

Research on Virtual Simulation Experiment Teaching of Scraper Conveyor Condition Monitoring and Fault Diagnosis

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Abstract: The scraper conveyor status monitoring and fault diagnosis virtual simulation experiment system is designed and developed based on the operating environment of the scraper conveyor in the fully mechanized mining face. Using augmented virtual reality teaching resources, through immersive display and interactive operation experiments, students are guided on basis of scraper conveyor mechanical cognition, master the virtual teaching experiment of state monitoring and fault diagnosis such as broken chain monitoring, motor fault classification and identification, reducer compound fault separation, etc. The teaching practice shows that the system can overcome the harsh production environment in coal mines and the risk factors caused by equipment failure, improve students' understanding of the mechanical fault diagnosis technology, and mobilize students' enthusiasm for experiments and initiative to enhance students' innovative ability.

Keywords: Scraper Conveyor; Virtual Simulation; Condition Monitoring; Fault Diagnosis; Experimental Teaching.

1. Introduction

Coal mining equipment intelligence is China's '14th Five-Year Plan' focus on the direction of development, intelligent coal machinery and equipment in coal mining has been increasingly used. Scraper conveyor state and environmental sensing, monitoring, diagnostic technology, is the most effective means to promote safe and efficient mining in coal mines, is an important foundation for the intelligent development of coal mines. However, due to the harsh production environment and unsafe factors caused by equipment failures in underground coal mines, students are unable to visit and practice the production site in underground coal mines, especially for the knowledge of related equipment failures, which seriously restricts students' mastery and practice of intelligent condition monitoring and fault diagnosis technology of scraper conveyor. With the rapid development of virtual simulation and VR technology, many colleges and universities at home and abroad have begun to study the teaching methods and talent cultivation modes mainly featuring virtual simulation and have made remarkable achievements, but the virtual simulation experimental teaching of the condition monitoring and fault diagnosis of the scraper conveyor featuring the mine is very rare. For this reason, it is of great significance to construct a virtual simulation experimental project for condition monitoring and fault diagnosis of scraper conveyor based on the on-site scene of the comprehensive mining working face and integrating advanced intelligent fault diagnosis technology.

This virtual simulation experiment system starts from the demand of mechanical engineering students' training practice, integrates virtual simulation, computer, network communication and cloud platform technology, visualizes signal acquisition, signal processing, fault diagnosis model training and model testing, and condenses them into four modules, nine knowledge points, and eighteen operation steps, including the scraper cognitive experiment, scraper broken chain monitoring, motor fault classification and identification,

and the reduction gearbox composite fault separation. Eighteen operation steps, in the interaction so that students cognitive scraper conveyor condition monitoring and fault diagnosis development and design of core elements, in the immersive learning to complete the experimental design, and through the sharing of platforms and other universities, enterprises to share the construction of the cultivation of high-quality, innovative professionals needed for the high-quality development of mechanical engineering.

2. Experimental System Architecture

The virtual simulation experimental system is designed to include six parts, including pre-course study, scraper conveyor structure assembly, chain breakage detection, motor fault classification and identification, reducer composite fault separation, and practical assessment. Based on the augmented virtual reality technology, the experimental system restores the real scene of the scraper conveyor in the comprehensive mining face, and guides students to recognize the structural assembly of the scraper conveyor under the virtual field environment through the observation and study of the selection and assembly of the module structure, selection and installation of the sensors, algorithms and results, and to master the methods and principles of the chain-breaking monitoring, the classification and identification of the motor faults, and the separation of the composite faults of the speed reducer.

Virtual simulation experiment system through three-dimensional simulation and virtual reality technology dynamic simulation demonstration SGZ-764/400 scraper conveyor, to achieve a full range of immersive experimental scenes, intuitive operation and human-computer interaction links, breaking the traditional teaching of experimental teaching equipment, environment and other realities of the limitations. The whole teaching process is carried out in pre-course study, simulation operation and assessment practice, which guides students to think and explore deeply from the basis. The virtual simulation project includes the following four parts.

3. The Main Content of the Virtual Simulation Experiment

3.1. The Basic Knowledge of Scraper Conveyor Chain Breakage Monitoring and Fault Diagnosis System Awareness

The pre-course study includes three parts: application

scenarios, scraper conveyor machinery knowledge, condition monitoring and fault diagnosis. From the ‘pre-course study’ into the ‘application scenarios, scraper conveyor mechanical cognition, condition monitoring and fault diagnosis’ basic knowledge learning interface, before the experiment through the study of this knowledge, students can have a more comprehensive understanding of the system, see Figure 1 for details.



Fig 1. Virtual simulation system ‘pre-course study’ session

3.2. Scraper Conveyor Structure Assembly

This experiment includes module structure selection, assembly and automatic operation demonstration, through three-dimensional simulation and virtual reality technology dynamic simulation demonstration of SGZ-764/400 scraper conveyor head structure, intermediate structure, tail structure and ancillary devices and for moving the conveyor with the

arrangement of the pusher device. Through the combination of assembling and answering questions of each part, animation display and immersive human-computer interaction operation such as displaying the name of the model structure, disassembling and combining, the students can understand and master the structure and composition of the scraper conveyor as well as the assembling process.

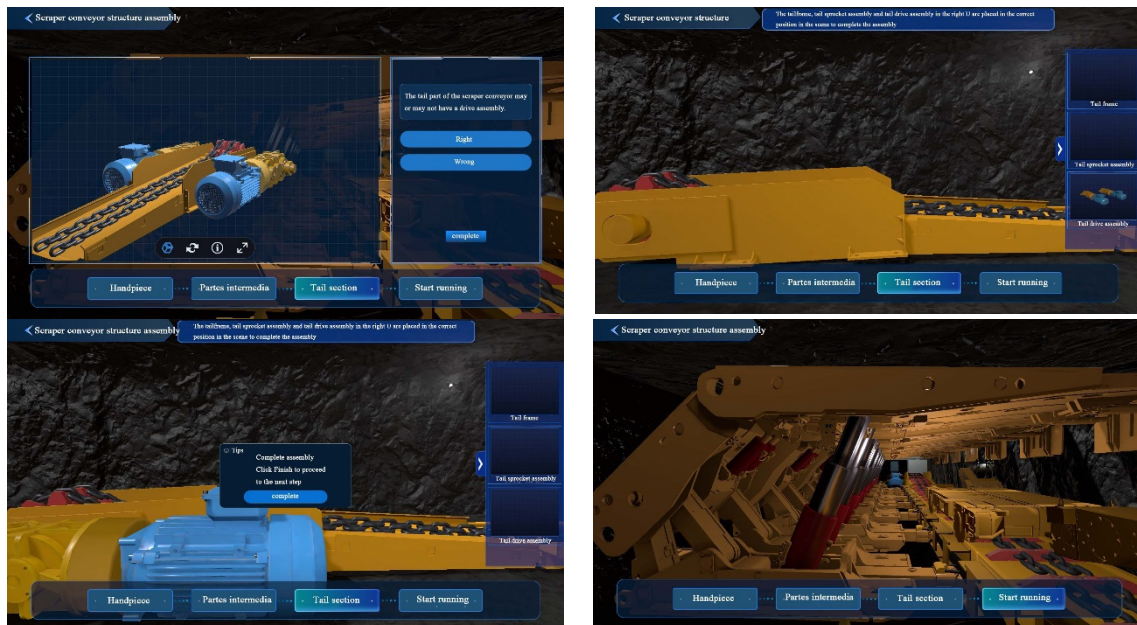


Fig 2. Scraper conveyor structure assembly experiment interactive interface

3.3. Chain Break Monitoring.

At present, there are mainly vibration diagnostic method, noise diagnostic method, temperature diagnostic method and Hall sensor diagnostic method for broken chain monitoring of scraper conveyor, and Hall sensor diagnostic method is adopted in this experiment, which installs Hall sensors at the head and tail of the machine, and installs magnetic blocks on the scraper, and builds a magnetic field at the head and tail of

the scraper conveyor, and monitors the change of magnetic flux when the scraper passes through the constructed field by using the principle of Hall effect to determine the state of the scraper, and determines whether the scraper chain is in a loose state by monitoring the time difference between the adjacent scrapers passing through the head or tail. By using the Hall effect principle to monitor the change of magnetic flux when the scraper passes through the magnetic field constructed to

judge the state of the scraper, and by monitoring the time difference between adjacent scrapers passing through the head or tail to judge whether the scraper chain is in a loose state. Students learn the working principle of broken chain detection through pre-study before class, choose the correct sensor from vibration sensor, noise sensor, temperature sensor,

Hall sensor, and complete the interactive operation of sensor installation, field wiring, and demonstration of the upper computer interface in the operation process, so as to have a deeper understanding of the principle of Hall sensor diagnosis of the scraper chain state of the scraper conveyor.

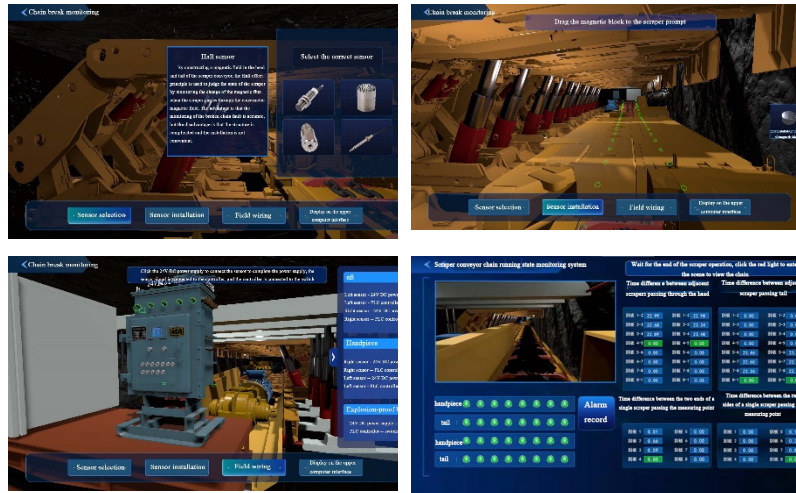


Fig 3. Interactive operation interface of scraper conveyor chain break detection experiment

3.4. Identification of Motor Fault Classification.

The current motor fault identification methods mainly include vibration acceleration sensor identification, acoustic sensor identification, temperature sensor identification, and the vibration acceleration sensor is used in this experiment. In the experiment, students learnt different forms of sensors and their working principles, and selected the correct type of sensor for motor monitoring signal acquisition according to the application scenarios of different sensors. After the vibration acceleration sensor collected the signal characteristics of the motor in three directions, students judge the signal selection according to the amplitude of the vibration signal, select the Y or Z direction signal with a larger amplitude for fault identification, and do Fourier transform signal preprocessing to get the spectrum map. The system

uses the frequency domain signal as the direct input of the network, the students choose the sigmoid function as the activation function in the process of establishing the deep neural network based on the autoencoder, the optimal deep neural network designed a total of five layers, the students by the needs of the signal analysis to complete the selection of the input layer, the three intermediate hidden layers and the output layer, and finally use the BP algorithm to fine-tune the parameters of the entire network to achieve the classification and identification of motor faults. Achieve the classification and identification of motor faults. By completing the interactive operation of sensor selection, installation, field wiring and demonstration of the upper computer interface, students have a deeper understanding of the principle of vibration acceleration sensor to identify the state of the scraper conveyor motor and the analysis process of the deep neural network.

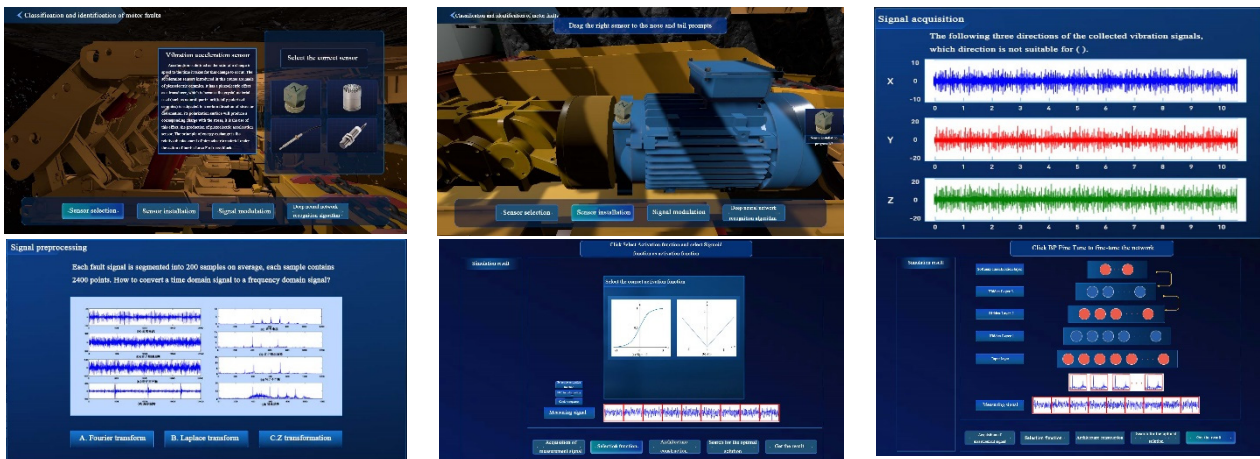


Fig 4. Interactive operation interface of scraper conveyor motor fault classification and identification experiment

3.5. Reducer Compound Failure Separation.

This experiment reducer fault diagnosis method using vibration acceleration sensor identification, students by

choosing to use the vibration signal collector to collect vibration signals, obtained by the fault gearbox time domain waveform. Experimental system pop-up time domain spectrum of the collected composite signal, students select the

correct signal separation algorithm for the ‘gearbox composite fault separation modulation’. Based on the results of the composite fault separation, the students compare and select the components that are likely to fail. The signal is subjected to a blind source separation algorithm to obtain two main signal components. The intermediate shaft rotational frequency of 2.44 Hz (theoretical value 2.54 Hz) can determine that a gear on the intermediate shaft has a fault. The second major fault frequency is 91.41Hz, the comparison shows that this value is similar to the third pole meshing

frequency of 91.35Hz, which can be judged as a fault in the pinion gear of the intermediate shaft. The main fault frequency is 13.67Hz and its harmonics, and the comparison shows that the value is similar to the bearing inner ring fault frequency of 13.78Hz, which can be judged as the bearing inner ring fault. Students are familiar with the algorithm that should be used to separate the compound faults of the gearbox in the experiment, and master the mechanism of the blind source separation algorithm.

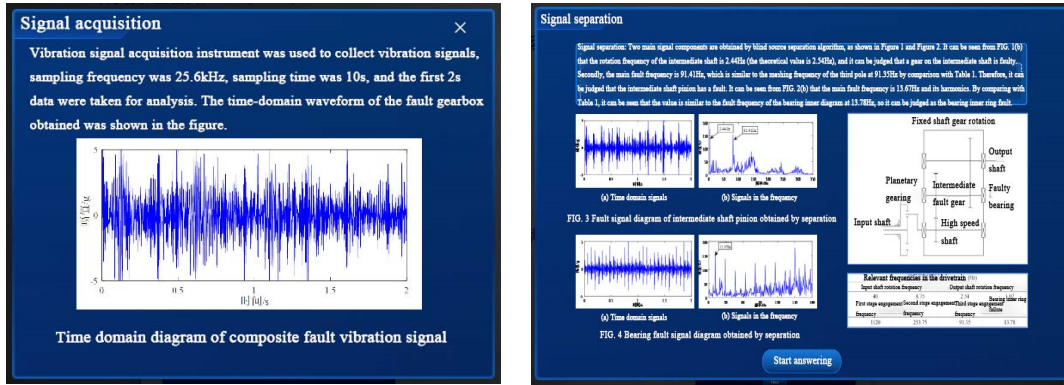


Fig 5. Scraper conveyor gearbox compound fault separation monitoring interface

4. Experimental Teaching Process

This experimental teaching adopts the three-stage teaching strategy of pre-course preparation, in-class experiment and post-course evaluation. Students in the pre-course independent study and design experiments related to the fault diagnosis process and fault classification, composite fault separation principle, the teacher in the class through the knowledge of the explanation, on-site or online guidance,

group discussion and other ways to guide the students experiments; post-course organization of the students online and offline works of mutual evaluation, the teacher summed up and commented on the design works. The three-stage teaching process runs through teacher-student and student-student interaction. The whole experimental teaching process is shown in Figure 6.

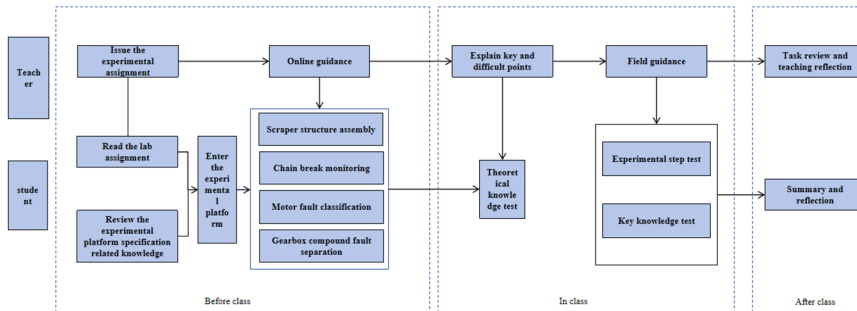


Fig 6. Flow chart of experimental teaching process

5. Experimental Teaching Methods

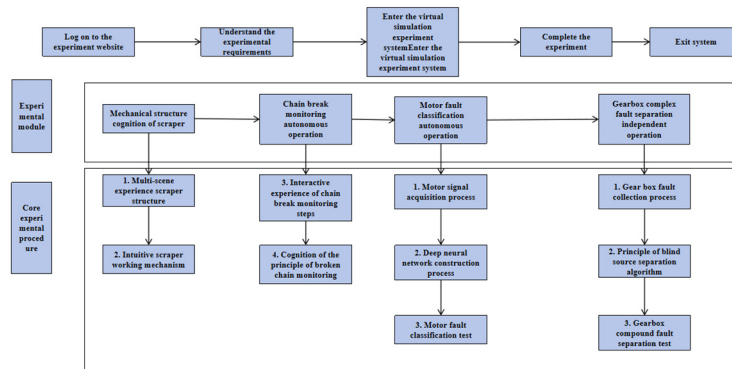


Fig 7. Analysis diagram of the experimental method of the virtual simulation system

As a comprehensive experiment, it aims to train students to apply and understand the knowledge they have learnt, and focuses on their practical engineering ability. In the experimental process, students should be good at establishing two 'links', one is the intrinsic link between the knowledge of the various courses within the discipline of mechanical engineering; the second is the link between the knowledge of the discipline and the task objectives, the knowledge of each subject is systematized, and finally, the theoretical knowledge is applied to the specific experimental planning. To make full use of the advantages of virtual simulation experiments, fast, modifiable, repeatable, good at 'trial and error' in the exploration of experimental planning rules. The experimental system mobilizes the enthusiasm and initiative of students to carry out experiments, so that students can design their experiments and operations while mastering the basic knowledge. The experimental method is shown in Figure 7.

6. Summary

This experimental system is designed and developed based on the operating environment of the scraper conveyor in the comprehensive mining face, and makes use of augmented virtual reality teaching resources to guide the students to carry out virtual teaching experiments based on mechanical cognition of the scraper conveyor chain breakage monitoring, motor fault classification and identification, and intelligent fault diagnosis technology such as the separation of complex faults of the reducer, etc., by using the immersive display and interactive operation experiments. The experiment is student-centred, and the guided teaching process is carried out through the immersive display and interactive operation of the experimental platform, and the students can share the experimental resources on the PC or master the knowledge and skills in the virtual environment of the coal mine in the laboratory through the VR technology, which is a breakthrough in the traditional teaching method. After the completion of the experiment, random questions, on-site practical exercises, the degree of knowledge mastery of the students to assess, improve the students' comprehensive application of knowledge and the ability to practice and innovation, to solve the teaching problem that students are difficult to systematic learning and experimentation in the dangerous environment of the real mine.

At present, the scraper conveyor condition monitoring and fault diagnosis virtual simulation experimental system has been used in mechanical engineering and mining engineering and other professional mining machinery, mine transport and hoisting, electromechanical transmission control and electromechanical integration system design and other professional core courses teaching, for the 'mining machinery', 'mechanical fault diagnosis', 'mechanical vibration and control' and other related courses teaching to provide mine high-risk environment comprehensive and strong, fault diagnostic technology systematic, innovative, high complexity of the typical experiments, significantly improve the level of teaching and training for the intelligent construction of coal mines, the basic theories of the solid, follow the development of the forefront of science and technology of the comprehensive and innovative talents.

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