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Challenges and Countermeasures in the Teaching of Material Mechanics in Vocational Colleges

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Abstract: Material Mechanics is an important subject for science and engineering students in vocational colleges. However, its teaching effect has not been up to par for a long time. In order to improve the teaching quality, this paper discusses four problems existing in the teaching of Material Mechanics and proposes corresponding countermeasures. Rich animations and Mises stress nephograms can be formed using new techniques, such as finite element simulation, making it easier for students to understand abstract concepts. The introduction of engineering-related cases can enhance students' interest, and students' hands-on skills and innovation can be improved with open mechanics laboratory. The suggestions are worthy of reference and should be flexibly applied to the teaching of Material Mechanics.

Keywords: Material Mechanics; Teaching; Vocational colleges; Vocational education; Countermeasures

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1. Introduction

Material Mechanics has important applications in civil engineering, mechanical engineering, mining engineering, and other professional fields. It is an important subject in engineering colleges, playing an important role in cultivating scientific quality, engineering quality, and innovation skills [1-3]. With the rapid development of vocational education, the curriculum setting and credit hour allocation of vocational colleges have undergone significant changes. The teaching hours of Material Mechanics have been shortened, but its teaching content has not been reduced; moreover, there is not much of an improvement in its teaching methods. The traditional teaching system has revealed a great deal of absurdity in this context. For instance, the teaching framework of Material Mechanics is primarily based on undergraduate colleges, and its teaching content is overly broad, all-embracing, and theoretical. Vocational college students, unlike conventional undergraduates, have poor learning capabilities, particularly in areas of theoretical deduction and arithmetic. Too many complicated theoretical derivations and calculations make the subject extremely tedious and difficult to stimulate interest in students [4-6]. For a long time, there has been a dearth of mechanics experimental equipment at vocational institutions, and experimental Material Mechanics training has received little attention. These are some of the challenges in learning the abstract concepts of Material Mechanics. Many students are unable to learn and comprehend the mechanical properties of different materials even with the help of experiments. In short, the traditional teaching method of Material Mechanics can no longer meet the educational needs of current vocational education; therefore, it should be explored and reformed.

The rapid development of information technology and digital technology provides technical support for the reform of teaching content and teaching methods in vocational colleges [7-12]. For instance, finite element and other technologies can simulate intuitive animations and stress nephograms, which is convenient for students to gauge abstract concepts, such as stress concentration, necking, and instability. The application of these new technologies not only improves the learning efficiency and quality of students, but also reduces the pressure faced by teachers.

On the one hand, there is much irrationality in the traditional teaching system; on the other hand, the development of new technologies provides technical support for the reform of vocational education. In this context, systematically identifying the challenges existing in the teaching of Material Mechanics in vocational colleges and proposing targeted countermeasures are highly worthwhile for research.

In consideration of the actual teaching situation in vocational colleges, this paper expounds some problems existing in the teaching of Material Mechanics, and in view of these problems, corresponding countermeasures are put forward.

2. Existing problems

It is necessary to systematically identify the challenges faced by Material Mechanics in vocational colleges. The research team consists of frontline teachers with years of teaching experience. They have carried out extensive discussions on the teaching quality of Material Mechanics and discovered four issues.

2.1. A dull teaching process that fails to stimulate students' interest

Material Mechanics is a subject with strong applicability. In the course of teaching, teachers should not only pay attention to imparting theoretical knowledge, but also cultivating students' skills to solve practical engineering problems [13]. As this subject has many concepts and formulas, involving a large number of mathematical derivations, its teaching content is dull, and it is difficult to stimulate students' interest. In addition, students lack internship or industrial field research experience, as well as the understanding of the subject's purpose and enthusiasm to learn. The teaching of Material Mechanics involves bending of beams, torsion of shafts, combined deformation of bending and torsion, etc. Teachers have to perform mathematical calculations and draw stress diagrams as well as torque diagrams on the blackboard based on the results. If the students are not paying attention, they will not be able to keep up with the lectures. After-class tasks are likewise difficult and thorough, requiring a significant number of mathematical computations. Students generally lack enthusiasm and the drive to learn due to their poor computing skills.

2.2. Stereotypical textbook assignments

After-class assignments further consolidate and improve the classroom content. The assignments from local Material Mechanics textbooks are too stereotypical and far from practical engineering application. In some textbooks, the assignments only modify the data of known examples. These assignments are generally for the students to review the formulas as they play a very limited role for understanding a knowledge point. They have little connection with practical engineering problems, which is another common issue. The research team carried out a survey on the graduation designs of junior college students and found that nine out of 33 students were unable to design the diameter of a drive shaft based on engine torque output (or safety check). With an aim of cultivating applied talents, the goal of teaching Material Mechanics in vocational colleges is to enable students to master basic principles and methods of mechanical analysis and be able to use relevant theories to solve practical problems. It is clear that the students' practical skills and the capabilities to apply theoretical knowledge to solve practical problems have not been well exercised and developed.

2.3. Extreme teaching goals

There is a certain gap in terms of the quality of students between vocational colleges and ordinary undergraduate colleges. Vocational colleges frequently relate to undergraduate institutions when setting teaching objectives. Since students in vocational colleges have a weak foundation in basic subjects, such as mathematics and physics, in addition to weak computing and analytical skills, it is difficult to achieve high teaching objectives. In order to complete their teaching tasks in class, teachers have to make quick progress in teaching. Students generally feel that the content is not easy to understand and digest, and that it is a challenge to complete their homework after class. The knowledge system of Material Mechanics echoes back and forth, with the front content serving as the basis of the back content. The effectiveness of the following class's teaching is influenced by the quality of homework completed after class. This forms a vicious circle, where teachers are under more pressure, while students find it more difficult to learn. In short, appropriate teaching objectives that fully consider the characteristics of talent training in vocational education should be formulated.

2.4. Insufficient attention to mechanics experiment

The experimental course of Material Mechanics has two purposes. First, it improves students' experimental skills and enables students to master the basic knowledge, experimental methods, and techniques of mechanics experiment. Second, it cultivates students' practical skills and innovative spirit, as well as improves their capabilities to analyze practical engineering problems. However, vocational colleges do not emphasize much on the experimental side of Material Mechanics, in which the proportion of class hours occupied by the experimental side is negligible. The research team conducted a questionnaire survey on several graduates. The findings of the study suggested that students have not mastered the basic operation of mechanics experimental equipment, and they still need to consult books and relearn if they wish to carry out mechanical tests on a certain part.

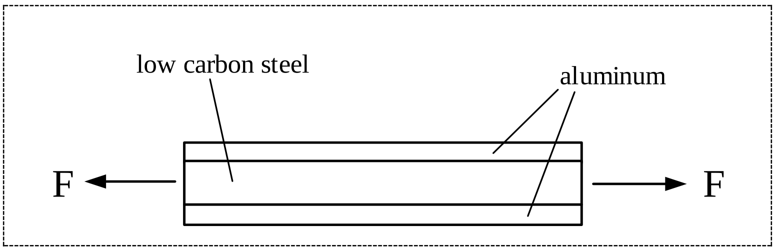

Figure 1. Specimen of composite layer for tensile test

Mechanics experiment is a traditional teaching method based on verification; that is, to verify the accuracy and authenticity of a formula via experiment [14-17]. As a result, students lack the opportunity to explore independently, and their ideas cannot be verified through experiments. Students can, for example, use tensile testing to discover that aluminum has a lower tensile strength than mild steel. Some students may come to envisage the tensile characteristics of aluminum and low carbon steel composite plates (as illustrated in **Figure 1**). The experimental conditions are available, however owing to the laboratory management system and the difficulties of reimbursement of samples, only some teachers encourage students to undertake experiments for exploration. In short, mechanics experiment receives insufficient attention, its teaching method is too conventional, and students' thinking capacity cannot be sufficiently strengthened.

3. Countermeasures

3.1. Apply new technologies such as finite element simulation

The finite element software has a very powerful post-processing function, which can be used to display Mises stress nephograms and animations of stress, strain, deformation velocity, and other variables during material deformation [18,19].

Finite element modeling and simulation have been used in teaching by the research team. Abaqus software has been used to model and a large number of Mises stress clouds have been simulated. These materials have been applied to teaching experiments, and good teaching results have been achieved.

The necking and fracture of tensile experiments have always been perplexing for students. Students are unable to visually appreciate the stress or strain distribution of the sample with necking during mechanics experiments. Therefore, their understanding of material deformation and fracture is not deep enough. The abundant stress nephogram data obtained from the finite element model can solve this issue. **Figure 2** shows a Mises stress nephogram of the model during necking and fracture of a sample under tension. In **Figure 2**, the Mises stress nephogram is colored to show the difference of stress values at different positions of the sample. The more the color tends to blue, the smaller the Mises stress. On the contrary, the more the color tends to red, the greater the Mises stress. In addition, the rich data also facilitate students to understand the deformation law of the sample under external load. The data in **Figure 2** reflect the numerical statistics of Mises stress in different areas of the sample under different external loads.

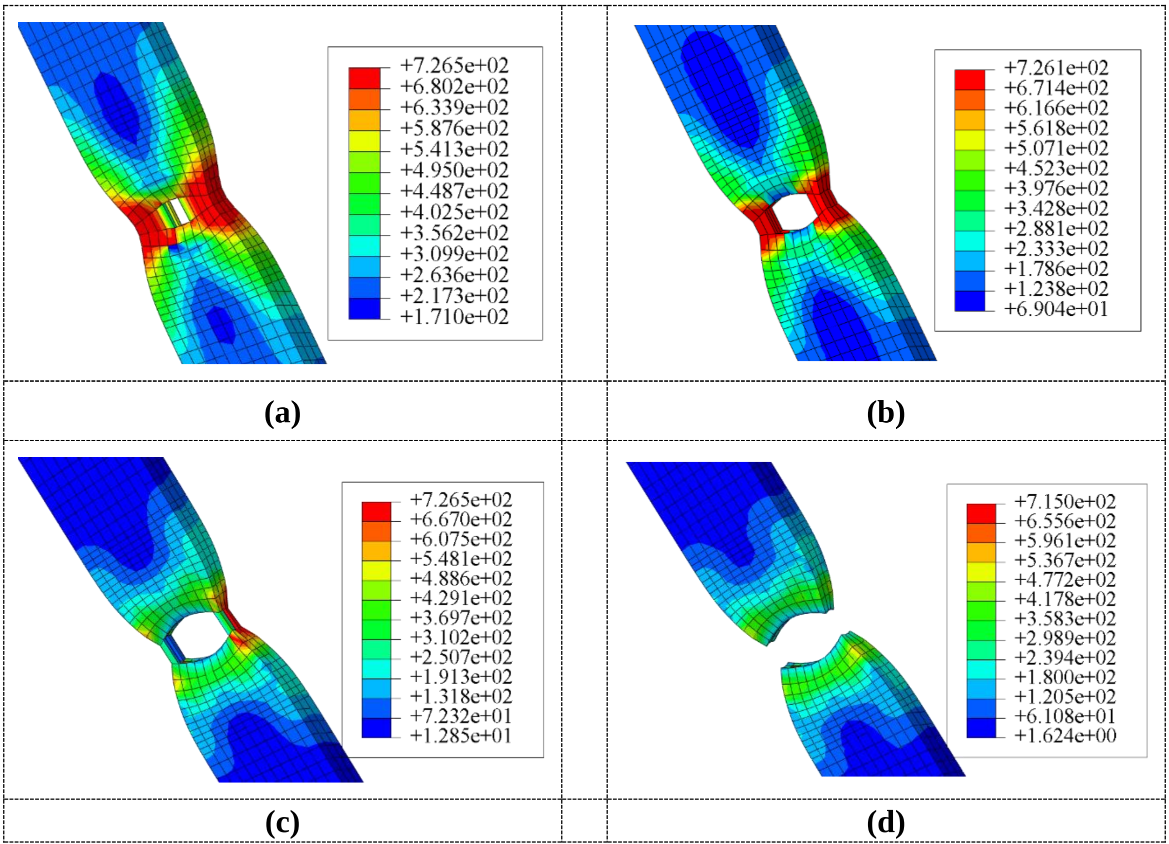

Figure 2. Necking of the finite element model; **(a)** t = 9.75 s; **(b)** t = 11.25 s; **(c)** t = 12.75 s; **(d)** t = 13.5 s

Similarly, the research group also carried out a finite element modeling and simulation of a torsion experiment. **Figure 3** shows the stress distribution of the shaft under torque.

Teaching practices have shown that finite element simulation can stimulate students' interest in learning, as well as deepen their understanding of abstract and complex mechanical behaviors. It can be seen from **Figure 3** that under the action of torsional couple, there are obvious differences in stress distribution at different positions from the axis. The stress value is greater as it moves further away from the axis, and vice versa. The depiction of finite element stress nephogram is easily accepted by students compared to the formula derivation in the textbook.

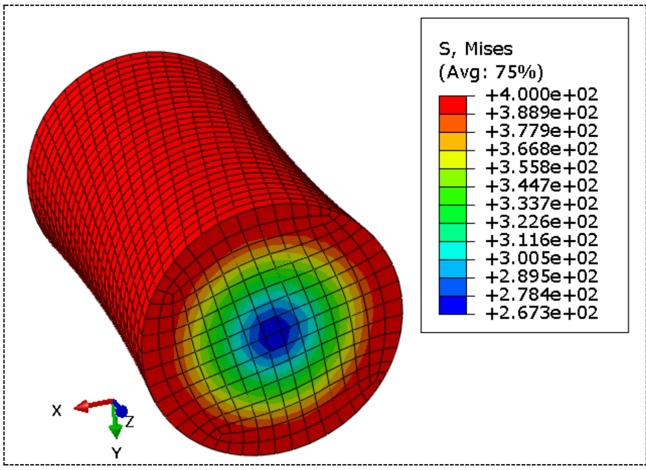

Figure 3. Finite element analysis of solid shaft under torsional action

3.2. Introduce engineering cases to enhance learning interest

The introduction of typical engineering cases can emphasize the importance of Material Mechanics, attract students' attention, and enhance their interest in learning. As an example, clips of hitting icebergs and sinking ships in the film "Titanic" can be used for discussing a case when analyzing the brittleness of materials. By analyzing the mechanical properties of the remains of hull steel, experts found that the steel changes from plasticity to brittleness at a very low temperature. In this way, the hull is liable to fracture under small load impact. In view of the brittle fracture, the Titanic sank into the Atlantic with more than 1,500 people on board. What a painful lesson it was. The introduction of video clips into the teaching content intangibly instills the importance of the course among students. In Material Mechanics, materials with a deformation rate of more than 5% are regarded as plastic materials, while those with a deformation rate of less than 5% are regarded as brittle materials. Combined with the film, students will gain an in-depth understanding that the deformation resistance of brittle materials is far lower than that of plastic materials. The introduction of engineering cases will not only enhance students' interest in learning, but also emphasize the importance of this course [20]. Taking the automobile major as an example, integrating the design of automobile key parts into teaching may produce more beneficial teaching effects. For example, Ferrari and other high-end sports vehicles not only offer a stunning aesthetic ordeal but also a high level of safety. These safety designs are inseparable from the basic theory of Material Mechanics. What elements should be considered in the design and processing of shafts with large torque output? With these problems in mind, the teaching effect will be much better when teachers explain theoretical knowledge in conjunction with actual images.

3.3. Keeping the laboratory accessible

Mechanics experiments in vocational colleges are currently conducted as classes, and students are given a certain time to perform experiments. This kind of setting limits students' autonomy. Keeping the laboratory open all day long from Monday to Friday will be beneficial to students. During this period, they can make appointments with laboratory teachers or their own classroom teachers to take part in innovative experiments independently based on their understanding of certain knowledge points and learning schedule. However, in carrying out experiments, teachers should be present to provide guidance and supervision, so as to deal with unexpected issues that may occur in the process and ensure the safety of students. The research team aided several students who participated in the Beijing College Students' Mechanical Design Competition the previous year as the mechanical properties of several key parts of the entries needed to be measured experimentally.

The research team dealt with the person-in-charge of the laboratory and guided the students in testing the mechanical properties of some parts of the entries. This mechanical property testing of the entries is an active behavior in contrast to the traditional mechanics experiment teaching. The students initially put forward the test requirements and formulated the experimental scheme. They completed the experimental operation and data analysis by themselves. The use of the laboratory accelerated the production progress of the entries in the competition and improved the students' practical skills. As known to all, the talent training in vocational education is oriented to skilled and applied talents. In contrast to the learning of theoretical knowledge, the cultivation of skilled and applied talents is inseparable from corresponding experimental equipment. Open laboratories are common in foreign universities and local research institutes. However, the accessibility of laboratories is far from enough in vocational colleges.

4. Conclusion

Materials Mechanics is an important basic subject for many majors in engineering colleges. It plays a crucial role in laying a professional foundation and cultivating professional quality among students. Through Material Mechanics, students will be able to master basic theoretical knowledge and the methods of mechanical analysis. In addition, students will also be able to integrate what they have learned to simplify practical engineering problems into mechanical models, establish mathematical equations, and use numerical analysis results of equations for practical problems to evaluate the size of parts or mechanical structure. In order to improve the learning effect of students, this paper makes an in-depth analysis on the problems existing in the teaching of Material Mechanics in vocational colleges, and proposes several countermeasures. This study concludes that frontline teachers should further reflect on the aforementioned problems and improve the teaching quality of Material Mechanics. The countermeasures suggested in this paper are worthy of practice in teaching.

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Disclosure statement

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