Application of CAE technology in the experimental teaching of metal tension and compression

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Abstract. Metal tensile and compression experiments suffer from the problems of little equipment and large errors in experimental operations. Students are instructed to use CAE techniques to model and analyze the simulation of metal tension and compression experiments. The stresses and strains in each part of the metal are analyzed and patterns and influencing factors are obtained. Laboratory teaching content is linked to specialized software to increase students' interest in learning. CAE simulation software helps students improve their ability to design and analyze problems for subsequent professional courses, competitions, and projects.

Keywords: Metal Stretching, Metal Compression, CAE Technology, Pedagogical Application.

1 Introduction

Metal tensile and compression experiments is engineering mechanics, mechanical foundation, mechanical engineering materials, and other courses within the classroom experiments, and experiments for all mechanical students. Tension and compression experiments are a combination of classroom theory teaching and experimental teaching. The metal stretching and compression experiment can cultivate students' practical ability and improve their ability to apply what they have learned to solve professional problems[1]. A demonstrative approach to teaching metal stretching and compression experiments is used due to the large size and high acquisition cost of the materials stretching and compression lab equipment, which consumes metal specimens for each stretching and compression experiment. Students lack opportunities for hands-on experimentation and lack motivation to learn about experiments. Metal tensile and compression experiments require quantitative parameters such as stress-strain curves, stress-displacement curves, etc. obtained from force transducers[2]. When there is a problem with the force transducer or the wrong clamping method, the parameter results obtained are in error from the real results. With the development of computer technology, the emergence of software that uses the computer to simulate the entire process of the experiment. In the software the user can choose the type of experiment,

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such as metal stretching, metal compression, metal torsion, and can choose different kinds of materials for the experiment. When installing the fixture experiment step, click on the picture to complete the installation. This method does not reproduce the entire process of assembling and clamping the specimen, and the student is not aware of the problems that can occur during assembly and clamping and the areas that need attention. Students are not motivated to learn about using simulation software for experiments [5].

This teaching in addition to the original demonstrative teaching, add CAE software simulation tensile and compression specimen modeling teaching. CAE software was used to simulate the tensile and compression specimens and the simulation results were calculated to study the simulation results in comparison with the experimental results. Modeling process requires students to model in three dimensions, define material properties, mesh dissections, define physical fields, and analyze results. The modeling process can be good for exercising students' CAE ability, cultivating students' hobby of learning CAE software, and letting students understand the relationship between CAE and experiment.

2 Metal Tensile and Compression Test

The commonly used metal tensile and compression testers are shown in Fig 1(a). In tensile experiments it is necessary to twist the fixture to clamp the tensile specimen as shown in Fig 1(b). When the clamping force is insufficient, it causes the tensile specimen and the fixture to slip relative to each other, resulting in the tensile experiment not being completed. Students are inexperienced in clamping the first time they do a tensile experiment, which can lead to problems with clamping. When the tensile clamping force is found to be insufficient, the tensile experiment has already begun. The tensile apparatus showed no significant change in force at the same time as the change in displacement, indicating that there was a relative movement between the fixture and the metal tensile specimen piece and the tensile experiment failed [3]. The compression experiment is relatively simple, simply place the compression specimen at the center of the disc in Fig 1(c).

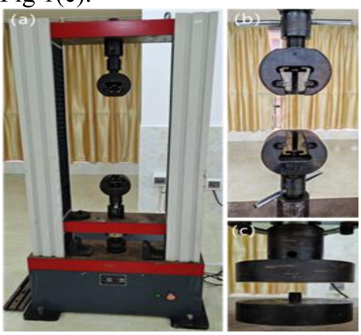

Fig. 1. (a) Tensile compression tester.(b) Tensile fixture (c) Compression fixture.

When the tensile experiment is completed as shown in Fig 2(a), the tensile specimen is mild steel, which is broken in the middle and has an obvious necking phenomenon[4]. The larger radius end of the mild steel ends is the clamping end, and there are clear signs of clamping at both ends. The elongation of the tensile specimen can be observed during the stretching process, and the phenomenon of radius reduction occurs in the middle. The total length of the mild steel tensile specimen is 210mm, the length of the large end is 40mm, the length of the middle equal section is 100mm, the length of the large end is 15mm and the length of the middle equal section is 10mm. Mild steel specimens stretched to 35mm pull off and sound. Mild steel specimens will have an increase in temperature at the point of pulling, so you can have students touch the break with their hands to feel the temperature difference, as well as observe the shape of the break. Fig 2(b) shows the cast iron in compression with cracks inclined at 45° angle. The compression cast iron experiment allows students to understand the problems that can occur during the compression of cast iron [6]. Demonstrations of experiments increase students' interest in learning. The metals commonly used in tensile experiments are cast iron, mild steel, and aluminum. The metals commonly used in compression experiments are cast iron, mild steel, and aluminum. The phenomenon of different metal stretching and compression is different, through the experiment to observe the phenomenon of metal stretching and compression can deepen students' impression of the properties of different metal materials.

Fig. 2. (a) Tensile specimen stretched. (b) Compression specimen compressed.

3 Application of CAE technology to simulate metal tension and compression experiments

CAE (Computer Aided Engineering) refers to the use of computer-aided solutions to practical engineering problems, which can be structural mechanics, electromagnetic, thermal, fluid, and other physical field analysis. The user creates a geometric model in the CAE software, defines the physical fields of the geometric model, meshes the solution part of the geometric model, and finally computes the solution. CAE software improves design efficiency reduces design costs, and is widely used in various fields. Students are introduced to the operation and functionality of CAE software, which involves geometric modeling, physical field definition, meshing, and other operations. Students generally find it difficult to use CAE software for the first time, so finite element analysis of metal tensile and compression models can improve their confidence in using CAE software. The metal stretching and compression geometry is simply modeled without complex assembly relationships and surfaces. There is only one material and one part in the model, so the physical field definition is simple. The simulation results can be compared with the experimental results so that students can identify problematic areas of modeling and modify them. Using CAE software to model metals in tension and compression develops students' ability to use CAE software and improves their ability to solve design problems with finite element analysis. Assist to students in analyzing complex engineering problems in the future.

3.1 CAE Simulation of Metal Tensile Experiment

The students are asked to measure the mild steel tensile specimen with the specimen dimensions shown in Fig 3(a) and geometrically model the specimen in CAE software. Students are required to map the total length of a tensile metal specimen as well as parameters such as the value of the diameter of the large end and the value of the diameter of the isotropic section. Mapping mild steel specimens hones students' mapping skills. Modeling checks the accuracy of the values measured by the students.

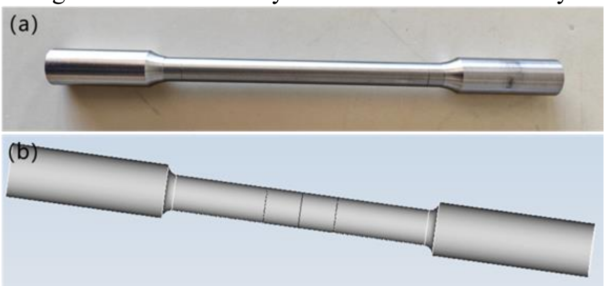

Fig. 3. (a) Mild steel tensile specimen. (b) Geometric model of mild steel tensile specimen.

The metal stretching geometry is modeled as shown in Fig 3(b). Geometric modeling is easy to draw, but it also requires students to have some knowledge of engineering drawing, by drawing sections in 2D and then rotating and stretching them. The process of geometric modeling can develop students' geometric thinking and drawing skills. According to find data the density of mild steel is 7640~8100 kg/m^3, in this study the value of the density of mild steel is selected as 7200 kg/m^3. Mild steel has high plasticity and toughness, relatively low strength and hardness, and is commonly used for tensile testing. The Young's modulus of mild steel is 190~210 GPa and in this study, the value of Young's modulus of mild steel is selected as 200 GPa. The larger the Young's modulus, the smaller the elastic deformation of the material when subjected to force. The Poisson's ratio of mild steel is between 0.27 to 0.3 and in this study, mild steel Poisson's ratio is selected as 0.285. Poisson's ratio describes the ratio of transverse contraction to longitudinal contraction when a material is subjected to unidirectional tension or compression, reflecting the nature of transverse deformation of the material during stress. The determination of the parameters will allow students to understand the importance of Young's modulus determination in university physics experiments, as well as being able to practice their skills in searching the literature on how to find the parameters of mild steel materials. When creating a physical field, it can serve as an exercise for students' specialized knowledge. How to constrain a metal specimen requires knowledge of related courses such as mechanical principles and mechanical design. In the tensile experiment, Fig 3 tensile specimen ends are clamped by Fig 1(b) tensile fixture, the upper fixture is the fixed end not moving and the lower fixture is the downward moving end. Movements in the fixed x, y, and z axes as well as rotations around x, y, and z in six degrees of freedom are performed in the simulation model at the left big end of Fig 3(b). Considering that only the up and down directions were moved in the tensile experiments, five degrees of freedom were carried out at the big end of the right side for the fixed y and z axes as well as for the rotation around x, y, and z, and the movement in the x-axis direction was retained. The deformation of the tensile specimen is investigated by specifying the displacement of the large right end. Considering that the main deformation of the tensile specimen lies in the middle, the meshing density of the middle is chosen to be higher than that of the two ends, so that the accuracy of the calculation results can be balanced with the efficiency of the calculation. Let the students study the effect on the calculation results by adjusting the grid size of the tensile metal specimen to cultivate their spirit of inquiry. Solve the calculation can be obtained as Fig 4 tensile specimen simulation results. Necking of the metal tensile specimen subjected to tension can be observed in Fig 4, and comparison with Fig 2(a) reveals a consistent form of necking.

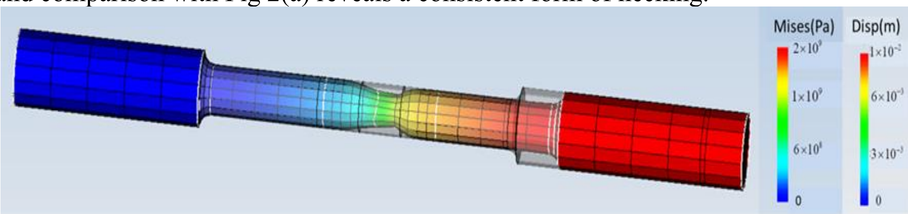

Fig. 4. Simulation results of tensile specimen.

3.2 CAE Simulation of Metal Compression Experiment

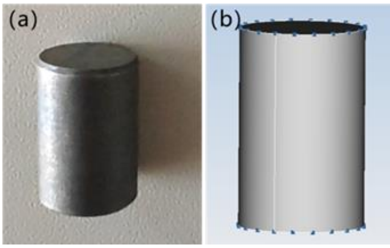

Fig. 5. (a) Cast iron compression specimen in kind. (b) Cast iron compression specimen geometric modeling.

Students perform geometric measurements on cast iron compression specimen Fig 5(a). In this study cast iron density value is selected as 7350 kg/m3, Young's modulus value is selected as 140 GPa and Poisson's ratio is selected as 0.285. In the modeling process, considering that the upper platen is compressed vertically downward, the bottom of the compression specimen is defined to have 6 degrees of freedom for fixed x, y, and z axes of movement as well as rotation around x, y, and z. The simulation model is shown in Fig 6(b).

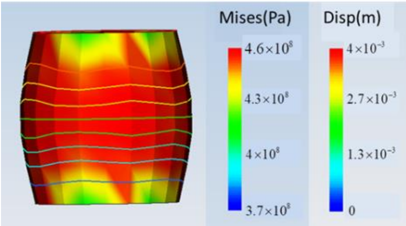

Fig. 6. Compression specimen simulation results

4 Conclusions

In the tensile and compression experimental teaching, combined with CAE software for simulation experimental teaching. Students observe the phenomenon of metals being subjected to changes in tension and compression through demonstrative experiments. The students measure the specimen and then geometrically model the specimen, analyze the physical field, mesh the specimen, and finally calculate the results in the CAE software. Simulation results and experimental results verify each other to improve students' learning interests and cultivate their research spirit. This teaching method improves students' finite element analysis skills such as geometric modeling, physical field analysis, and mesh dissection.

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