EasyChair Preprint

№ 2146

Construction and application demonstration of virtual simulation experimental teaching center for mechanical equipment

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December 12, 2019

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***Abstract*—Relying on the strong discipline advantages and abundant scientific research achievements, the virtual simulation experimental teaching center of mechanical equipment of Northeastern University is facing large, complex and high-end mechanical equipment, aiming at improving students' engineering practice and innovation ability, and has established an experimental teaching system with complete projects, advanced contents, rich resources and the combination of virtual and real. Expansibility, compatibility and prospective simulation experiment management and sharing platform are built in the experimental center. To realize centralized management, open use and sharing of teaching resources. Moreover, we have a high-level experimental teaching team with rich experience in teaching and scientific research, which has formed the experimental teaching characteristics of "laying equal stress on physical experiment and virtual experiment", "laying equal stress on in-school learning and off-campus practice", "laying equal stress on theoretical learning and scientific research".**

Keywords—virtual simulation; Northeastern University; experimental teaching system; mechanical equipment

I. GENERAL SITUATION OF CONSTRUCTION

Northeastern university is a multi-disciplinary and research-oriented national key university with engineering as its main part. It is also a key construction University of "211 Project" and "985 Project" of the state. The College of Mechanical Engineering and Automation is one of the four key engineering colleges in Northeast University. At present, the college has four undergraduate majors: mechanical engineering, vehicle engineering, industrial design, process equipment and control engineering, and they are all the key construction majors of the university. Among them, mechanical engineering is a national characteristic specialty, Liaoning ordinary colleges and universities undergraduate engineering personnel training mode reform pilot specialty, process equipment and control engineering major is Liaoning characteristic specialty.

The rapid development of computer technology, multimedia technology, virtual reality technology, artificial intelligence technology and database technology provides reliable, safe and economical experimental methods and means for the design and development, processing and manufacturing, assembly testing, fault detection and comprehensive training of large and complex mechanical equipment [1]. In recent years, schools and colleges have attached great importance to the construction of virtual simulation experiments and laboratories. During the Eleventh Five-Year Plan period, more than 20 million yuan was invested in the construction of virtual teaching environment, virtual laboratory conditions, teaching staff and experimental reform.

In the process of development, the virtual simulation experimental teaching center of mechanical equipment follows the experimental teaching concepts of "laying equal stress on physical experiment and virtual experiment", "laying equal stress on in-school learning and off-campus practice", "laying equal stress on theoretical learning and scientific research"[2]. The virtual simulation experimental teaching center of mechanical equipment mainly undertakes the virtual design,

virtual processing, virtual assembly, virtual measurement and virtual engineering training courses of four undergraduate majors of mechanical engineering, vehicle engineering, industrial design, process equipment and control engineering and other related majors of the college. In addition, it also serves the under graduates' various innovative competitions and postgraduate research. The Centre currently has:

- The virtual simulation laboratory of mechanical foundation
- The virtual simulation laboratory of mechanical vibration and reliability
- The virtual prototyping technology laboratory
- The virtual machining and simulation laboratory
- The virtual instrument and virtual test technology laboratory
- The hydraulic drive virtual simulation laboratory
- The virtual simulation laboratory of vehicle engineering
- The virtual simulation laboratory for process equipment and control
- The industrial design virtual simulation laboratory

II. EXPERIMENTAL TEACHING RESOURCES

Nine virtual simulation laboratories have set up 55 virtual simulation experiments involving 30 courses. The center undertakes experimental teaching, design practice and engineering training practice teaching for related majors of the whole school, with an annual teaching workload of 27780 hours. According to the teaching needs of different majors, classified teaching is implemented in virtual simulation experiment teaching. For students majoring in mechanical engineering, basic experiment, design experiment and comprehensive experiment are offered. Some students choose innovative experiment. For students majoring in non-mechanical engineering, virtual simulation experiment teaching is mainly based on basic experiment and supplemented by a few design and synthesis experiments. In addition, as the main supporting unit of the University Students' extracurricular technological innovation design and production, the center provides equipment, equipment, places and guidance.

Table 1 virtual simulation experiment of major and class hours

College	Major	Class Number	Class Size	Class Hours	Person Hours
College of Mechanical Engineering and Automation	***Mechanical engineering***	14	30	50	19500
	Process equipment and control engineering	3	90	30	3600
	Industrial design	1	30	12	360
	Vehicle engineering	2	60	30	3600
College of Materials and Metallurgy	***Material forming and control engineering***	4	30	6	720
	Metallurgical engineering	5	30	6	900
	Thermal energy and power engineering	2	30	6	360
	Material science and engineering	2	30	6	360
	Environmental science	2	30	6	360
College of Resources and Civil Engineering	***Environmental engineering***	2	30	6	360
	Mining engineering	3	30	6	360
	Safety engineering	2	30	6	360
	Mineral processing engineering	2	30	6	360
College of Science	***Solid mechanics***	1	30	6	180
Total	13	41		152	27780

The main virtual simulation experiments are shown in Table 2.

Table 2 Virtual simulation experiment scheme of mechanical equipment

Virtual Simulation Experiment of Mechanical Foundation		
Name of experiment item	***Experimental type***	***Name of the original theoretical Course***
• Mechanism Improvement Innovative Design Experiments	Foundation type	*Machine Design*
• Innovative Design Experiments of Composite Mechanisms	Foundation type	

• Cam mechanism motion simulation experiment • Dynamic performance simulation experiment of mechanism • Virtual assembly and disassembly experiment of reducer • ADAMS Practical Practice	Foundation type Comprehensive type Design type Open type	*Foundation of Mechanical Design* *Mechanical Principle*
Virtual Simulation Experiment of Mechanical Design		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Virtual simulation experiment of mechanical vibration • Virtual simulation experiment of mechanical reliability • Robot motion simulation analysis and three-dimensional modeling experiments • Product reverse design experiments • Virtual simulation experiment of product optimization design • Solidworks software application • ANSYS software application • Virtual testing technology experiments • Virtual instrument design and development experiments • Product parametric design and development experiments	Comprehensive type Comprehensive type Comprehensive type Innovative type Comprehensive type Open type Open type Open type Comprehensive type Design type	*Theory and Application of Modern Machinery Design* *Sensors and Testing Technology* *Computer Aided Abrasive Tool Design* *Theory and Application of Mechanical Vibration* *Development and Application of Mechanical CAD*
Virtual Simulation Experiment of Mechanical Manufacturing		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Virtual prototype and function simulation experiment • Virtual programming and simulation of NC system • Virtual machining experiment • Application experiments of programmable controller PLC • Industrial robot programming	Comprehensive type Comprehensive type Open type Comprehensive type Comprehensive	*Technical Foundation of Machinery Manufacturing* *Machinery Manufacturing Equipment*
and simulation experiments • Practical exercises and simulation experiments of proe • UG practical exercises and simulation experiments • Comprehensive experiments of flexible systems • Comprehensive experiments of advanced manufacturing technology	type Open type Open type Comprehensive type Innovative type	*Technology* *NC machine tool technology* *Electrical Control Technology of Machine Tool* *Tolerance and Technical Measurement* *Advanced Manufacturing Technology*
Virtual simulation experiment of electromechanical and hydraulic control		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Simulation experiment of position servo system • Virtual disassembly experiment of hydraulic components (pumps, cylinders and valves) • Design and simulation of hydraulic circuit • Dynamic performance simulation of hydraulic system • Time domain response and analysis experiments • Comprehensive simulation experiment of control system correction • Design and simulation of mechanical automatic control system • Virtual instrument design and development experiments • Comprehensive simulation experiment of hydraulic system • Hydraulic station virtual assembly experiment	Comprehensive type Open type Design type Comprehensive type Design type Comprehensive type Open type Innovative type Open type Comprehensive type	*Hydraulic and Pneumatic Transmission* *Pneumatic Transmission and Control* *Design of Mechatronics System* *Control Foundation of Mechanical Engineering*
Virtual simulation experiment of process equipment and control engineering		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Fluid flow resistance simulation experiment • Simulation test of characteristic curve of centrifugal pump • Simulation experiment of fluid	Comprehensive type Design type Design type	*Process Principle* *Thermal Engineering* *Fluid*

relative particle separation • Experiments on hydrodynamic characteristics of packed column • Functional simulation experiment of vacuum pump • Virtual experiment of liquid-liquid extraction • Virtual experiment of innovative design of vacuum pump	Comprehensive type Comprehensive type Design type Open type	*Mechanics* *Vacuum Coating* *Drying Capacity and Equipment* *Water Treatment Technology* *Vacuum Application*
Virtual simulation experiment of industrial design		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Comprehensive experiment of color composition • Design and production of three-dimensional animation • Industrial product creative design experiments • Rapid prototyping of industrial products • Virtual design experiments of industrial product appearance	Comprehensive type Innovative type Comprehensive type Design type Comprehensive type	*Product Design* *Product Display Design* *Appearance Design of Construction Machinery Products* *Design of External Protection for High-grade CNC Machine Tools* *Product Form Design of Large-scale Complete Equipment*
Virtual simulation experiment of vehicle engineering		
Name of experiment item	***Experimental type***	***Name of the original theoretical course***
• Virtual experiment on structure and principle of automobile driving system • Virtual experiment on structure and principle of automobile transmission • Simulation experiment of dynamic characteristics of automobile suspension • Comprehensive simulation experiment of automobile system • Functional simulation experiment of automobile electronic control system • Virtual disassembly and assembly experiment of automobile	Foundation type Foundation type Design type Comprehensive type Design type Comprehensive type	*Vehicle Design* *Automobile Structure* *Automotive Electronics Technology* *Design of Automobile Body Structure* *Principle of Internal Combustion Engine* *Automobile Test*
• Vehicle Virtual Driving Experiment • Innovative Automotive Design	Open type Innovative type	*Automobile Manufacturing Technology* *Vehicle CAE Technology*

III. FUNCTION AND EFFECT

The virtual simulation technology provides a new method for principle demonstration, function simulation, fault diagnosis of large-scale complex mechanical equipment, process verification of complex precision parts, simulation analysis of complex integrated control and operation training of large-scale complex mechanical equipment, and makes up for many shortcomings of physical experiment of large-scale complex mechanical equipment [3].

The center fully serves undergraduate teaching, and can provide undergraduates with virtual prototype design and development, virtual assembly and function simulation, virtual processing and simulation analysis, virtual experiment and virtual measurement, virtual driving and virtual operation, virtual engineering practice for large and complex mechanical equipment such as high-grade numerical control machine tools, full-face road header, Aerospace long equipment, metallurgical complete set equipment, etc. Training (NC programming, PLC programming) and other virtual experiments and virtual practice training courses [4].

The virtual simulation experiment has many advantages, such as good vividness, intuitive experimental effect and good safety [5].It is beneficial for students to understand and master the principle, manufacturing and assembly technology, use and operation of complex mechanical structures, to stimulate students' learning enthusiasm and innovative thinking, and to students' innovative practical activities[6].

The center implements open management, enhances the utilization rate of resources and maximizes the benefits of resources. On the premise of satisfying the experimental teaching of Undergraduates in our college, it is open to all undergraduates and postgraduates. In addition to virtual simulation experiment teaching, the center also serves all kinds of innovative competitions for undergraduate and graduate students. In the past three years, more than 1200 people have participated in various innovative competitions and completed more than 400 innovative competitions with excellent results. The center and cooperative enterprises build and share, open resources to cooperative enterprises, and provide technical training and new product development services for enterprises. In recent years, more than 600 technicians have been trained for machinery and equipment manufacturing enterprises such as Shenyang Machine Tool Group, Shenyang Blower Group and Shenyang North Heavy Industry Group, and more than 200 new products have been developed by advanced virtual simulation methods. Shenyang Daily reported on the front page of April 26, 2011 that Northeastern University Digital Design and Manufacturing Research Group used advanced virtual simulation experimental means to serve the new product development of

enterprises. In addition, the Holiday Center is open to primary and secondary school students, receiving more than 1300 visits to primary and secondary school students.

IV. CHARACTERISTICS AND INNOVATION

In the process of development, the center follows the experimental teaching concepts of "laying equal stress on physical experiment and virtual experiment", "laying equal stress on in-school learning and out-of-school practice", "laying equal stress on theoretical learning and scientific research"[7]. Through virtual simulation experiments, many shortcomings such as high cost, difficult maintenance and poor safety of physical experiments for large and complex mechanical equipment are supplemented.

The center serves undergraduate experimental teaching with scientific research equipment and transforms scientific research achievements into experimental teaching means. It not only improves the experimental advancement, but also helps to broaden students' horizons and improve students' learning enthusiasm and learning effect [8].

We should strengthen cooperation and exchanges with enterprises in the construction of virtual simulation experimental teaching centers, increase investment in the construction of virtual simulation experimental teaching centers, and better serve the development of new products while cultivating talents. Through multi-field and deep-level cooperation, the construction level of virtual simulation experiment teaching center is guaranteed, and the advantages of enterprise in site, equipment and personnel are fully utilized to improve the teaching quality and effect of virtual simulation experiment.

Fig. 1. The virtual simulation system

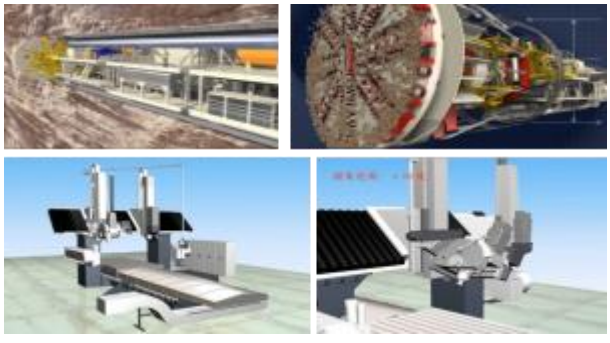

Fig. 2. The virtual simulation experiment interface

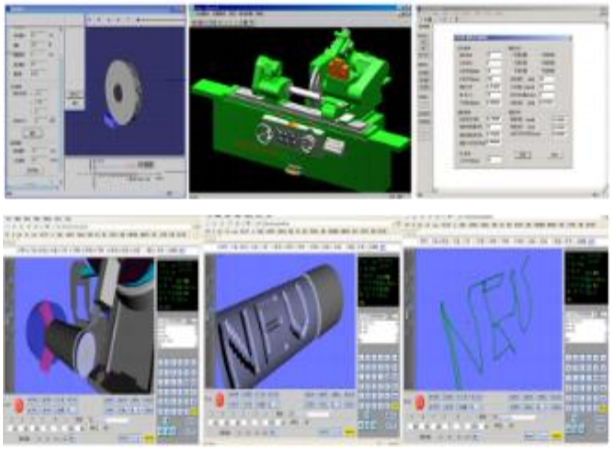

Fig. 3. The virtual simulation experiment interface

Fig. 4. The virtual simulation system

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