Application Research of Simulation Technology in Vocational Education Technical Skills Competition

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Abstract. During the preparation of the technique and skills competition, the students encountered the problem that the mechanical properties of the beam could not be measured experimentally. In order to solve this problem, the research team proposed the idea of simulation using finite element modeling. The students established a geometric model at the request of the teachers and put forward specific simulation requirements. On this basis, the finite element model was established, and calculation was carried out on a computer. A large number of Mises stress nephograms and rich data were obtained by the simulation, which solved the students' doubts and accelerated the production progress of the students' entries. In the process of solving the problem, problem analysis ability, language expression ability, and data processing ability of the students have been significantly improved. The technique and skills competition is an important part of the vocational education system. Simulation technology in the design of entries has been little studied and should be paid attention by scholars.

Keywords: simulation technology · modeling · three-point bending · technical skills competition · vocational education

1 Introduction

Vocational education and general education are two different types of education with equal importance. Since the reform and opening up, vocational education has provided strong talent support for China's economic and social development. As China enters a new development stage, industrial upgrading and economic structure adjustment are accelerating, and the demand for technical and skilled talents in all walks of life is becoming more and more urgent; therefore, the important position and role of vocational education are becoming more and more prominent [1]. Because vocational education is positioned to cultivate skilled application talents, participation and preparation of various technique and skills competitions have become an important supplement to campus education [8]. In 2019, nine departments including the Ministry of Education issued the "Vocational Education Quality Improvement Action Plan (2020–2023)", which clearly

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stated that vocational colleges should "play the leading role of promoting education and learning through competitions" [4].

As a good platform for vocational education to improve the vocational quality of students, the vocational skills competition not only promotes the continuous deepening of education and teaching reform, but also strengthens the linkage between the government, industry, enterprises, and vocational colleges, and has become an important effective means in comprehensively improving the cultivation quality of the technical and skilled talents [12]. The skills competition has a complete standard system, a competition environment closer to the real production scene, and a fair and just evaluation mechanism, and is the most direct way for vocational colleges to test the talent cultivation quality [10]. Integrating the content of the technique and skills competition into classroom teaching, on the one hand, can speed up teaching reform and build an education model for real job ability training; on the other hand, can enable teachers to improve professional theory and practical skills around the actual operation of enterprises, and promote the construction of "double-teacher" teaching staff [11].

In recent decades, various technique and skills competitions have been highly valued by vocational colleges, and the number of participating teams and students has increased significantly. Taking the Henan Provincial Competition of the "Internet+" College Student Innovation and Entrepreneurship Competition as an example, up to 288,000 students from 98 vocational colleges signed up in 2021 [2]. Compared with undergraduate schools, vocational schools lack experimental equipment, which to some extent restricts the quality of entries and the progress of preparation. For example, several students in our school were faced with the dilemma of being unable to carry out mechanics experiments when producing their entries. The research team adopted modeling and simulation technology to assist the students in the calculation of mechanical behavior.

With the improvement in computing ability of computers and the popularization of simulation software, simulation technology has been greatly developed in many fields, such as metallurgy [9 and 7], transportation, fire protection, medical treatment [3 and 6], military, and education (Streufert, 2001). However, the application cases and related studies of simulation technology in vocational college skills competitions are few and should be paid enough attention.

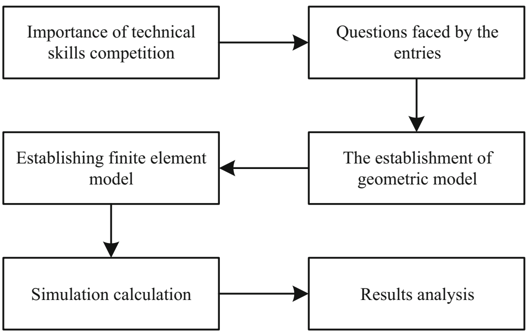


Fig. 1. The research logic diagram of the paper.

This paper uses simulation technology to solve the problem encountered by the students in the preparation of skills competition. In the process of solving the problem, problem analysis ability, expression ability, and data analysis ability of the students have been improved.

The research ideas of this paper are worth being applied to more fields of vocational education. The research logic of this paper is as shown in Fig. 1.

2 Problems Encountered

In order to participate in the "Internet+" College Student Innovation and Entrepreneurship Competition in July 2022, three students from Beijing Polytechnic formed a participating team. Under the guidance of the research team, the participating team preliminarily formed the entry of the "Unmanned Disaster Rescue Vehicle".

The application scenario of the entry is: at the disaster scene, the unmanned rescue vehicle enters the dangerous area to transport emergency rescue materials (such as medicines and rescue equipment). It can be seen from the above application scenario that the load capacity of the rescue vehicle is an important parameter of the entry.

As shown in Fig. 2, the upper part of the rescue vehicle is a load platform, and the lower part of the load platform is a battery pack. The load platform is separated from the battery pack by a load-bearing steel beam. Obviously, an overweight load will cause severe bending deformation of the beam, which in turn will press the battery pack and cause an accident. In order to ensure the reliability of the entries, the team members hope to carry out a three-point bending mechanical experiment to test the bending resistance of an H-shaped steel beam to be used. The students' solution and test requirements were recognized by the research team. On the one hand, the school does not have corresponding mechanical experimental equipment. On the other hand, after H-beam is purchased, it needs to be cut according to sample size requirements of

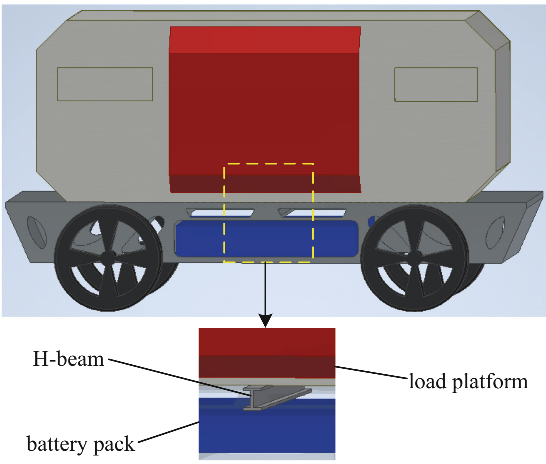


Fig. 2. H-beams for load bearing.

three-point bending test equipment; but the school has no corresponding cutting device. Therefore, students' idea of doing experiments cannot be realized. In order to solve students' problems and promote the progress of the entries, the research team considered using finite element software for modeling and simulation calculation.

The research team introduced the basic theory and related software of finite element to the participating students. In order to establish a more accurate model for bending performance simulation, it is necessary to establish a geometric model.

3 Modeling

3.1 Geometric Model

In order to exercise the problem analysis ability and drawing ability of the students, the task of establishing a geometric model was assigned to the students by the research team.

The students looked up a lot of relevant materials in spare time. Finally, the students determined the specific dimensions of the beam and the test requirements, and formed the geometric model diagram as shown in Fig. 3 and Fig. 4 (the diagrams were drawn by the students).

The parameters are as follows: The length of the H-beam to be simulated is $L =$ 100 mm and height $H = 10$ mm. The indenter and the two supports have the same structure, with diameter $D = 20$ mm and axial length $z_1 = 10$ mm. The indenter is tangent to the upper surface of the beam at the center of the beam. The two supports are tangent to the upper surface of the beam. The distance between the axis of the two

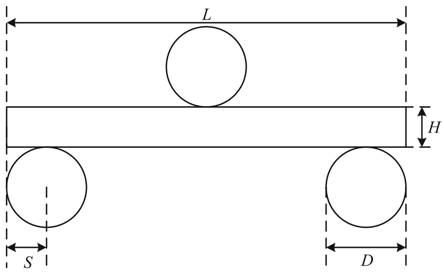


Fig. 3. Geometric model of the H-beam bending test.

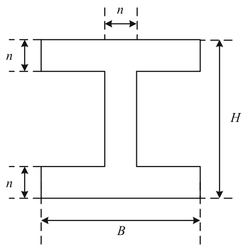


Fig. 4. Cross-section of the H-beam.

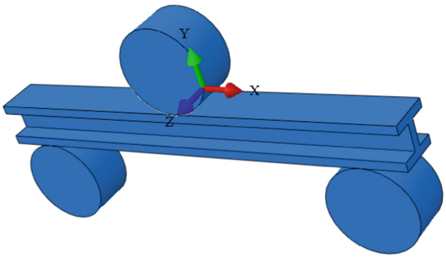


Fig. 5. Finite element models and the coordinate system.

supports and both ends of the beam is $s = 10$ mm (as shown in Fig. 3). The geometric dimensions of H-beam cross-section are shown in Fig. 4, in which wall thickness is $n = 2$ mm and H-beam width is $B = 10$ mm ($B = z_1$). The test parameters of the students are as follows: the reduction amount H ranges from 1 mm to 6 mm, and the step factor is 1 mm. The data to be measured are as follows:

(1) The stress distribution of the beam corresponding to each reduction amount and the maximum stress value.
(2) The pressure value of the load platform (self-weight is not considered) corresponding to each reduction amount.

3.2 Finite Element Model

According to the above dimensions, the finite element model was established by the research team using ABAQUS software. The indenter and the two supports are designed to be rigid without regard to the setting of its material properties. The material property of the H-beam are set as follows: density of the material $\rho = 7.9 \times 10^3$ kg/m^3, elastic modulus $E = 210$ GPa, and Poisson's ratio $\lambda = 0.3$.

The plastic deformation of the beam are set as: $\sigma_1 = 418$ MPa, $\varepsilon_1 = 0$; $\sigma_2 = 500$ MPa, $\varepsilon_2 = 0.0158$; $\sigma_3 = 606$ MPa, $\varepsilon_3 = 0.0298$; $\sigma_4 = 829$ MPa, $\varepsilon_4 = 0.25$; $\sigma_5 = 932$ MPa, $\varepsilon_5 = 0.55$; $\sigma_6 = 1040$ MPa, $\varepsilon_6 = 0.85$.

In the ABAQUS software, "element type" of each part is selected as C3D8R. "Approximate global size" of the beam was set as 1 mm, and the supports and indenter were set as 2 mm. In order to set "load" and "boundary condition" more reasonably, operation points RP-1 (0, 40, 5), RP-2 (-40, -40, 5) and RP-3 (40, -40, 5) were created. Three special points are defined and bound to three rigid bodies in the model. The indenter was set as a "rigid body" and bound to the point RP-1. Similarly, the left support was set as a "rigid body" and bound to the point RP-2, and the right support was set as a "rigid body" and bound to the point RP-3. In "interaction", the friction coefficient was set to $\mu = 0.2$. In "boundary condition", all six degrees of freedom on the RP-2 and RP-3 were constrained. RP-1 was constrained to move only in the Y-axis to realize the pressure on the normal direction of the beam. In order to ensure the convergence of the model calculation, the left surface of the beam (surface $x = -50$ mm) was constrained to move only in the X-axis and Y-axis, and the other four degrees of freedom are constrained.

The time of the "step" command was set to $t = 1$ s, and the "H-output" command is set to $T = 10$ times. The finite element model is shown in Fig. 5.

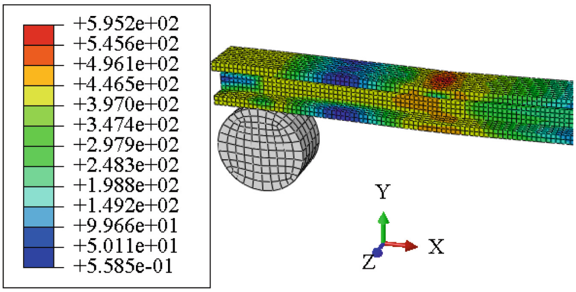
4 Simulation Calculation and Analysis

According to the experimental needs of students, loading is set up in the software. The pressure of the indenter was set along the negative Y-axis direction. The displacement of the indenter is 1 ~ 6 mm and step factor is 1 mm.

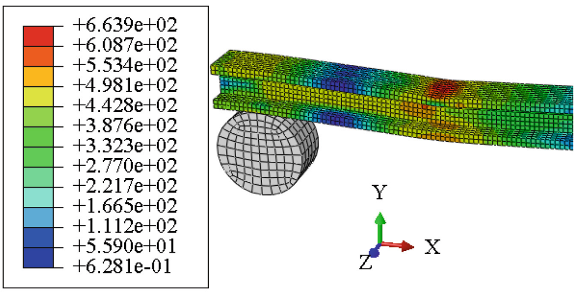
The deformation behavior of the beam under different displacements was simulated. In order to analyze the Mises stress more clearly, the indenter is concealed.

4.1 Simulation Results

When the displacement of the indenter is small, the Mises stress nephogram calculated by the model is shown in Fig. 6. Figure 6 (a) and Fig. 6 (b) show the simulation results when displacement $H_1 = 1$ mm and displacement $H_2 = 2$ mm respectively. As can be seen from Fig. 6, when the displacement is small, the overall bending deformation of H-beam is not obvious. The Mises stress is not large as a whole, but it is concentrated



(a)



(b)

Fig. 6. Mises stress nephograms of the finite element model under different displacements: (a) 1 mm; (b) 2 mm.

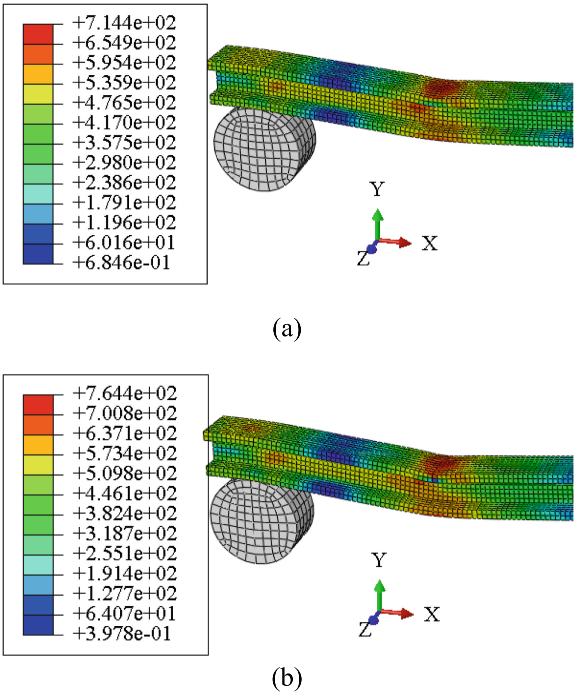


Fig. 7. Mises stress nephograms of the finite element model under different displacements: (a) 3 mm; (b) 4 mm.

and its maximum value is not small. The maximum Mises stresses are 595.2 MPa and 663.9 MPa respectively when displacement $H_1 = 1$ mm and displacement $H_2 = 2$ mm.

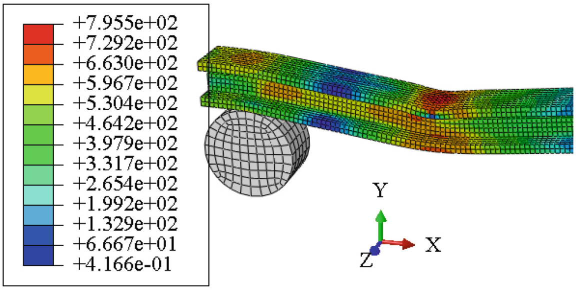
Similarly, Mises stress nephograms of the finite element model with displacements of 3mm and 4mm were obtained, as shown in Fig. 7. Figure 7 (a) and Fig. 7 (b) show the simulation results under displacement $H_3 = 3$ mm and displacement $H_4 = 4$ mm respectively.

As can be seen from Fig. 6 and Fig. 7, the bending degree of the beam increases with the increase of pressure, so does the Mises stress at the same part of the beam. The stress concentration in the two figures appears directly below the indenter. With the further increase of displacement of the indenter (concealed), the bending deformation of the beam becomes more obvious.

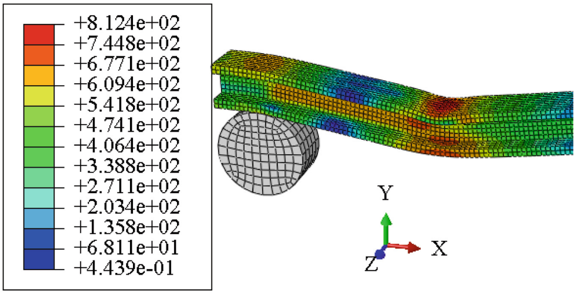
Figure 8 is the Mises stress nephograms with 5mm and 6mm respectively. It can be seen from Fig. 8 that the stress distribution of the H-beam is more uneven. Similar to Fig. 6 and Fig. 7, the stress at the cross-section of the beam directly below the indenter is the most concentrated in Fig. 8.

The maximum Mises stress value based on simulation calculation of the finite element model under all displacements was counted, and the statistical results are shown in Fig. 9.

It can be seen from Fig. 9 that the maximum Mises stress value of the finite element model increases with the increase of displacement. Individually, the maximum Mises stress increase gradually decreased.



(a)



(b)

Fig. 8. Mises stress nephograms of the finite element model under different displacements: (a) 5 mm; (b) 6 mm.

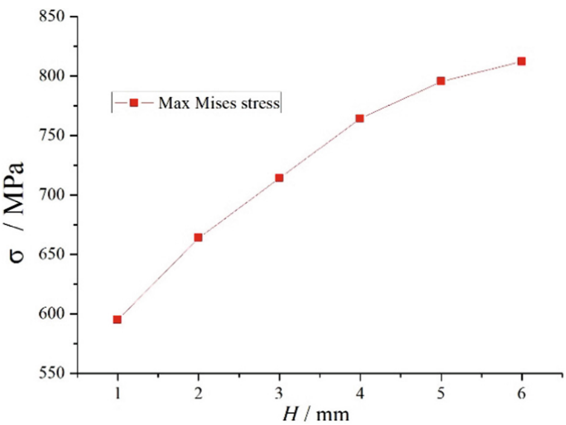


Fig. 9. This caption has one line so it is centered.

In order to better study the stress concentration, the cross-section (plane with $x = 0$) of the model with displacement $H_6 = 6$ mm was observed, as shown in Fig. 10.

As can be seen in Fig. 10, the upper and lower H-beam flanges are both bent in the Z-axis direction. And both ends of the upper H-beam flange are no longer in contact

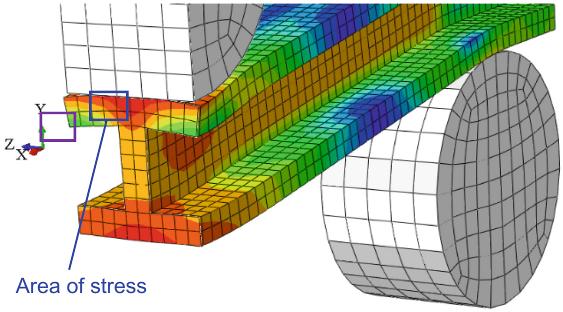


Fig. 10. Mises stress distribution on the H-beam cross-section.

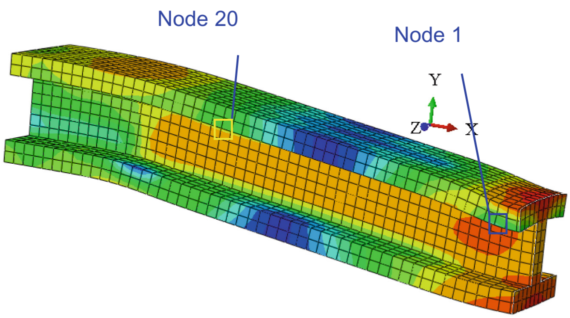


Fig. 11. Several nodes of the H-beam were marked.

with the indenter. Due to no support below both sides of H-beam flange, the stress is released (as shown in the purple box area in the figure). Correspondingly, the maximum Mises stress (as shown in the blue box area) occurs at the junction of H-beam web and the H-beam flange.

In order to better study the bending deformation, some nodes of the beam were marked. As shown in Fig. 11, the node directly below the indenter was marked as Node 1 (as shown in the blue wireframe in the figure). Along the negative X-axis direction, the adjacent nodes were marked as Node 2, Node 3, Node 20 in turn (as shown in the yellow wireframe in the figure).

It can be seen from Fig. 12 that under the same displacement, the closer the node to the Y-axis (the smaller the number marked in Fig. 11), the greater the displacement. With the increase of displacement, the displacement of the same node increases. When the displacement is small, the displacement of each node is close, that is, the bending degree of the beam is small. Under the displacement of the indenter $H_1 = 1$ mm, the displacement of Node 1 is $h_1 =$ -1.004 mm, while the displacement of Node 20 is h_{20} = -0.09179 mm. The difference between h_1 and h_{20} is only 0.9122 mm.

With the increase of the displacement of the indenter, the Y-axis displacement difference between the nodes becomes larger and larger, that is, the bending degree of the beam becomes more and more obvious. Under the displacement of the indenter $H_6 =$ 6 mm, the displacement of Node 1 is $h_1 =$ -6.285 mm, while the displacement of Node

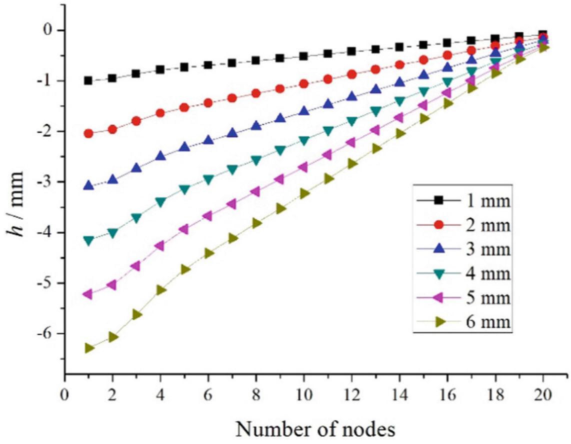


Fig. 12. Displacement of nodes in Y-axis direction.

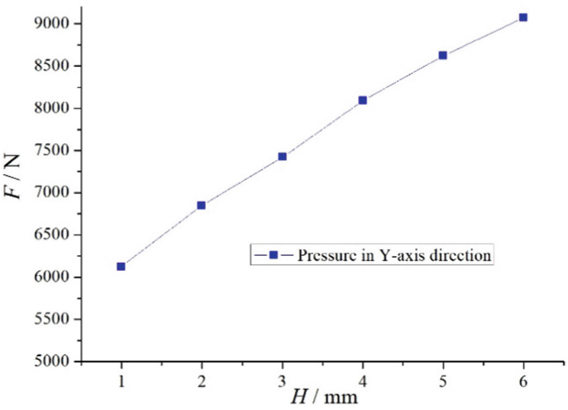


Fig. 13. Pressure statistics in the Y-axis.

20 is h_{20} = -0.3419 mm. The difference between h_1 and h_{20} is 5.943 mm. It is also important to note that, the difference between H_1 and h_1 is due to warping at the edge of H-beam flange, which is consistent with Fig. 10.

Data in the software "ODB" is called. The relationship between indenter displacement and indenter pressure is analyzed. The statistical results are shown in Fig. 13. It can be seen from Fig. 13 that the pressure of the indenter increases with the increase of the down displacement.

There is an approximate linear relationship between them. When the displacement is $H_6 = 6$ mm, H-beam has undergone serious distortion (as shown in Fig. 8). However, the beam is subjected to pressures of up to $F = 9075$ N. This shows that the bending resistance of H-beams commonly used in engineering is indeed very superior.

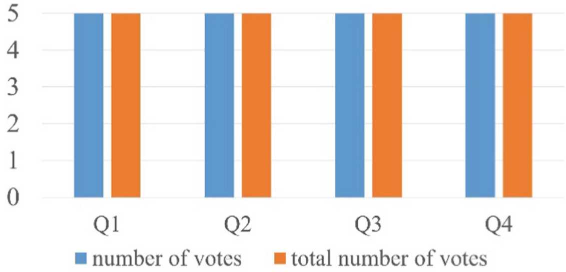


Fig. 14. A questionnaire about ability improvement.

4.2 Results Analysis

A large amount of data and the Mises stress nephogram were obtained from the finite element simulation calculation. At the request of the research team, students put together the test reports. The data from these test reports supports the design and optimization of the students' entries and accelerates the progress of the entries.

During the whole problem-solving process, the students have done a lot of work, and their abilities in all aspects have also been exercised. The research team only did two tasks of finite element modeling and simulation calculation, and all other tasks were undertaken by students, including:

J1: determining the specific dimensions of the test specimen;

J2: determining specific needs for test data;

J3: making a three-dimensional drawing of the sample;

J4: processing the data, wherein Fig. 9, Fig. 12, and Fig. 13 are all drawn by the students using the "Origin" software based on the simulation data, and the wireframes and text annotations in Figs. 10 and 11 were also made by the students.

J5: writing a test report. Similar to J4, students completed project reports under the guidance of the teachers. The report contains figures, tables and formulas, which provide necessary data support for the technical skills competition entries.

In the process of undertaking the above-mentioned work, the ability of the students has been greatly improved. The research team conducted a questionnaire, and the survey questions are as follows:

Q1: has your problem analysis ability been improved?

Q2: has your data analysis ability been improved?

Q3: has your drawing ability been improved?

Q4: has your language communication skills been improved?

The five students who participated in the competition answered "yes" to the above four questions, as shown in Fig. 14. The research team communicated with the students about the questions of the questionnaire. Among them, the problem analysis ability and data analysis ability are the most mentioned by the students.

Before the finite element modeling, the students' needs for testing were completely vague. That is, it is believed that testing is necessary, but how to perform a test exactly? what are the dimensions of the test specimen? which values are tested? etc., all the above are not clear. At the request of the research team, through the data review, we have mastered a lot of testing knowledge and have a deeper understanding of tensile measurement. Of course, the specific requirements for the test became clearer, and a geometric model was drawn. The students said that they knew how to analyze and deal with similar problems in the future. Under the guidance of the research team, the students learned to use the origin software to make a coordinate graph. How to adjust the axis amplitude? How to adjust the size and font of the text? How to set the symbol color? These seemingly simple questions were pondered by the students one by one. The students said that they knew how to deal with similar data processing problems in their future work.

In addition, the students' knowledge has been expanded. The students learned about the basic theory of finite element and the basic principles of ABAQUS software. Two students in the participating team are very interested in simulation technology and ABAQUS software. The two students made it clear that they would take time to learn ABAQUS software in the future. Students are interested in learning and willing to take the initiative to learn, which is what all teachers want to see. From this point of view alone, the research team's efforts are valuable.

In conclusion, the problems faced by the entries are solved through the simulation technology. In the process of solving problems, the students' various abilities have been exercised and improved.

5 Conclusion

In view of the problem that mechanical experiments cannot be performed, the research team proposed a solution to modeling and simulation. With the joint efforts of the participating team members and the research team, the problem was solved, and the main conclusions of this paper are as follows:

(1) The finite element modeling and simulation technology can be used for solving mechanical testing problems in technical skills competitions.
(2) In the process of using the simulation technology to solve problems, the students undertook a lot of work, and the work helped the students to improve their problem analysis ability, data analysis ability, language communication ability and written expression ability. In addition, the simulation technology also expands students' knowledge. Vocational colleges should pay more attention to the modeling and simulation technology, and the technology should be applied in more fields.

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