Teaching Cases Analysis of Integration of Electromechanical Control of Linkage Mechanism

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Abstract. In the teaching design of electromechanics integration for mechanism, three designs (machinery, motor and control) work in parallel. Before the mechanical team completes the design, the motor and control team needs to obtain information about the machinery in advance. The integrated teaching of the three elements of machinery, motor and control of the planar linkage mechanism is discussed in this article, creating an enhanced environment for electromechanics integration in teaching mechanism combining the virtual simulation and physical production, integrating the five aspects of design, simulation, control, manufacturing and testing, therefore establishing an innovation model of mechanical principles of research and exploratory type teaching, problem-oriented learning-type teaching.

Keywords. Planar linkage mechanism; teaching; simulation

1. Introduction
The teaching of mechanical principles is a professional basic course with prominent comprehensive, applicable, practical, theoretical and practical nature. It is provided mainly oriented at students majoring in mechanics and relative mechanical specialty, and plays the role of a connecting link between the preceding and the following. The teaching of mechanical principles requires students to master the basic theories of mathematics, mechanics and engineering science, as well as professional knowledge of mechanical engineering, and to use them for solving complex engineering problems such as the analysis, design, and control of motion machinery[1]. During the teaching design of mechatronics-oriented mechanism, three designs (mechanism, motor and control) work in parallel. Before the mechanical team completes the design, the motor and control team needs to obtain information about the machinery in advance. The mechanical information can be provided by virtual prototype technology in advance. An enhanced environment for electromechanics integration combining virtual simulation and physical production, to explore the formation of a "five integration" teaching system. Therefore, an innovative model of mechanical principles focusing on research and exploration type teaching and a problem-oriented learning model is created[2].

2. 3D design and 3D physical production of planar linkage mechanism for knowledge engineering
How to effectively combine the concepts of components and parts, as well as mechanism diagrams and mechanism design drawings independently but organically, is worth exploring to form an integrated teaching method in the teaching process of mechanical principles. In the mechanism diagram, regardless of the shape of the component, the component is represented by a simple line specified by the national standard, such as pantograph movement diagram as shown in Figure 1. The pantograph is the electrical equipment with which the electric locomotive receives electric energy from the overhead lines which is installed on the roof of electric locomotive. Therefore, a pantograph
needs to be designed to link the power grid with locomotive and maintain the good operational stability. When the pantograph is raising, the speed should be slower when it is close to the wire, and when the pantograph is retracting, the speed should be faster. This may avoid the bow head and wires being burned by high-voltage arcs formed between the pantograph wires, resulting in affecting the contact performance of the bowstring. The pantograph should respond quickly to the motive power, and the power grid of the railway is changing, so the height of the pantograph also changes accordingly during the whole process of operation of the locomotive. The pantograph needs to react quickly and maintain stable contact during operation.

Based on the knowledge template of 3D design, the skeleton is created in combination with the shape features, constraints and geometric characteristics of the existing mechanical 3D design model, with the mechanism motion diagram taken as the skeleton definition in this paper. The skeleton and curved surface-oriented components are created through the design model based on component to realize the design model resulted from the component instantiation technology, so as to adapt to the rapid change of component shape in the teaching process, as shown in Figure 2.

![Figure 1. Diagram of pantograph movement](image1)

![Figure 2. Features of component geometry level](image2)

Static teaching aids and computer virtual simulation teaching strengthen students' understanding of movement trajectories and movement principles to a certain extent, which are often the key and difficult points of classroom content. Therefore, when the isolated solid-state teaching aids and virtual simulations don’t meet the actual learning needs of students, its own teaching methods needs to be improved for the teaching of the planar linkage mechanism [3].

When carrying out the teaching, scissors, rivets, teaching requirements and teaching examples
necessary for making a planar linkage mechanism shall be provided for students, and the cardboard or plywood shall be prepared by students themselves, to make the real planar linkage mechanism. Through changing the length of the original moving parts or components, the students draw the motion trajectory of the planar linkage mechanism, draw the crank angle between extreme positions and the dead center position according to the actual object, master the quick-return movement, and master the existence conditions of the crank. Combined with walking mechanism of Chang'e-4 and Chang'e-5, deploying mechanism of solar windsurfing, lunar sampling mechanism, the application of mechanical principles in my country's deep space exploration and the latest achievements in my country's aviation industry are introduced. 3D printing technology is introduced into the teaching of mechanical principle courses, through the instant design and manufacturing of the organization, students are required to have an intuitive and clear understanding of the structure of the mechanism[4]; at the same time, the need to prepare teaching props and single teaching aids in advance shall be overcome during the traditional teaching process. While printing the mechanism, according to the operation needs of the actual mechanism, it is guaranteed that the movement of the mechanism is realized through the driving device and the control system after making the teaching aids by 3D printing. The physical production of typical planar linkage mechanism is carried out by team work using the aforementioned three-dimensional design results of the planar linkage mechanism, and the analysis method of the linkage group split and kinematics analysis is mastered, as shown in Figure 3.

![Figure 3. 3D printed full hinge four-bar mechanism and its components](image)

3. Virtual motion simulation of planar linkage mechanism and parameter extraction of electromechanical control device

Through the analysis of the teaching content of the mechanical principle of the typical full hinge four-bar mechanism, the corresponding teaching content of structure, kinematics and dynamics is integrated into the mechanism motion simulation process, and the kinematics and dynamic parameters are extracted based on the mechanism simulation. This allows students to systematically constructing a knowledge system of mechanical principles instead of learning new knowledge from knowledge points shown by the traditional teaching animation, so as to stimulate students' curiosity to master mechanism simulation through real structural design, kinematics and dynamics simulation. The kinematical diagram of the pantograph shown in Figure 1 is a hinged four-bar mechanism with simple structure, which is easily processed and operated for the desired movement. The transmission angle of this mechanism is greater than 30°; through ADAMS simulation analysis, the trajectory of Point P deviates from the idealized vertical straight trajectory, which is less than 100 mm, as shown in Figure 4[5].
Due to the constraint of the traditional teaching mode, the effective breakthroughs have not been made in the realization of electromechanics integration for the teaching of mechanical principles. The design of the mechanism's driving device and the realization of the control system have always been the key points during the process of teaching mechanical principles. This article introduces a variety of different types of driving devices into the teaching process of the linkage mechanism and its evolution, and develops the corresponding control system, as shown in Figure 6. At the same time, the corresponding control system is designed as an open architecture for students to reproduce outside class. This breaks the students' traditional impressions of many mechanical principles, formulas, concepts, and symbols, and guides students in the reproduction and innovation of the teaching process, cultivates students' interest in learning, as well as the ability to spontaneously discover and solve engineering problems.

Virtual parameter collection can be completed through motion simulation. A variety of sensors can be used to complete the start-stop control, position control of the actual mechanism, and acquisition of the angular velocity, velocity, force and other parameters of the real mechanism, and
compare them with the virtual simulation results, as shown in Figure 7[6]. Through the research of this article, the traditional teaching method by which only the mechanism motion parameters (linear displacement, linear velocity, linear acceleration, angular displacement, angular velocity, rotational speed, angular acceleration) are mastered is broken through in the teaching process, and the mechanism design, simulation analysis, and physical parameter analysis are integrated with the teaching process completely.

**Figure 7. Acquisition of mechanism parameters**

4. Conclusions
Taking the kinematics of the planar linkage as the main line, a theoretical analytical formulas for the displacement, speed, acceleration and other parameters of the planar linkage is established in the theoretical course. In real life, a dynamic evolution curve of each parameter of the mechanism is revealed through 3D printing of the manufactured material object based on cardboard and 3D design, drawing kinematics curves, introduction of learning curve and information technology into practical courses to make animation of mechanism movement diagrams. The mechanically movable 3D printing mechanism is combined, to test the actual dynamic evolution curve of each parameter of the mechanism through sensors and computer-aided testing systems; the difference between theoretical and actual dynamic evolution curves are compared and analyzed, and the causes of errors are analyzed. In the end, the cultivation of the following comprehensive innovation and entrepreneurship abilities is realized, such as the abilities of innovation, practicality, comprehensive analysis and problem-solving ability, mastery of modern institutional virtual design and modern testing technology.

Acknowledgment
This article was funded by the teaching research and reform project of Southwest Jiaotong University's undergraduate education "The five-integrated teaching exploration of the electromechanical system of the linkage mechanism, No. 1903058".

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