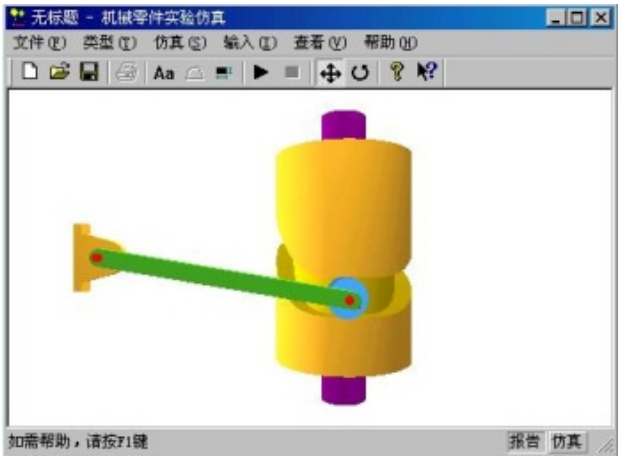
Figure 5. Operating sequence of two main functions



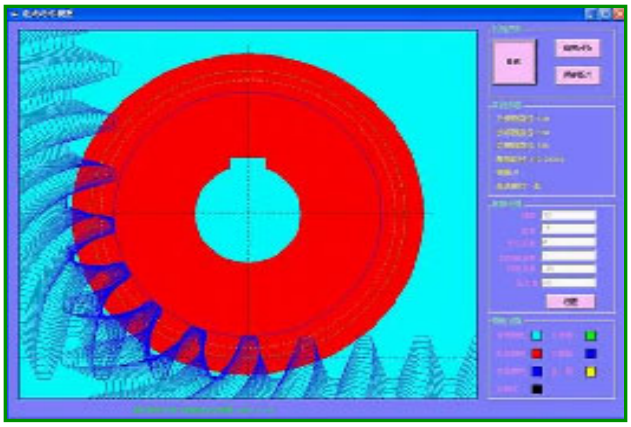
a) Analysis and simulation system of mechanism motion



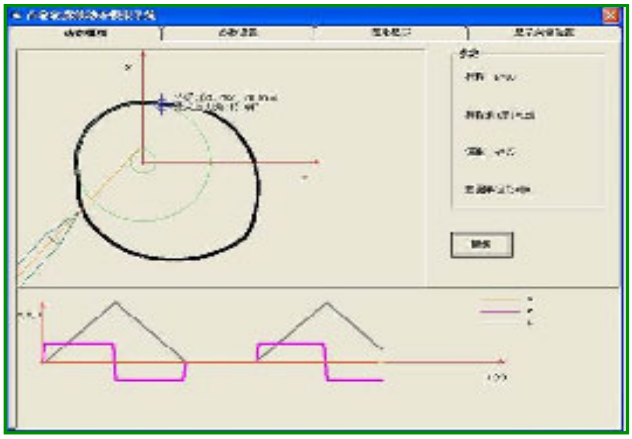
b) Virtual design system of the controlled five bar mechanism



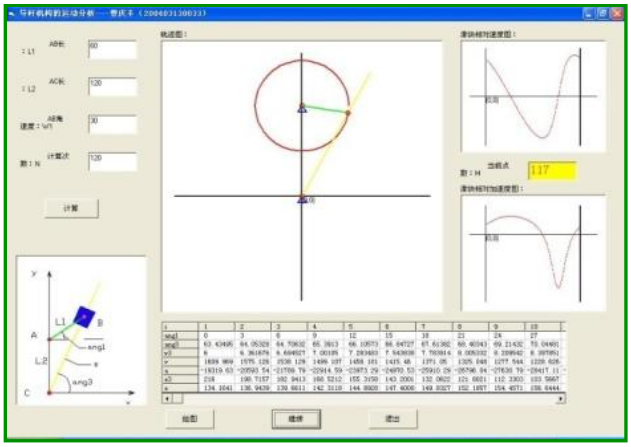
c) Mechanism motion simulation software



d) Gear forming simulation software



e) Simulation software of cam mechanism



f) Simulation software guide bar mechanism

Figure 6. Parts interface of teaching software

IV. APPLICATION OF SIMULATION TECHNOLOGY IN MECHANICAL DESIGN

"Mechanical design" is a very important professional basic course in the teaching system for cultivating mechanical talents, which play an important role in the whole course system. The content of the course not only embodies the comprehensive application of some basic courses, it also lays a foundation for the follow-up professional courses related to learning and future work. "Mechanical design" is mainly about the working ability (mainly carrying capacity) of design theory and methods of the general machinery parts, which are the most commonly used in the mechanical engineering. From the content of the curriculum framework, every chapter of content is independent, and there is no direct correlation in technological logic. The types, characteristics, engineering experience, and design principles of this course are complex, so the students in the learning process felt frustrated.

The planetary gear train has been widely applied in fields of aviation, ship building, and metallurgy. It has many merits, such as small size, compact structure, high bearing capacity, large power transmission and high efficiency, etc. The NGW planetary gear train, which consists of a sun gear, a planetary gear, and a fix inner gear, has the characteristics of a simple structure, small axial dimension, super manufacturability, and large transmission

ratio through multistage series. It has been one of the most widely used equipments in driving devices. So, the study of the NGW planetary gear has great significance in prompting the technology of planetary gear trains[9].

Romax Designer is a British Romax company specializing in product development and simulation of the gear transmission system CAE software used for the design and analysis of the gear transmission system. The Romax software development and transmission project consultation has more than 10 years of experience in the field of transmission. Released in 1995 by Romax Designer, it has become the industry standard tools in the field of gear transmission and is widely used in automobile gearboxs, wind energy and other fields. The Romax Designer spans from the establishment of the conceptual model, the component strength analysis, the reliability prediction for system vibration, and the noise (NVH) design content prediction of the whole transmission system, constituting a closed-loop solution mechanism of the gear transmission system. It provides model analysis and optimization for a variety of complex gear transmission systems. The Romax Designer software startup interface is shown in Figure 7.

In the component list, select “Concept Planetary” to complete the definition of a planet gear, as shown in Figure 8. The planetary gear design tool provides three input parameters in different ways: “Module and number of teeth,” “Ring reference diameter and number of teeth” and “Ring reference diameter and module.” Then choose the first input mode, the input module, the pressure angle, and the number of planetary gears as well as the gear tooth number and tooth width. The detailed parameters of the interface are shown in Figure 9. The multi body dynamics model of reduction of the rigid flexible hybrid system is shown in Figure 10.

V. APPLICATION OF SIMULATION TECHNOLOGY IN MECHANICAL SIGNAL ANALYSIS

The course introduces the composition and principles of the static and dynamic stress measuring system and the combination group bridge method of unidirectional stress, combined stress, plane stress, and complex stress in combining theory with practice, which highlight the technical applications of performance parameter measurement in the space of particle positions, load spectrum, and residual stress. The course also introduces the structure of vibration, noise, experimental modal testing system, test method, and data processing. It additionally has a brief introduction to the new techniques of the test field, such as sensor network technology, virtual instrument technology, the wavelet analysis method, etc. To strengthen the understanding of the course and to cultivate the students' practical and innovative ability, we introduced LabVIEW software into teaching.

A monitoring system using LabVIEW as a platform was designed; its functions include data collection, data storage and analysis, trend analysis, and fault diagnosis. In the design, it is the full use of LabVIEW’s graphical programming’s quick, convenient advantages, which combines DQmax’s powerful features and DataSocket to complete remote monitoring and fault diagnosis of the production system in a steel plant. It is significant in steel production to accelerate the speed of access to the production information, to improve the utilization rate of energy, and to optimize the process of production.

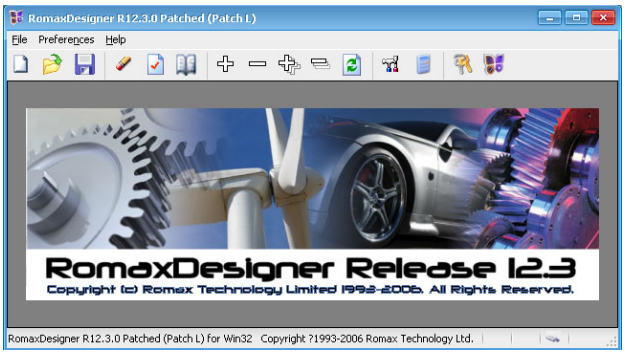


Figure 7. The start interface of Romax Designer software

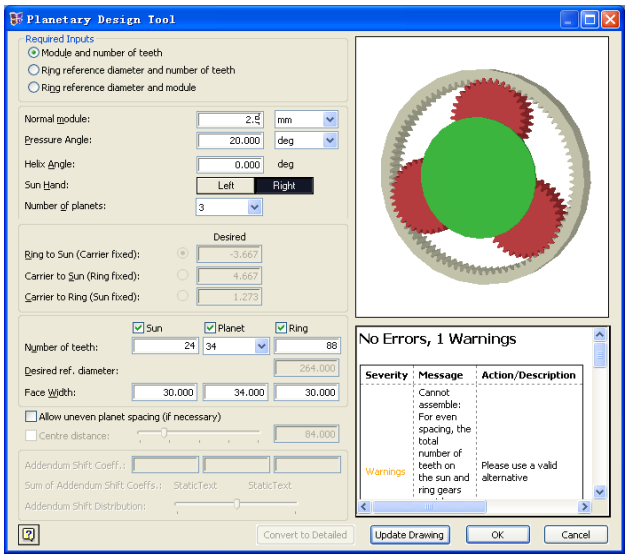


Figure 8. The conceptual model in planetary gear

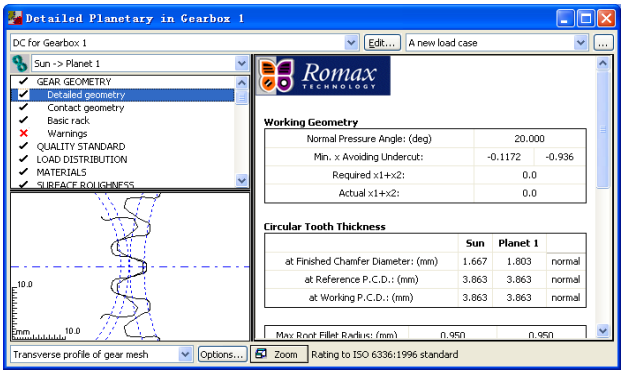


Figure 9. The detailed design process

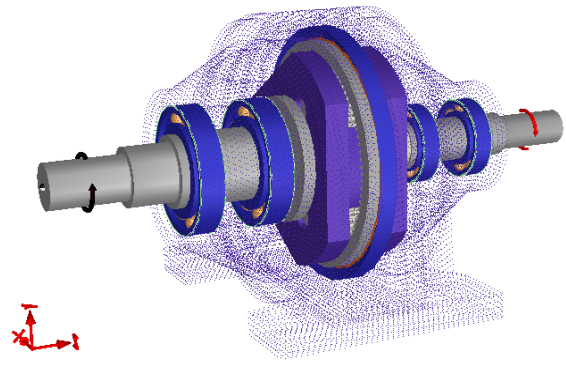


Figure 10. The virtual prototype model of NGW31 planetary gear reducer

Shown in Figure 11, the measurement signal from the sensor after signal conditioning is transferred to the computer by the DAQ card; finally, the programs written in LabVIEW extract the data[10].The signals to be acquired include the vibration signals, the displacement signals, the temperature signals, the flow rate signals, the pressure signals, and the differential expansion signals. According to these types of signals, corresponding collection tasks are created, as are the relationships among the actual measurement points and channels of acquisition tasks, collection frequency, number of acquisition samples, and other information stored in the database. The information can be added and changed according to actual demands in the server. Figure 4 shows the interface adding and changing the information collection tasks.

The signal detection analysis module is applied to the field data analysis and processing to provide data support for the intelligent fault diagnosis module and the field staff‘s judgment[8]. Function: Signal time-domain waveform analysis uses different equipment to obtain the characteristics of signals in time domain diagram, autocorrelation, cross-correlation, probability density, time-domain envelope, and time domain analysis. Signal frequency domain analysis is the analysis of an equipment acquisition signal such as amplitude spectrum, phase spectrum, cross-power spectrum, envelope spectrum, and cepstrum. Signal three-dimensional spectrum analysis uses the three-dimensional spectrum observed in the rotor’s dynamic response process under its many frequency components[11]. Analysis of the signal amplitude is the signal acquisition, including the mean, maximum, minimum, rms value and kurtosis, etc. The signal trend graph has historical data for the use of statements (day\month\year), observing whether there is a significant change in trend on the magnitude of the equipment’s key parameters and then predicts the possible failure of a position. Signal monitoring and analysis include timely signal analysis and fault data analysis. Timely signal analysis obtains timely analysis of the eigenvalues (Figure 12); failure data analysis is obtained by searching the database through the file protocol of DataSocket to download fault data. After filtering, these signals are made time domain.

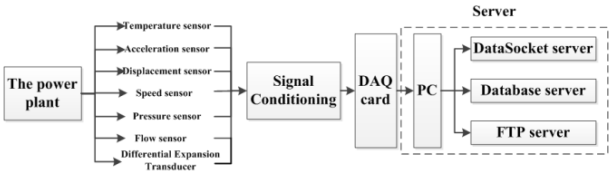


Figure 11. A high-frequency signal acquisition task

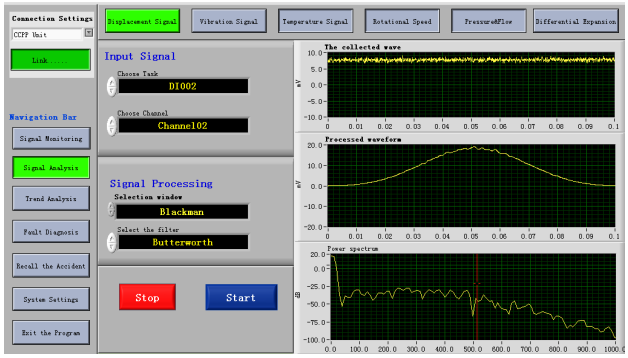


Figure 12. Signal analysis module's interface of the client

VI. TEACHING EFFECT

In recent years, significant results have been achieved on the training of outstanding mechanical engineering. Students participated in various scientific and technological competitions, obtained national first prizes in mechanical innovation design competitions, third prize in the national Challenge Cup, and first prize and 22 national awards in the mechanical products digital design competitions. The number of the provincial awards is more than 60. Students have applied for 8 patents in the field of mechanics and have published more than 20 papers. Students have developed simulation software for cam mechanism motion, dynamic simulation software for processing of gear generating, and mechanical principles of typical mechanism motion analysis software. The students acquired 3 software copyright registrations "based on the motion mechanism of rod group analysis and simulation system (2008SR19352),” “the controlled five bar mechanism of virtual design system"(2008SR19354),” and the “mechanism motion simulation software based on OpenGL (2011SR006789).” The employment rate has reached 99%, and their average salary is more than the general undergraduates receive.

VII. CONCLUSION

The authors of this article have studied the effectiveness of teaching using modern simulation technology and taking the theory of mechanics, mechanical design and mechanical signal analysis as examples. The simulation technology can not only be used to teach students about the content of the 3 courses, but it can also strength the students’ understanding and ability. Through combining simulation software and the 3 courses with multimedia courseware, no real hardware environments or resources are required. For example, as a practical achievement, software of a five-bar matrix type can help students quickly understand the theory of mechanics and also learn to use the simulation to analyze a problem. Presentation directly in the classroom allows students to see the real-time simulation results and to increase their awareness. Results from the teaching of practical activities show that the teaching methods presented in this article can reduce learning difficulties in these courses and better stimulate students’ interest in learning, while developing their ability to solve problems at the same time.

ACKNOWLEDGMENT

This research was supported by the Higher Education Teaching Reformation Project of Hubei Province of China (2012218 and 2013221) and Teaching Reformation Project of Wuhan University of Science and Technology (2013Z021).

REFERENCES

[1] Li G.F., Kong J.Y., Jiang G.Z, et al， Reflections on training outstanding mechanical engineer. *The exploration and practice of higher education innovation and outstanding talents fostering*, pp.17-20(2013).

[2] Zhao M.Y.， Wang X.J.， Jiang H， Practical Teaching System Innovation of Excellence Engineer in Mechanical Design Manufacturing and Automation Profession. *Science & Technology Information*, 21,pp. 34-36(2013).

[3] Zhang L.F., Fu C.M., Peng H.G， Exploration of the Teaching Reform Mechanical Engineering of the Outstanding Engineers Courses for Training --Take Hunan Institute of Engineering as an

Example. *Journal of Hunan Institute of Engineering*, 21, 4,pp.108-110(2010).

[4] Yu C.L.， Strengthening Practical Teaching and Promoting the Cultivation of Outstanding Mechanical Engineers. *Journal of Zhejiang Institute of Science and Technology*, 29, 1, pp.30-32(2012).

[5] Chen G.H., Liang J.. Thinking on Culturing Excellent Engineers of Process Equipment and Control Engineering. *Higher Education In Chemical Engineering*, 28, 2,pp.45-49(2011).

[6] Zhong L.P., Shi J.X., Zhang W.F.. The Exploration of the "3 + 1" Applied Talents' Cultivation in Mechanical Major under the Background of Excellent Engineers Training. *Science and Technology Management Research*, 31,16,pp.158-160(2011).

[7] Cai X.J., Liu X.C., Xu L.L., etc. Deepening the Reform of Excellent Engineer Mechanical Design. *Research and Exploration in Laboratory*, 31,6,pp.152-154(2012).

[8] Zhao J.C., Wang W.，An application of modern simulation technology in teaching and training. *Computer Simulation*,21,5,pp.193-196(2004).

[9] Huang X.L., Wu Z.H.， Modern simulation technology and Its Applications. *Read And Write Periodical*,6,1,pp.68-67(2009).

[10] Li H.,Dai J.H.， Application of simulation technology in manufacturing system. *Computer Simulation*, 3,pp.71-75(2003).

[11] Cui Y.H.， Application of simulation technology in theory teaching. *Capital Education Journal*, 12,pp.171-172(2012)

AUTHORS

Gongfa Li received a Ph.D. in Mechanical Design and Theory from Wuhan University of Science and Technology in China. Currently, he is an associate professor at Wuhan University of Science and Technology, College of Machinery and Automation, China. His major research interests include mechanical CAD/CAE, modeling and optimal control of complex industrial processes. He has published nearly thirty papers in related journals.

Jia Liu was born in Shanxi province, P. R. China, in 1990. He received a B.S. in Mechanical Engineering and Automation from Wuchang Institute of Technology, Wuhan, China, in 2012. He is currently occupied in his M.S. in Mechanical Design and Theory at Wuhan University of Science and Technology, College of Machinery and Automation. His current research interests include mechanical CAD/CAE, signal analysis, and processing.

Ying Sun received an M.S. in Mechanical Engineering from Wuhan University of Science and Technology, China, in 2004.She is an Associate Professor of the College of Machinery and Automation, Wuhan University of Science and Technology. Currently, his research interests are mechanical engineering, optimal design and computer aided engineering.

Guozhang Jiang was born in Hubei province, P. R. China, in 1965. He received a B.S. degree from Chang'an University, China, in 1986, and an M.S. degree from Wuhan University of Technology, China, in 1992. He received a Ph.D. in Mechanical Design and Theory from Wuhan University of Science and Technology, College of Machinery and Automation, China, in 2007. He is a Professor of Industrial Engineering, and the Assistant Dean of the College of Machinery and Automation, Wuhan University of Science and Technology. Currently, his research interests are computer-aided engineering, mechanical CAD/CAE and industrial engineering and management system.

Jianyi Kong received a Ph.D. in Mechanical Design from Universität der Bundeswehr Hamburg, Germany, in 1995. He became a professor at Wuhan University of Science and Technology in 1998. Currently, he is the President of Wuhan University of Science and Technology, China. He serves on the editorial boards of the *Chinese Journal of Equipment Manufacturing Technology*. He is a director of the Chinese Society for Metals, etc. His research interests focus on intelligent machine and controlled mechanism, dynamic design and fault diagnosis in electromechanical systems, mechanical CAD/CAE, intelligent design and control, etc.

Hegen Xiong received a Ph.D. in Materials Processing Engineering from Huazhong University of Science and Technology, China, in 2005.He is a Professor of the College of Machinery and Automation, Wuhan University of Science and Technology. Currently, his research interests are manufacturing information, job shop scheduling, flow shop scheduling and computer-aided engineering.

Submitted 27 November 2013. Published as re-submitted by the authors 20 March 2014.