Application of Finite Element Simulation Technology in the Teaching of Process Equipment and Control Engineering

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Abstract: Improving the teaching level of the professional courses of Process Equipment and Control Engineering has an important role in promoting the cultivation of compound and applied equipment talents. In this paper, finite element simulation technology is introduced into the teaching of Process Equipment and Control Engineering. Taking the finite element analyses of truss beam in the filled tower and fixed tube-sheet heat exchanger as examples, the complementary role of finite element simulation technology for the theoretical and practical teaching of professional courses was introduced. Teaching practice shows that the visualization of finite element analysis results can effectively stimulate the interest of students in learning, deepen their understanding and mastery of theoretical knowledge, improve the ability of students to use finite element simulation technology to solve practical engineering problems, and achieve the unity of teaching and learning in professional courses.

Key words: Finite Element Simulation; Professional Courses; Theoretical Knowledge; Practical Teaching

1. Introduction

The Process Equipment and Control Engineering major of Yulin University aims to cultivate high quality applied talents to serve the economic and social construction in Yulin and its surrounding areas, with good humanistic scientific literacy, social responsibility, engineering professional ethics and innovation awareness. After four years of study in university, students should master the basic theoretical knowledge in mechanical engineering, chemical engineering, control engineering, etc., and should have the ability to design, manufacture, maintain process equipment and develop technologies for new chemical plants. They can be engaged in process equipment design and manufacturing, technology development, engineering application, production management, technical service and other work in the fields of chemical industry, petroleum, energy, machinery, environmental protection, pharmaceuticals, food and labor safety, etc. [1-3].

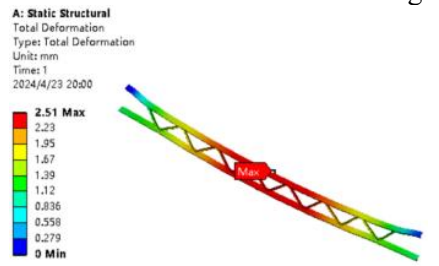
Courses such as Engineering Mechanics, Engineering Fluid Mechanics, and Process Equipment Design are the core courses of the Process Equipment and Control Engineering Major. Engineering mechanics includes two parts: theoretical mechanics and material mechanics, which mainly cultivate students' engineering awareness, engineering ability, scientific quality, and innovation ability [4]. Engineering Fluid Mechanics mainly studies the internal laws and basic principles of fluid flow, and cultivates students' ability to theorize practical engineering problems [5]. Process Equipment Design mainly cultivates students' ability to independently acquire and comprehensively apply professional knowledge of process equipment, and exercises students' ability to independently solve various problems caused by equipment in the actual production process and team cooperation ability [6]. These courses are theoretical, with cumbersome formula derivation, and strong engineering practice, which puts forward high requirements for students' learning ability. Finite element analysis can visualize the abstract practical engineering problems vividly and concretely, which can help students deeply understand the teaching content of these courses, thereby improving the classroom teaching effect [7-9]. Huang Yiqun [10] believes that the teaching idea of combining material mechanics with the finite element demonstration in classroom helps to improve students' enthusiasm and participation in class, and enhance students' intuitive perception of the abstract concepts in

Material Mechanics. Xie et al. [11] introduced the method and practice of combining Computational Fluid Dynamics and Fluid Mechanics Courses in the form of examples, so as to improve the classroom teaching effect of Engineering Fluid Mechanics. Wang et al. [12] introduced finite element into the teaching of Process Equipment Design, and found that finite element simulation effectively deepened students' understanding of the derivation of complex theoretical formulas.

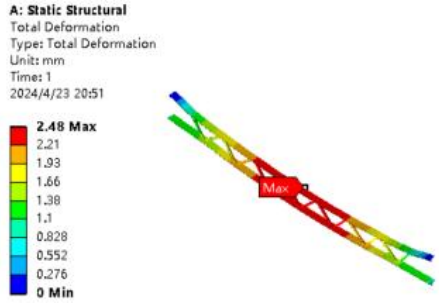
Therefore, this paper applies the finite element simulation technology into the teaching of the core courses of the Process Equipment and Control Engineering. the application of the advanced finite element simulation technology helps to deepen students' understanding and mastery of profound professional theoretical knowledge and practical application of engineering, so as to cultivate compound and applied talents specializing in the design, manufacture, operation and maintenance of equipment for the establishment of the national-level Energy Revolution Innovation Demonstration Zone in Yulin.

2. The Distribution of Stress and Deformation of the Truss Beam within the Plate Tower

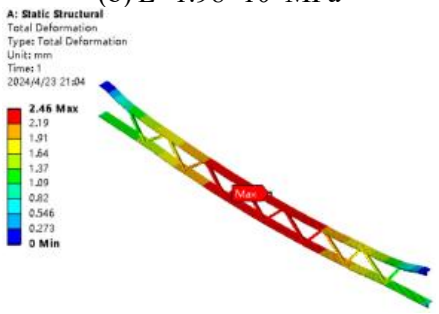
Beams are important load-bearing components in engineering structures and are widely used in industrial processes, such as single-girder crane beams, girders of overhead cranes, and train axles [13]. When a beam is subjected to a lateral load perpendicular to the axis, one of the basic deformations common in engineering practice, i. e., bending deformation, occurs. the bending of beams is an important part of material mechanics and involves the internal forces, the stress and the deformation of bending, as well as strength and stiffness calculations of beams. When teaching this chapter, the finite element analysis of a truss girder in a packed tower with an intermediate section subjected to transverse concentrated forces is used as an example to demonstrate the influence of carbon steel materials with different elastic moduli on the stress and deformation of the truss girder, as shown in **Figures 1** and **Figures** 2. From the intuitive observation in Figures 1 and 2, the maximum deformation of the beam is located in the middle of the chord span on the truss girder, and the maximum deformation decreases with the increase of the elastic modulus of carbon steel. the maximum stress is at the junction between the end of the chord and the support on the truss girder, and the change of the elastic modulus of the carbon steel material has no obvious effect on the maximum stress. Introducing finite element simulation technology into the teaching of truss girder makes students intuitively observe the deformation behavior of truss girder and the stress distribution law caused by it, deepening students' understanding and application of material mechanics theoretical knowledge**.**



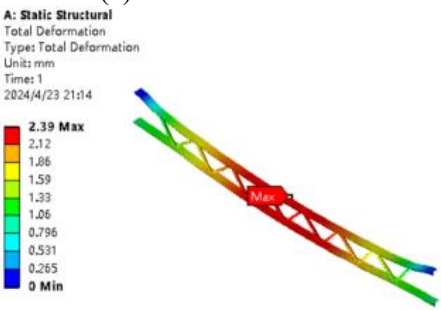
(a) E=1.96×10^5 MPa



(b) E=1.98×10^5 MPa

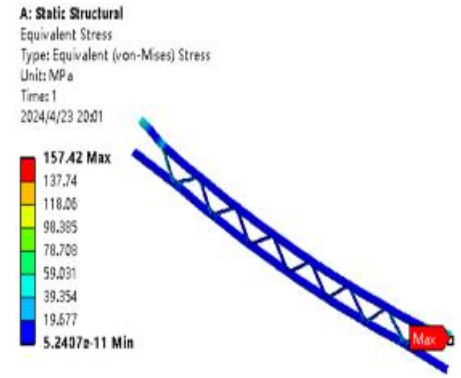


(c) E=2.00×10^5 MPa



(d) E=2.06×10^5 MPa

Figure 1. Deformation Cloud with Different Modulus of Elasticity



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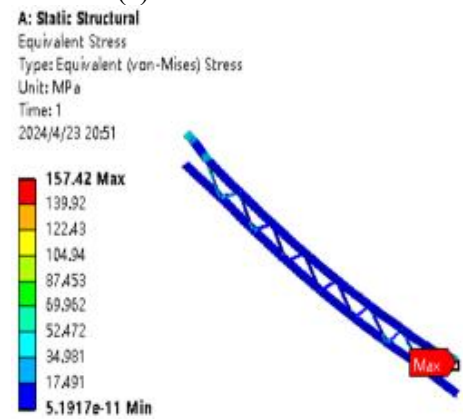
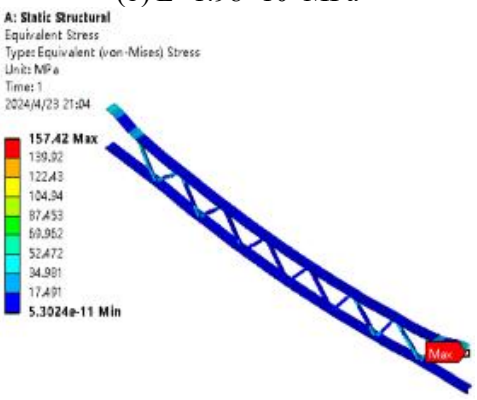


(b) E=1.98×10^5 MPa



(c) E=2.00×10^5 MPa

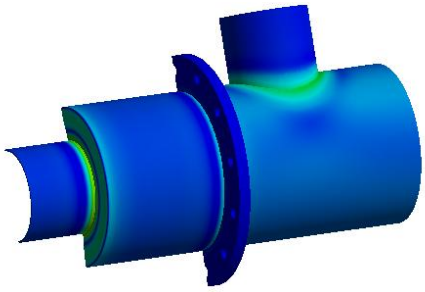
(d) E=2.06×10^5 MPa

Figure 2. Stress Cloud with Different Modulus of Elasticity

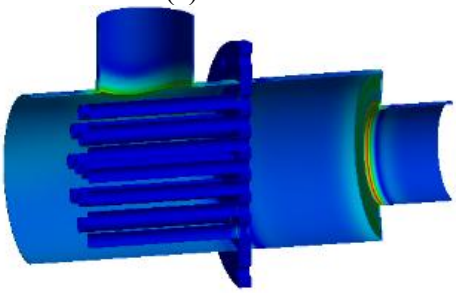
3. The Stress Distribution and Temperature Distribution of the Fixed Tube-Sheet Heat Exchanger

Heat exchange equipment is a kind of process equipment widely used in many industries such as chemical, food, and pharmaceutical industries. Its main function is to transfer heat from the material with higher temperature to the material with a lower temperature, so that the temperature of materials can meet the process requirements, so as to meet the needs of the production process. Heat exchange equipment is also an effective device for recovering remaining heat, waste heat, and low-grade heat energy [6]. In the chapter on heat exchanger equipment, a finite element analysis is performed on a fixed tube-plate heat exchanger under steady-state conditions during normal operation, as shown in Figure 3. Under this working condition, since the pipe and shell work at the same time, the heat exchanger is subjected to the pressure of the pipe and the shell at the same time, and the heat transfer process has been carried out for a period of time, so the heat exchanger has thermal stress under this working condition. From Figure 3, students can intuitively conclude that the maximum stress occurs at the entrance of the pipe journey, and the stress here is significantly higher than the stress of the rest of the components. the minimum stress occurs on the heat exchanger tube bundle. In addition, a finite element analysis was performed on a fixed tube-plate heat exchanger with different baffle spacing, as shown in **Figure 4**. Students can see from Figure 4 that when the baffle spacing is 125 mm, the heat transfer effect is the best, and the temperature distribution is more uniform. At the same time, students are guided to summarize according to the simulation results: the number of baffles of the heat exchanger should be arranged moderately, so that the heat exchange effect will be more obvious, and the heat exchange coefficient will be significantly improved. If the number of baffles is small, the spacing of the baffles is too large, resulting in too low heat transfer coefficient, uneven temperature distribution, and the vibration of baffles induced by excessive unsupported span. A large number of baffles and too small spacing of baffles may result in increased resistance to fluid flow. Using finite element simulation technology in teaching Heat Exchange Equipment makes students have a more comprehensive

understanding of the relevant knowledge of heat exchange equipment through the stress contour and temperature contour diagram output by the finite element software, deepening the students' understanding and application of the theoretical knowledge of process equipment design and engineering fluid mechanic's course.

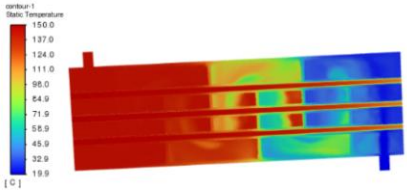


(a) outboard

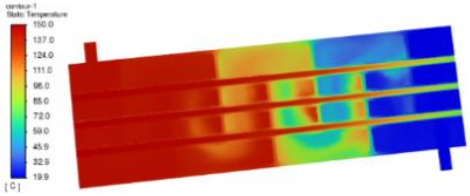


(b) inboard

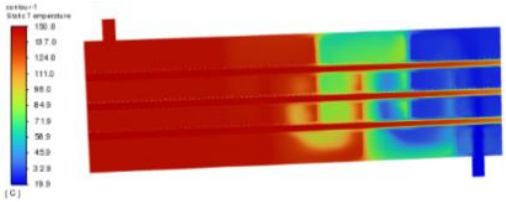
Figure 3 Stress Cloud Map of Heat Exchanger Under Normal Working Conditions



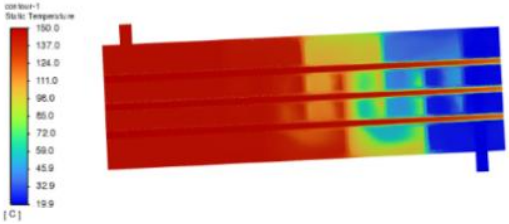
(a) the spacing between baffle plates is 140 mm



(b) the spacing between baffle plates is 125 mm



(c) the spacing between baffle plates is 110 mm



(d) the spacing between baffle plates is 100 mm

Figure 4 Temperature Cloud Map with Different Spacing Between Baffle Plates

4. Conclusion

The application of finite element simulation technology in the teaching of Process Equipment and Control Engineering can effectively make up for the deficiencies of the professional courses full of abstruse theoretical knowledge and short of practical experience, and deepen students' understanding and application of the teaching content of professional courses. It is of great significance for cultivating high-quality chemical equipment talents with solid professional foundation and advanced analysis software.

Acknowledgments

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