DOI: 10.21062/mft.2023.066 http://www.journalmt.com

Exploration and Realization about Teaching Experimental of CNC Machine Tool Based on Virtual Simulation Technology

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In order to cultivate student's professional skills and enhance student's practical ability, this paper proposes to create a virtual simulation experiment system of NC machine tool based on SolidWorks software platform, taking vertical machining center as the research object, which is integrated by three modules of NC machine tool structure, machine tool operation and machine tool processing. Firstly, the detailed assembly relationship of each subsystem of the machine tool, the assembly relationship of the overall equipment and the system composition are displayed intuitively by 3D modeling, so that students can understand the 3D modeling method and structure composition of complex CNC machine tools. Secondly, according to the machining process characteristics of vertical machining center, using typical parts to create the virtual simulation platform to carry out complex parts programming and machining methods and steps based on vertical machining center. Through the full combination of virtual simulation experiment and actual equipment, it has significant results in improving student's interest in learning, ensuring teaching effect, reducing material waste, avoiding machine tool accidents and so on. And combined with the actual processing, operation of CNC machine tool experiment to achieve the combination of virtual and real, vivid image, rigorous and realistic, open and sharing, expand the numerical control technology class teaching and talent training. It also provides a good reference for similar curriculum development.

Keywords: Virtual simulation, Numerical control training, Design of experiment, Simulation platform

1 Introduction

Numerical control machine tool is a typical mechatronics product, its processing precision is high, can adapt to the complex parts of the efficient and high-precision processing application, its system composition involves a wide range, including machinery manufacturing, computer technology, metal cutting technology, electronic and electrical technology, students to master the knowledge and related professional content is more, with a certain degree of learning difficulty. It is difficult to grasp and understand the content of numerical control technology directly through the teaching of theoretical courses. Therefore, it is necessary to help students better understand and master the course content in practice teaching, based on relevant theoretical knowledge and experiments. However, due to the complex control of each motion axis and tool path during machining with NC machine tools, the correctness of NC program driving NC machine tools cannot be identified manually, especially for the machining of complex parts. This situation not only greatly reduces the efficiency of machine tools, but also brings unpredictable risks to the safety of machine tools. This paper is mainly designed for the virtual simulation experiment platform of numerical control machine tool in vertical machining center. It is composed of two parts: hardware design of vertical machining center NC machine tool and virtual simulation experiment platform. For the complex CNC machine tool experimental teaching, there are common problems of high experimental cost, data is not easy to obtain, high risk, this paper proposed the development of numerical control machine tool virtual simulation experiment system based on SolidWorks software platform, taking vertical machining center as the typical object, the virtual simulation experiment can more intuitively display the detailed assembly relationship of each subsystem of machine tool, the assembly relationship of the overall equipment and the system composition. Let the students understand the 3D modeling method of complex CNC machine tools and the processing technology based on CNC machine tools, and carry out the programming and processing methods and steps of complex parts. The system can be used for classroom demonstration and experimental teaching, which is convenient for students to combine theory with practice and improve the ability of engineering practice.

2 Numerical control technology virtual simulation experiment design

Because the experiment involved in numerical control technology has the characteristics of strong practice and high risk, numerical control technology virtual simulation experiment must demonstrate the mechanical structure of numerical control machine tool, numerical control machine tool operation, processing process, and obtain the same effect as the actual numerical control equipment operation and processing, reveal the structural principle of numerical control machine tool. Take the feed transmission system of NC lathe as an example, this system is the biggest difference between NC machine tool and ordinary machine tool. The transmission system of ordinary lathe is very complex, but very intuitive, through disassembly, assembly into the feed box can directly understand the transmission process of ordinary lathe. There is no feed box on the CNC lathe, and its transmission control is completed by the servo motor on each coordinate axis and the CNC system. Its speed, position and precision control can reach very high requirements, compact structure, high assembly precision, it can't be disassembled and assembled, and students have difficulty in understanding its transmission principle. In order to better let the students master the working principle and structure of each system on the CNC lathe, through the software SolidWorks and other CNC lathe parts for three-dimensional modeling, based on each coordinate axis for virtual assembly and complete the CNC lathe motion simulation. Through the virtual simulation experiment, students can complete the disassembly and assembly of CNC lathe parts, make and view the assembly sequence of the machine, and view the production of motion simulation and other practical teaching contents on the relevant engineering software platform as if they were on the equipment site in person operation, greatly enhance the enthusiasm of students to learn, better help students to understand and master the knowledge [2]. This implementation process is shown in Fig. 1.

On the relevant engineering software platform, students can complete the disassembly and assembly of various mechanical parts according to the assembly relationship of mechanical parts, make and view the assembly sequence of the whole machine, check and make motion simulation and other practical teaching contents under the guidance of teachers by using the three-dimensional modeling of the structure of CNC machine tools.

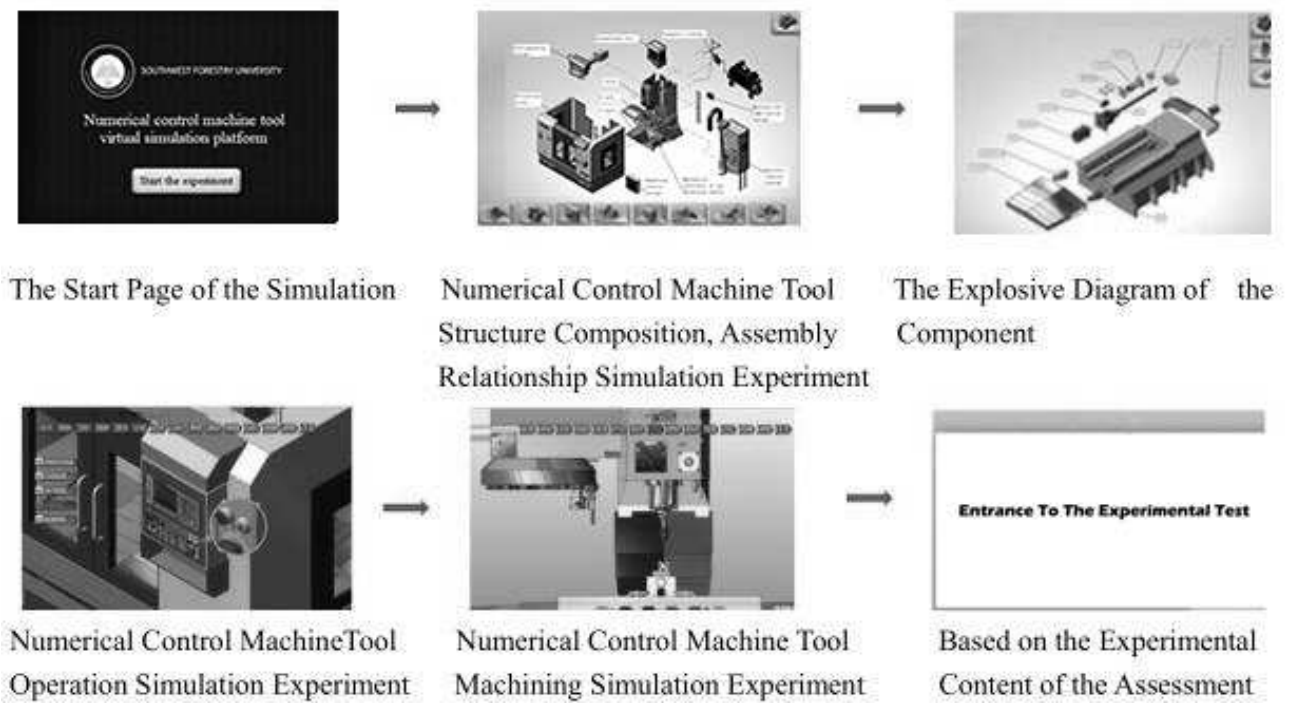

Fig. 1 *Numerical control machine tool virtual simulation experiment process*

Using the operation module in the created numerical control machine tool virtual simulation experiment system, students under the leadership of the teacher carried out the numerical control machine tool operation virtual simulation experiment on the computer, fully familiar with the function and use of each switch and button on the operation panel of numerical control machine tool, the operation of the knife, etc., so as to prepare for the virtual machining of the machine tool.

Using the machining module in the created numerical control machine tool virtual simulation experiment system, students carried out the numerical control machine tool machining virtual simulation

experiment on the computer under the guidance of the teacher. The drawings, processing technology and program of 10 machining parts as well as the computer processing simulation of corresponding parts were provided systematically to help students understand the processing methods and programming methods of different shapes and processes.

Based on the above experimental content, experimental tests are conducted and assessed according to the experimental content to better help students master the experimental content.

3 Development of numerical control machine tool virtual simulation experiment platform

3.1 Demand Analysis

As the CNC machine tool training equipment is expensive, it is difficult for schools to meet the needs of one-to-one training equipment and materials for students. In addition, CNC machining has a certain risk, due to program errors or operational errors; it is easy to cause equipment damage or personnel injury accidents. In the course of numerical control technology teaching, using virtual simulation practice teaching, can well solve the above problems [3]. After mastering the relevant technical details of numerical control technology, the specific operation and processing of parts on numerical control equipment can realize the integration and unification of virtual simulation and practical application, which can better help students master the operation and processing ability of numerical control machine tools, improve their practical level, and promote the coincidence of students' knowledge and ability with enterprise needs [4]. This virtual simulation experiment platform is based on Solid works, Composer, UE4 and other software, and based on the numerical control equipment of the engineering training Center of Southwest Forestry University, to develop and design a complete set of virtual simulation numerical control experiment platform. According to the requirements of the virtual simulation Training Center of Mechanical and Transportation College of Southwest Forestry University for experimental courses, with the enhancement of student's professional knowledge as the center and the improvement of student's practical application ability as the basis, virtual simulation modules such as "CNC machine tool structure", "Machine tool basic operation training", "complex parts process analysis and molding simulation processing" are taken as the main functions of the experimental platform. For each virtual simulation module, combined with specific knowledge points, the design and implementation of virtual simulation experiment content should be able to solve the following main problems:

- 1) Help students understand the basic requirements of CNC machine tools for mechanical structure, understand the working principle of the main transmission system and feed transmission system of CNC machine tools, and understand how to meet the requirements of the system structure of CNC machine tools by analyzing their mechanical components.
- 2) Taking the feed system of CNC machine tool as an example, using the 3D solid model of CNC machine tool created on SolidWorks tool platform, carry out virtual disassembly and virtual assembly experiments on the feed system of the machine tool to verify the correctness of its theoretical analysis.
- 3) Before the actual equipment operation, the virtual simulation machining module is used to understand the operation steps and processes of complex CNC equipment. Master the tool setting method of CNC machine tools.
- 4) Master the selection and application of fixture in parts processing. Design optimized process methods and select appropriate process parameters based on the processing workpiece.
- 5) Learn machining programming of parts based on CNC system requirements of CNC machine tools. Through different virtual simulation experiment contents, create the same processing scene as the actual processing environment, let students feel the on-site implementation process of machine tool operation and machine tool processing through the virtual system, realize the purpose of virtual on-site operation and processing.

3.2 Overall design of the system

Numerical control machine tool virtual simulation experiment involves more experimental content and projects, the relevant design content is also different. As a virtual simulation experiment system, each experiment must exist independently and establish corresponding logical correlation to form an interrelated and independent organic system, so as to meet the needs of experimental teaching in corresponding courses. [5] Therefore, the virtual

simulation system of the numerical control machine tool should not only meet the experimental teaching of the structure, operation, processing of the numerical control machine tool virtual simulation system to reflect the various implementation methods, but also consider the students in the process of use can be from the basic principle, basic structure to the application of professional knowledge of the cognitive law. According to the system structure and experimental steps shown in Fig.1, teachers should also give full consideration to the logical relationship between the matching and promotion of student's professional knowledge and the knowledge they have been taught in the process of carrying out the experiments, only in this way can the experimental content involved in CNC machine tools be combined with the teaching content of virtual simulation experiment, and finally achieve the teaching purpose of "virtual and real combination", thus forming the teaching system of numerical control machine tools virtual simulation experiment as shown in Fig. 2. [6]

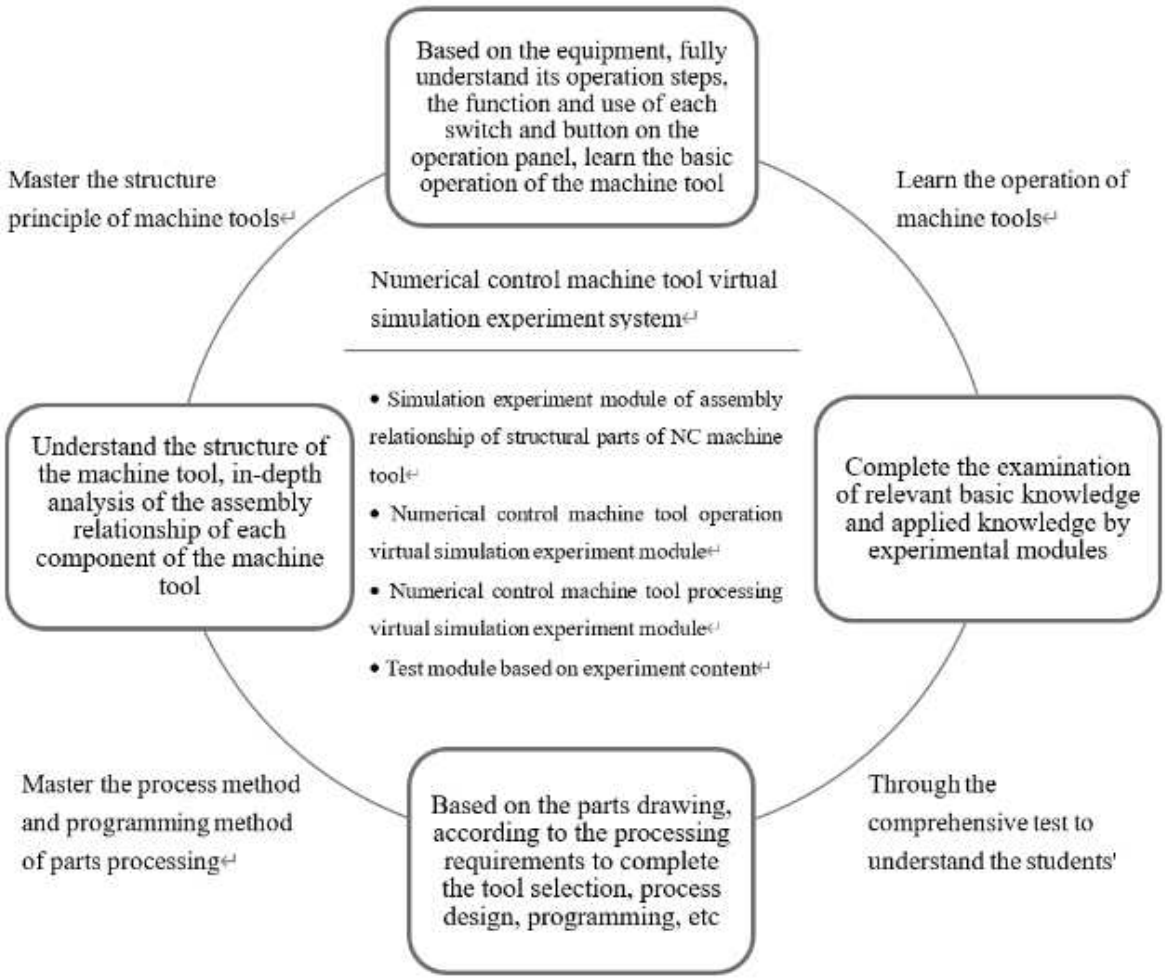

Fig. 2 *Overall design drawing of experimental system*

As shown in Fig. 2, the main parts of the virtual simulation experiment system of CNC machine tools are the structure composition, the simulation experiment module of assembly relationship, the operation simulation experiment module of CNC machine tools, the machining simulation experiment module of CNC machine tools, and the module of assessment based on experiment content. To complete the design of the system, the first use of three-dimensional modeling software SolidWorks strong characteristics of the establishment of the ability and parts and assembly control function, can quickly and efficiently complete the 3D model of CNC machine tools and can retain the complete design data, but also through the standard data format and other CAD software for data exchange. Secondly, interactive documents are made. Before the output of virtual simulation resources, personalized interactive document making schemes can be customized according to user's needs, and the content of virtual simulation resources can be updated in real time according to users' needs. Third, obtain interactive

virtual simulation resources. Through Solidworks modeling and Composer interactive document production, interactive virtual simulation resources can be output and generated interactive three-dimensional virtual reality can be interacted with. Participant's interaction with virtual simulation environment can provide people with immersive experience and effectively guide production practice and learning [7].

3.3 Numerical control machine tool virtual simulation experiment project introduction

The numerical control machine tool virtual simulation experiment system is mainly composed of the following modules, the specific components and function realization are shown in Fig.3.

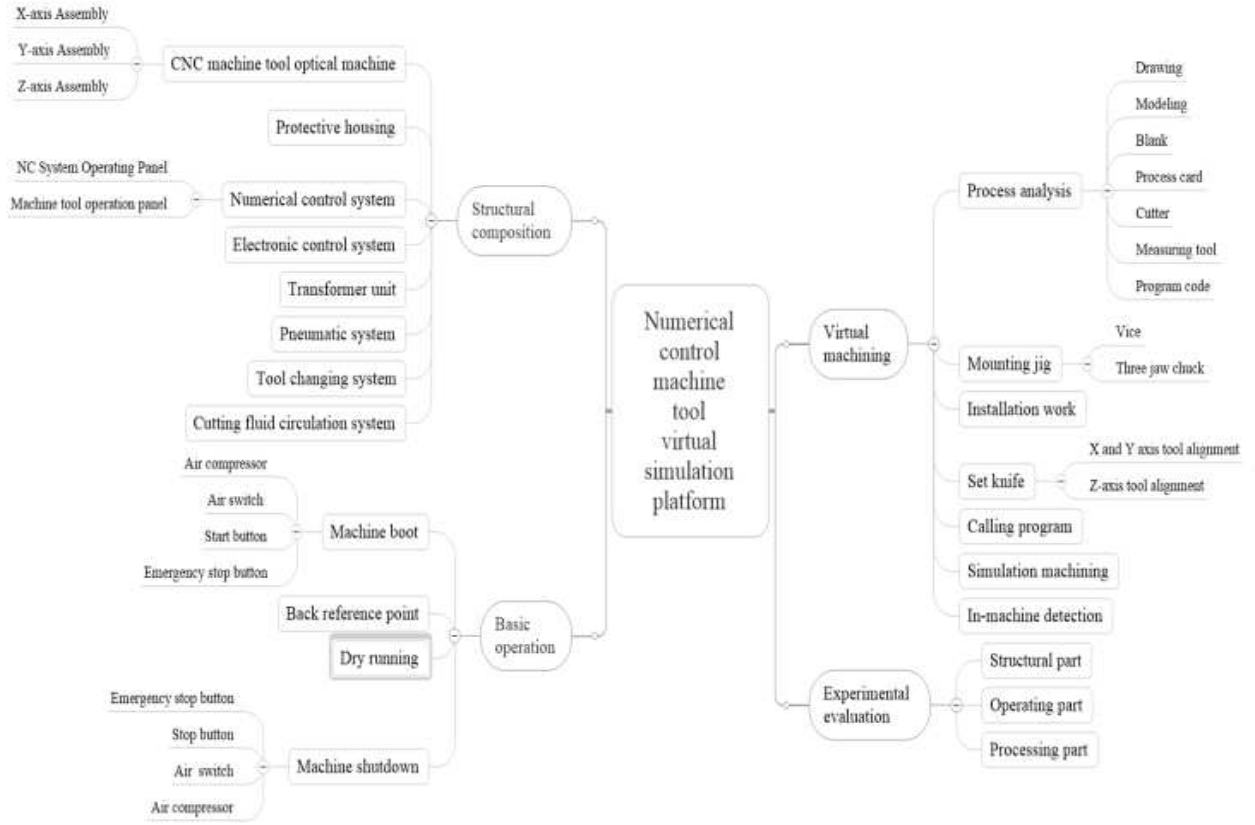

Fig. 3 *Tree structure of CNC machine tool virtual simulation system*

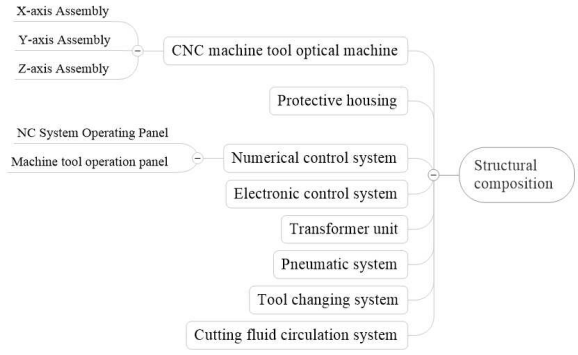

Fig. 4 *The functional modules in the structure*

Numerical control machine tool structure composition, assembly relationship simulation experiment module. The simulation experiment module divides the vertical machining center into eight sub-assemblies according to the actual functions. The feed system is the actual moving part of machining, the shell protective cover is the human-machine protection part, the numerical control system is the human-machine interface digital control part, the electric control system is the control signal power supply and the action response part.

The transformer unit is the strong current and weak current distinguishing part, the pneumatic system is the air compressor air path system, the tool changing system is the tool library and the tool changing action part, the cutting fluid circulation system is the coolant the road part. According to the method of step-by-step learning the sub-assembly is studied, and the machine tool internal structure is tested on the basis of understanding the function, which improves the single characteristics of the teaching method in the learning stage of machine tool structure caused by the machine tool cannot be disassembled [8, 18]. It is shown in Fig. 4.

Operation simulation experiment module of CNC machine tools. The module is divided into four parts according to the steps of the actual basic operation of the machine tool, which are boot up, back to the

reference point, empty operation, basic operation, it is the operation with the highest frequency in each use of the machine tool. As the basis of the operation of CNC machine tools in the case of student's first contact with CNC machine tools, to provide security for students, at the same time, develop the habit of opening, shutting down and air transport in order, in the maintenance of machine tools has a certain positive role.

Numerical control machine tool processing simulation experiment module. The module is divided into five parts according to the actual processing sequence, which are respectively: installation fixture, installation workpiece, tool setting, calling program and processing. The actual selection of processing issues is taken into account respectively. To make corresponding choices under the guidance of the overall processing strategy of parts, and learn the basic processing methods, cultivate students' basic processing ability and improve their professional ability [9].

Numerical control machine tool virtual simulation experiment evaluation module. As the quantitative index of students' experiment part, the evaluation module is divided into three parts in the design of the system. According to the learning and mastering of machine tool structure, basic operation and processing, question banks are set up respectively to randomly select questions to evaluate the learning of student's experiment link, and weighted with different weight factors, the final result is obtained through the total score, which can effectively check the learning effect of students.

3.4 Numerical control machine tool virtual simulation platform characteristics

The numerical control machine tool virtual simulation platform has the following characteristics:

- The software runs independently without installation. It can provide PC terminal use, through the campus computer room for teaching or student's independent learning, review.
- During the experiment, the class, student number and password should be used to log in. The teacher will check the student's learning progress and knowledge mastery by taking the class as the unit, and give specific teaching explanation according to the error rate. Interactive operation: click/press the corresponding key, and corresponding actions of "sinking" and "lighting" will appear.
- 3) In order to stimulate student's innovation ability, open source design is recognized, the students independently design the parts to be processed, conduct simulation, and score the software according to the scoring standard through step traversal.
- 4) The operation of the platform simulates the real operation of the machine tool, and prompts step by step in order to provide students with correct operation prompts.
- 5) Perform operation evaluation according to the prescribed operation sequence, which can correct students' bad operation habits and avoid unnecessary injuries in actual operation.

4 Teaching practice of numerical control machine tool virtual simulation experiment system

Based on the above analysis, taking the numerical control machine tool structure composition, assembly relationship simulation experiment module as an example, analyze and elaborate the function and use of the system. [10] As shown in Fig. 4, it is the simulation experiment module of the structure composition and assembly relationship of the virtual simulation system, which is divided into eight sub-assemblies according to the actual functions. In this module, after entering the experiment interface, firstly click the "structure module" as shown in Fig. 5. The student can then enter the interface shown in Fig. 6, at the bottom of the interface, there are 10 small ICONS, and you can enter the 8 sub-assemblies and the hand pulse generator as shown in Fig. 4 to understand their component composition and component composition of the sub-assembly. The specific experimental process is as follows:

- 1) Click the "Structure Principle" button as shown in Fig. 5, and the page as shown in Fig. will be entered.

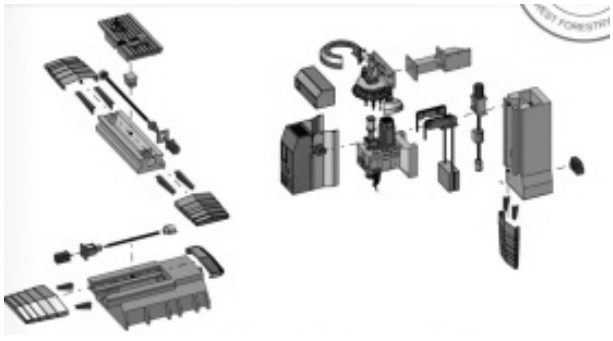

Fig. 5 *Virtual simulation experiment home page*

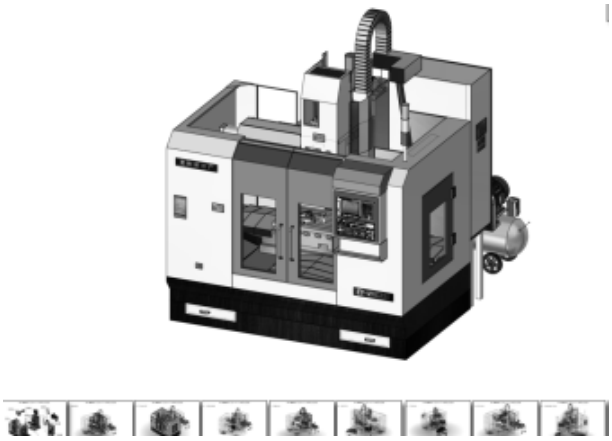

Fig. 6 *Structural principles page*

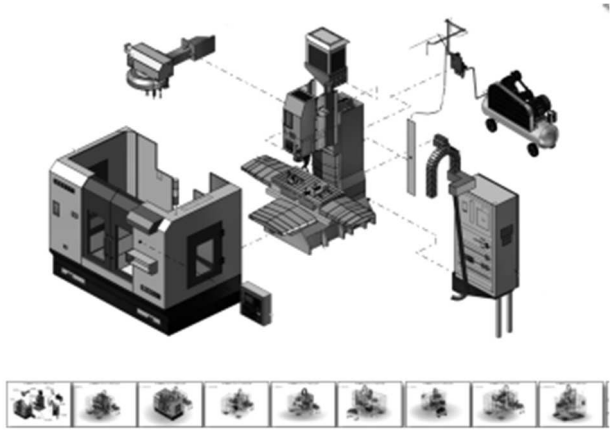

Fig. 7 *Explosion diagram of parts*

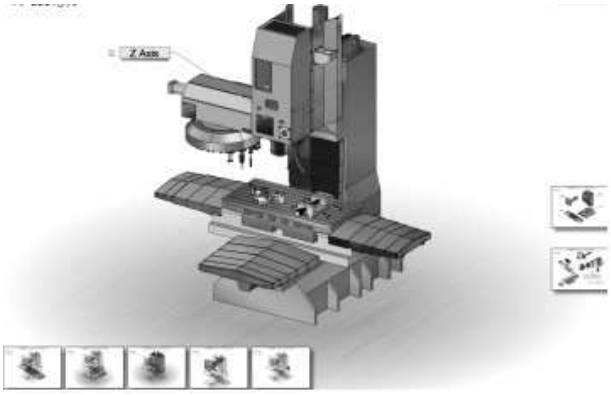

Fig. 8 *Machine tool bed structure model*

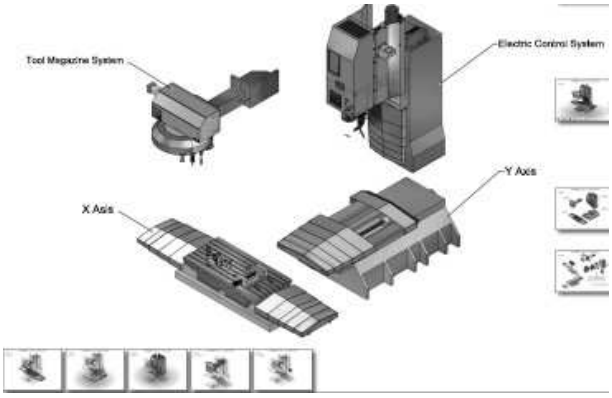

Fig. 9 *Explosion diagram of component of the bed*

Fig. 10 *Each part of the bed is divided into parts explosion*

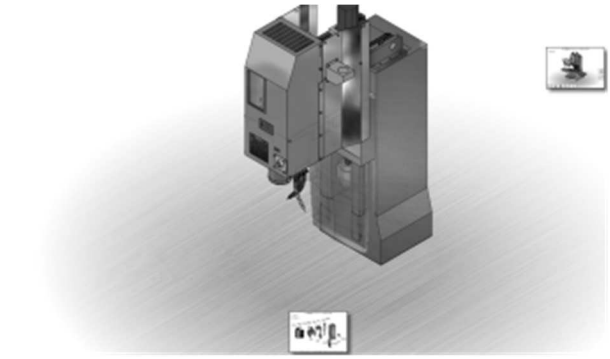

Fig. 11 *Z-axis component*

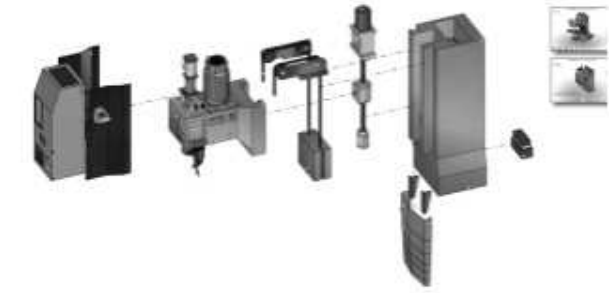

Fig. 12 *Explosion diagram of Z-axis assembly*

- 2) On the page shown in Fig. 6, click the first button in the lower left corner to enter the explosion diagram of parts shown in Fig. 7. Through this page, students can understand the overall mechanical composition of the equipment and the composition and name of the three-dimensional model of each component.This page mainly includes CNC machine tool, tool library system, electronic control system, protective cover, CNC system control box and operation panel and other parts, you can zoom in and out of the page through the mouse, you can also rotate the

model, in this experimental page can have an in-depth understanding of the composition and shape of each part of the machine tool.

- 3) Click the "bed" icon at the bottom of the page in Fig. 7 to enter the 3D model of "CNC machine tool Optical Machine" as shown in Fig. 8. On this page, students can clearly understand the component composition of each part of the CNC machine tool optical machine. Click the second button on the right of the page, and enter the explosion diagram of CNC machine tool optical machine parts as shown in Fig. 9.This page mainly includes X axis component, Y axis component, Z axis component, tool library system [11].You can zoom in and out of the page through the mouse, and you can also rotate the model. In this experimental page, you can deeply understand the composition and shape of each part of the machine tool optical machine.
- 4) This page gives the composition of Z axis component, Y axis component, X axis component and tool library system of the feed system, Click the fourth button on the right side of the page, and you can get the detailed component composition of the spindle component, Z-axis component, Y-axis component, X-axis component and tool library system, as shown in Figure 10, and the explosion diagram reflecting the assembly relationship. You can zoom in and out of the page with the mouse, or rotate the model. Students can zoom in and out of the page through the mouse, and also rotate the model. In this experimental page, they can have an in-depth understanding of the composition of each part of the machine tool optical machine. If you want to know the details of each part and the name of the part, you can continue to click the button at the bottom of Fig. 10 to further understand the detailed composition and assembly relationship of each part. Take the Z-axis component as an example. Click the button at the bottom of Fig. 10 to further understand the detailed composition and assembly relationship of each component [12]. Then you can enter the Z-axis component assembly drawing as shown in Fig. 11.
- 5) Click the button at the bottom of the page in Fig. 11, and you can enter the page of Z-axis component explosion diagram as shown in Fig. 12.You can zoom in and out of the page with the mouse, or rotate the model. Through this experiment, students can further understand the components and names of the Z-axis components, master the composition of the Z-axis components and the ordering relationship of the components, analyze the structure principle, and master the assembly relationship between the components [13].Other components can also be tested in a similar operation mode, as shown in Fig. 14, which is the component composition of each component of the CNC machine tool optical machine. Through the above operation mode, each part can complete the relevant cognitive experiment.
- 6) After completing the above simulation experiment module of structure composition and assembly relationship of CNC machine tool, click "Experiment test" button on the page to enter the experiment test of the experiment content. Through this test, teachers can understand the student's grasp of the structure and composition of CNC machine tools, the relevant experimental content and basic knowledge of assembly relations [14, 15]. Fig. 13 shows the overall structure of the system.

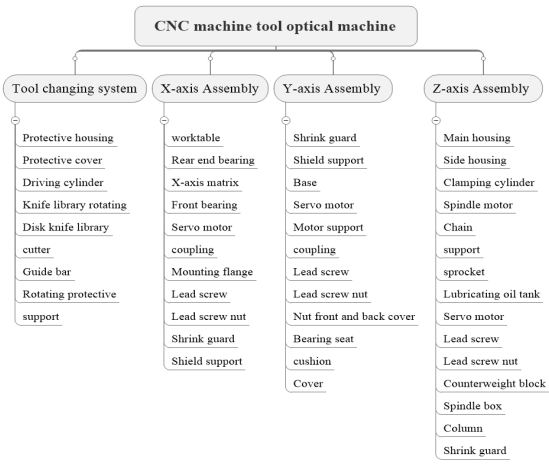

Fig. 13 *CNC machine tool optical structure composition*

5 Experimental examination

The virtual simulation system consists of four modules. It mainly consists of four modules: the structure of CNC machine tool, the simulation experiment module of assembly relationship, the operation simulation experiment module of CNC machine tool and the machining simulation experiment module of CNC machine tool. Each experimental module has a different assessment module. Based on the experimental content of different modules, different assessment contents are designed. The final assessment results are automatically recorded in the fourth assessment module based on different weights, and the assessment results are directly output. The examination contents of each module include basic knowledge, familiarity with experimental steps, correct and standardized operation of NC machine tools, standardized use of measuring instruments, correct selection of machining parameters, machining procedures submitted in the experimental report, correctness of experimental results, analysis and discussion of results, and solution of thought questions [16, 17].

6 Conclusion

Through the creation of four virtual simulation modules, this project helps students to truly and vividly understand the mechanical structure, composition, operation of CNC machine tools, and various knowledge and operation processes involved in parts processing of machine tools, students deeply understand and grasp the relevant knowledge and application of CNC machine tools, through the actual use of exactly the same steps, step by step real-time simulation of machine tool operation, processing process involved in the experimental content. The numerical control machine tool virtual simulation system not only helps students to understand and master the relevant theoretical knowledge of numerical control machine tools, but also helps students to master the whole process of actual operation and processing must be understood and mastered before the actual operation of numerical control machine tools.

With the development of virtual reality technology, teaching methods are constantly improved, and the channels for students to acquire knowledge are becoming more and more extensive. The training center, relying on the existing equipment, develops the training platform and achieves the combination of virtual and real, focuses on course teaching, and takes the agricultural machinery major as the student-oriented, which plays a certain role in improving and helping the cultivation of student‘s professional knowledge, practical ability and innovative spirit. It also provides some reference for the construction of experiment platform of relevant agriculture and forestry courses.

Acknowledgement

This project was funded by the "Yunnan Province higher education undergraduate teaching achievement project cultivation" (Liwei), the Science Research Fund Project of the Yunnan Provincial Department of Education (2019J0189), Southwest Forestry University teaching reform project (2023 Liulifu). We also thank Chen Xuerui for help in the design and completion of the project.

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