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Teaching Experiment in Engineering Mechanics Based on Simulation Technology: A Case Study

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Abstract: This paper explores the integration of simulation technology in Engineering Mechanics (EM) teaching in vocational colleges. A case study was conducted using the tensile test as an example, and digital resources, such as colored Mises stress nephograms, were obtained. These resources were integrated into the original curriculum to conduct teaching experiments. The results show that the use of digital resources significantly improved the quality of teaching in EM. The integration of simulation technology in EM teaching provides a promising direction for the improvement of vocational education and the cultivation of high-quality skilled talents. The development and application of more simulation-based teaching cases should be studied by scholars.

Keywords: Engineering mechanics; Simulation technology; Teaching experiment; Teaching; Vocational education

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1. Introduction

Vocational education plays a crucial role in cultivating high-quality skilled talents and contributing to industry and economic development [1]. However, traditional teaching methods in vocational colleges face challenges such as lack of student engagement, limited practical relevance, and insufficient development of experimental skills [2]. Thus, exploring innovative approaches to enhance teaching quality becomes imperative. Engineering Mechanics (EM) is widely applied across industries, yet its teaching in vocational colleges has long been subpar due to abstract concepts, complex formulas, and intricate experiments. Visual resources like animations, videos, and illustrations prove valuable in helping students grasp unfamiliar concepts. While early researchers have made significant contributions to improving EM teaching [3-10], research on digital resources remains scarce.

Finite element technology (FET), widely used in aerospace and automobile manufacturing for simulating and analyzing complex engineering problems [11,12], offers potential for educational application, particularly in teaching EM [13,14]. This paper presents a case study using a tensile test as an example. We integrate FET-derived digital resources into the curriculum and analyze their impact on EM teaching. Our objective is to explore innovative methods that can substantially enhance teaching quality in vocational colleges.

2. Challenges in teaching

EM provides the theoretical foundation for understanding and solving practical engineering problems. However, traditional EM teaching faces challenges. One is a lack of student interest as EM involves abstract concepts and formulas, which can make lessons boring without practical links. As a result, motivation and comprehension may decline over the course.

Another challenge is insufficient connection to engineering practice. After-class exercises aim to consolidate learning but domestic textbooks often present modular problems disconnected from applications. It limits applying theory to practical problems. Attention to mechanics experiments is also lacking.

Experimental courses develop skills, hands-on abilities, and innovative thinking. However, vocational colleges devote inadequate emphasis and class hours to experiments. Adopting traditional verification modes restricts independent exploration and interest.

Effective assessment and teaching monitoring methods are also necessary. This impacts personal development. In short, digital resources offer an important solution by visualizing abstract EM concepts. This research actively integrates finite element technology simulations. Resources like colored stress nephograms help students understand experiments, improving teaching quality in vocational colleges.

3. Teaching experiment

To address the challenges in the teaching of EM, this paper proposes an innovative teaching approach based on simulation technology and conducts a teaching experiment. We use the metal tensile test as an example to carry out the experiment.

3.1. Application of simulation technology

We developed a model using simulation technology and obtained digital resources represented by Mises stress graphs. **Figure 1** illustrates the FET-based mesh refinement finite element model. The model consists of rigid bodies at both ends, preventing any deformation. One end is fixed, while the other end is subjected to an axial load. Our objective is to analyze the stress distribution, stress concentration, necking, and fracture phenomena of the specimens at different time intervals. The model was simulated on a server, yielding a comprehensive dataset along with corresponding nephograms. **Figure 2** and **Figure 3** depict the Mises stress cloud images at different time intervals.

In the Mises stress nephograms, higher stress levels are represented by a redder color, while lower stress levels are depicted by a bluer color. In **Figure 2**, during the initial stage of the test (t = 4.5 s), the stress distribution within the sample became non-uniform. The stress in the middle region of the sample was significantly higher than at both ends, with a maximum Mises stress of 64.8 MPa. As the experiment progressed, the stress levels continued to increase, leading to a more pronounced stress concentration. At t = 7.5 s, the necking phenomenon in the middle region of the sample became more evident, resulting in an uneven stress distribution on the sample's surface, as shown in **Figure 3**. Finally, at t = 10.5 s, a crack formed in the middle of the sample, as depicted in **Figure 4**. These digital resources provide students with a convenient means to comprehend the stress distribution, necking, and cracking behavior of the sample during the tensile process.

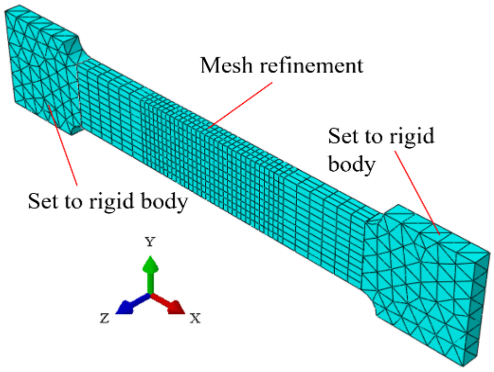

Figure 1. Finite element model after mesh division

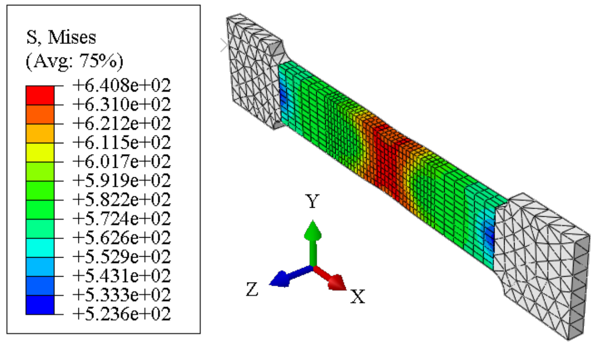

Figure 2. Mises stress nephogram with $t = 4.5$ s

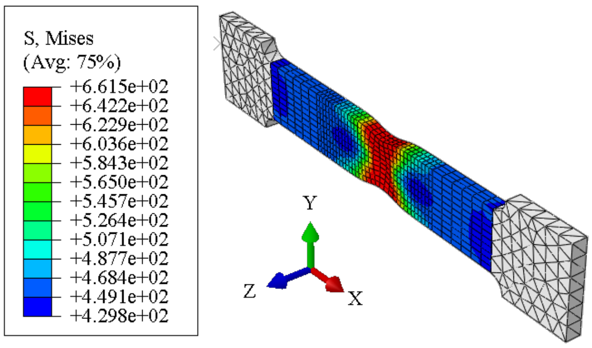

Figure 3. Mises stress nephogram with $t = 7.5$ s

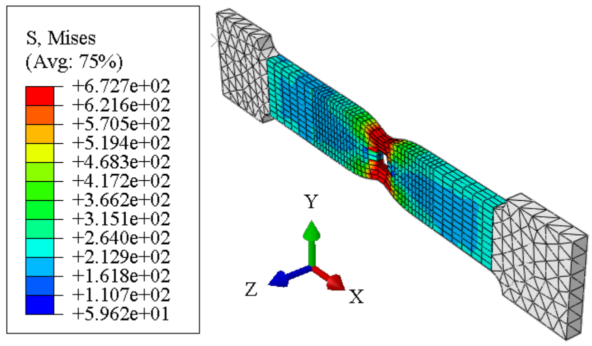

Figure 4. Mises stress nephogram with $t = 10.5$ s

3.2. Teaching evaluation

To evaluate the effectiveness of using color nephograms to help students understand the distribution of stress and deformation, we conducted a teaching experiment involving a total of 56 students in two classes. The students were asked to fill out a questionnaire with five questions. The survey questions are shown in **Table 1**. The questionnaire was multiple-choice, and students were given three options: agree, disagree, and neutral.

Table 1. Questionnaire survey on teaching evaluation

Number	Survey questions
Q1	Does the color stress nephogram help you understand the stress distribution of aluminum alloys when they are stretched?
Q2	Does the color stress nephogram help you understand the stress concentration, necking, cracking, and other behaviors of the sample?
Q3	Do you think this class is more interesting?
Q4	Do you hope to introduce more new technologies (such as FET) in your mechanics courses in the future?
Q5	Overall, are you satisfied with this teaching experiment?

3.3. Results

After the teaching experiment based on simulation technology was completed, we conducted a statistical analysis of the survey results of the students, as shown in **Figure 5**.

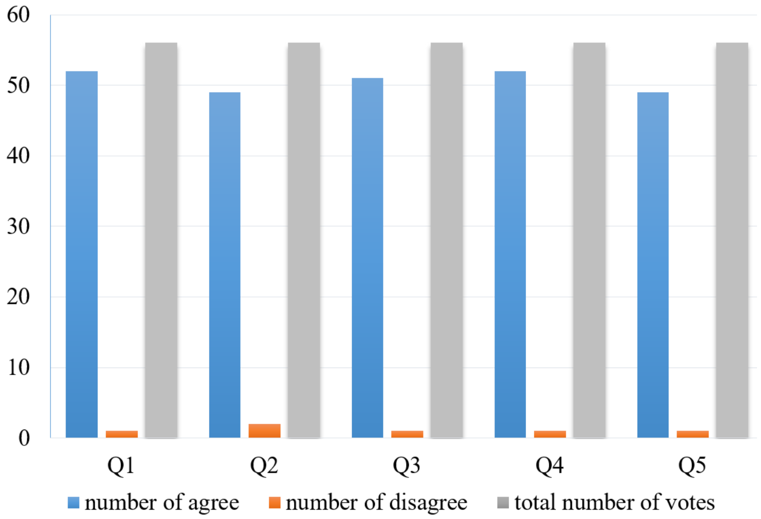

Figure 5. Evaluation results of teaching experiments

From **Figure 5**, we can see that students hold a positive attitude toward the innovation of FET-based teaching models. For Q1, 52 students agreed that the color stress nephogram helped them understand the stress distribution of aluminum alloys when they are stretched. Only one student disagreed, and three students were neutral. For Q2, 49 students agreed that the color stress nephogram helped them understand the stress concentration, necking, cracking, and other behaviors of the sample. Two students disagreed, and five students were neutral. For Q3, 51 students agreed that the class was more interesting. Only one student disagreed, and four students were neutral. For Q4, 52 students agreed that they hoped to introduce more new technologies, such as FET, in their mechanics courses in the future. Only one student disagreed, and two students were neutral. For Q5, 49 students were satisfied with the teaching experiment. Only one student was dissatisfied, and six students were neutral. Overall, the results of the questionnaire indicate that the use of color nephograms has a positive effect on students' understanding of EM concepts, and students are interested in the integration of new technologies such as FET in their mechanics courses.

4. Conclusions

This study integrated FET simulations into EM teaching. A tensile test utilized FET-generated digital resources like colored stress nephograms. Experiments validated incorporating these resources improved instruction. Results showed FET content significantly enhanced teaching quality. Stress nephograms aided students' understanding of complex concepts. Students welcomed new technologies and provided positive feedback on the benefits of FET. In conclusion, applying FET promotes quality vocational EM education. This research guides the utilization of FET, notably for EM. Combining FET with problem-based learning and analyzing outcomes may optimize teaching and learning. Continued exploration of innovations aims to strengthen standards and cultivate skills. Ultimately, FET advances vocational education by enhancing instruction and competencies.

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Disclosure statement

The author declares no conflict of interest.

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