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PENGGUNAAN TEKNOLOGI FEM SEBAGAI ALAT YANG BERKESAN UNTUK MENGAJAR PROSES PEMBUATAN MEKANIKAL

USE OF FEM TECHNOLOGY AS AN EFFECTIVE TOOL FOR TEACHING MECHANICAL MANUFACTURING PROCESSES

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Abstract
This paper describes how FEM (Finite Element Modelling) techniques can be applied to improve the quality of teaching and learning of mechanical engineering processes. Incorporating FEM techniques in the curriculum can bridge the gap between theoretical concepts and practical applications and provide hands-on learning experiences. With the help of FEM software, students can explore different design options, predict potential failure points, and optimize the manufacturing process to achieve desired results. In this project, the rolling process of sheet metal is chosen as a teaching example. The real-time deformation of metal materials in the rolling process is explained through FEM analysis so that students can learn how to deal with inhomogeneous loads, boundary constraints, and other situations. Through intuitive graphics and data generated by FEM simulation, students can fully understand the basic principles of the mechanical manufacturing process.

Keywords: FEM, simulation, analysis, teaching, mechanical

Use of FEM Technology As An Effective Tool For Teaching Mechanical Manufacturing Processes

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1. Introduction

1.1 Background

FEM analysis plays an important role in engineering applications (Madenci, E., & Guven, I. 2015). The mechanical engineering majors of most colleges and universities have offered courses related to FEM analysis, aiming to cultivate application-oriented talents with basic knowledge of FEM theory and the ability to operate FEM simulation software (Ebrahimi, F. (Ed.). 2012). Undergraduate colleges and universities need to position the training of students in line with the needs of enterprises so that they can be quickly put to work after graduation. The theoretical part of the FEM course involves a physical foundation and numerical analysis method, which requires high mathematical knowledge (Monk, P. 2003). For mechanical engineering students in undergraduate colleges and universities, it is difficult for them to master the relevant theories within a certain period. The theoretical knowledge of FEM technology is less used in practical engineering applications, and more often the FEM software is used to simulate and analyze the research object. The main work is to use FEM software to model, simulate, and analyze the results. In this paper, we will take the metal manufacturing process course of the university as an example, and comprehensively analyze the reasons for FEM technology as a tool for teaching mechanical manufacturing processes from the teaching content, teaching method, and assessment method.

FEM techniques have a wide range of roles and applications in engineering applications:

- Structural analysis. FEM analysis plays an important role in the field of structural engineering. It allows the calculation and prediction of stress, strain, displacement, deformation, and other parameters of a complex structure to assess the performance indicators such as strength, stiffness, stability, and fatigue life of the structure (Choi, K. K., & Kim, N. H. 2004). Through FEM analysis, it can optimize the design scheme, assess structural safety, discover potential problems, and guide structural improvement and optimization.
- Thermal analysis. FEA can be applied to the analysis and simulation of thermodynamic problems (Castaings, M., Bacon, C., Hosten, B., & Predoi, M. V., 2004). For example, in the fields of heat conduction, heat transfer, heat stress, etc., FEM methods can be used to study parameters such as temperature distribution, heat flow, heat stress, etc., to optimize the heat treatment process and improve the design of heat exchange equipment (Hachem,E., 2009).
- Fluid mechanics. FEM analysis plays an important role in the field of fluid mechanics (Lewis, R. W., Nithiarasu, P., & Seetharamu, K. N., 2004). For example, in the field of gas dynamics, fluid flow, liquid-structure interaction, etc., the FEM method can be used to solve the velocity field, pressure field, flow rate, resistance, and other parameters, and optimize the design and performance of the flow system (Reddy, J. N., & Gartling, D. K., 2010).
- Electromagnetic field analysis. FEM analysis can be used for modeling and solving electromagnetic field problems (Zhu, Y., & Cangellaris, A. C. (Eds.)., 2006). For example, in electromagnetic field distribution, electromagnetic induction, and electromagnetic wave propagation, FEM methods can be used to study parameters such as electric field, magnetic field, and electromagnetic field strength, and to optimize the design of electromagnetic equipment and electronic devices (Jin, J. M. 2015).
- Automotive engineering and aerospace engineering. FEM analysis has been widely used in automotive engineering and aerospace engineering (Gu, S. 2017). Examples include structural analysis and optimization of automobile bodies, engines, and suspension systems, as well as analysis and improvement of aircraft structures and flight dynamics parameters.

1.2 Literature Review

E. Shaghouei, D. C. Webb, and K. Kormi show how applied FEM to teaching and manufacturing in general. The method is expanded by utilizing explicit programs to simulate the sequential collisions between pins during ten-pin bowling and to study the collision of several rigid bodies during the collapse of a triangularly packed stack of pipes. Finally, the initial collapse of a triangularly packed stack of pipes due to gravity is examined using the FE explicit code. The examination of the numerous repeated collisions that resulted from the impact of a ball with a pin in a ten-pin bowling simulation is then conducted using the same technique and procedure (Shaghouei, Webb & Kormi 1995). However, their choice of teaching model is too complex and may lead to an insufficient understanding of FEM in teaching, this project will use a simpler FEM model to facilitate students' understanding of the mechanical engineering process.

Heyden E and Küchenhof J demonstrate the internal development of this platform in light of the technical specifications and requirements from the design education course. Results from a previously created product family architecture of a robotic system that served as a reference are integrated into this context. A module interface graph representing the product architecture displays the variety of components as well as their connections. The mechanical and electrical components that are being used, along with their computational and communication potential, are described. These initial product variants form the foundation ofa product family, which will continue to grow as additional modules and product variants are added each semester. The perspective highlights more opportunities for activities to be completed and the system's application as a cyber-physical system for upcoming product generations (Heyden et al. 2020). Their research lacks targeted instruction for FEM software, and this project focuses on the use of FEM technology in teaching and learning.

Grodotzki J, Müller B, and Tekkaya A have created a new application to improve classroom instruction through the use of augmented reality visualizations. It is compatible with both iOS and Android operating systems and shows various items along with extra information submitted by the teachers. This new format may be imported and automatically converted from several popular 3D file formats, including STL, OFF, and OBJ. The same holds for the outcomes of the FEM programs Abaqus, MoldFlow, and HyperXtrude. Result files can also be uploaded for free if they have been formatted for GiD, a well-known pre- and post-processor. The models and animations can be viewed, examined, and interacted with by users of the smartphone app. The platform and app are made to be simple for educators to set up and simple for students to use (Grodotzki, Müller & Tekkaya 2023) . Their project will make FEM software easier to use and expand the scope of FEM applications in teaching and learning.

FEM technology as a teaching tool has the advantages of strong practicability, good visualization, improving learning efficiency, and cultivating innovative thinking, which helps students to better learn and apply the knowledge of the mechanical manufacturing process.

- FEM technology can combine theoretical knowledge with practical application, and through simulation analysis and experimental verification, students can personally operate and observe the results, to improve their practical ability and hands-on ability (Lee, H. H. 2023).
- FEM technology can transform complex mechanical structures and processes into visual models and results, students can intuitively observe and analyze stress distribution, deformation of parts, etc., which helps them understand and master mechanical principles and process knowledge (Wriggers, P. 2008).
- FEM technology can quickly carry out a large number of simulation analyses, students can obtain more experimental data and results in a shorter period, deepen the understanding and memory of knowledge, and improve learning efficiency (Thompson, M. K., & Thompson, J. M. 2017).
- FEM technology can help students find problems and problem-solving abilities, through the optimization of different design parameters and process conditions, students can develop innovative thinking and the ability to solve practical engineering problems (Schweiger, H. F., & Peschl, G. M. 2005).

1.3 Aim and Objectives

The research objective of this project is to enable students to understand the principles of the mechanical manufacturing process, master common machining methods, and process flow and be familiar with the selection and optimization of process parameters through FEM technology (Childs, P. 2013). Skillful use of relevant FEM tools and software, and developing quality awareness and process improvement ability. The aim is to develop students with practical and problem-solving skills in mechanical engineering to support industrial manufacturing and product development. Specifically, the following objectives are included:

• To deepen students' understanding of the fundamentals of mechanical manufacturing processes, including material processing, product manufacturing processes, selection of process parameters, process planning, and optimization. To understand the characteristics, scope of application, advantages, and disadvantages of different machining methods and processes through FEM technology.

• FEM can help students master common mechanical manufacturing processing methods, such as milling, turning, drilling, grinding, stamping, and so on. Students need to understand the principles, operation techniques, and process requirements of each machining method, and be able to choose the appropriate machining method accordingto the actual situation.

• Students will be able to select appropriate process parameters and optimize parameters according to actual requirements and material properties. Students understand the influence of various process parameters (such as cutting speed, feed rate, depth of cut, etc.) on machining quality, efficiency, and cost, and can perform parameter analysis and optimization through this program.

Through this program, students gain proficiency in the use of common manufacturing process-related tools and software, such as CAD/CAM software, process planning software, FEM simulation and analysis software. Students learn the functions and operation of these tools and can use the software for process planning, machining simulation, and design optimization. Students are instructed to develop quality awareness and process improvement capability（Kanigolla, D., A. Cudney, E., M. Corns, S., & Samaranayake, V. A. 2014). This course enables students to understand the importance and methods of quality control and to be ableto carry out process improvement and problem-solving to improve product quality and manufacturing efficiency（Spanbauer, S. J. 1995).

2. Methodology

2.1 Course Design

According to the teaching objectives, teaching resources, and students' learning characteristics. The teaching module and teaching process of the mechanical manufacturing process is designed as follows:

• Through lectures, classroom teaching, or online learning platforms, students are introduced to the basic theoretical knowledge of the mechanical manufacturing process, including the process flow, the use of tools and equipment, commonly used materials, and their processing characteristics. Case studies or actual engineering projects can also be used to illustrate relevant concepts and practical applications（Balamuralithara, B., & Woods, P. C. 2009).

• Show students the key steps and techniques in the mechanical manufacturing process through simulated demonstrations or practical exercises. Demonstrations can be conducted using video teaching, laboratory practice, and FEM virtual simulation to allow students to visually observe and understand the use of various tools, machines, and equipment, and to learn the precautions and safety practices in operation（Kamińska, D.,Sapiński, T., Wiak, S., Tikk, T., Haamer, R. E., Avots, E., & Anbarjafari, G. 2019).

• To provide students with practical opportunities, actual manufacturing projects or experimental tasks can be arranged. Students select appropriate materials, process methods, and equipment for processing according to the teacher's instruction to complete specific parts processing or assembly tasks. In the course of practice, students can collect data, record observations, and reflect and summarize, thus deepening their understandingand mastery of the mechanical manufacturing process.

2.2 Principles of FEM

The concept of FEM was first proposed by Turner and Clough, the basic idea is to discretize the structure and represent the complex object by a finite number of easy-to-analyzeunits. The units are connected by a finite number of nodes, and the solution is synthesized according to the deformation and the related conditions （Garcia-Cely, C., & Heeck, J. 2016). With the development of computer technology, the FEM method has become more and more popular in the field of engineering applications, so that the field of application has been extended from plane problems of elastic mechanics to space problems, plate and shell problems, from static equilibrium problems to stabilization problems, dynamics and fluctuation problems, and the objects of analysis have been extended from elastic materials to plastic, viscous elasticity, viscous-plasticity, and composites materials, and the specialties involved have been extended from solid mechanics to fluid mechanics, Heat transfer, electromagnetism, and acoustics（ Clough, R. W. 2004).

FEM technology is a numerical analysis method used to solve the behavior and response of complex physical systems（Wittbrodt, E., & Kahsin, M. 2008). Its basic principle is to partition a continuous physical system into a finite number of discrete units and to obtain the behavior of the whole system by approximating the solution of the discrete problem.
In the FEM method, the physical system is discretized by discretization into a finite numberof subregions called FEMs. Each FEM is described in terms of definite shape and geometric properties. The FEMs are connected by nodes and the approximation of the solution is defined at the nodes（Huebner, K. H., Dewhirst, D. L., Smith, D. E., & Byrom, T. G. 2001). Therefore, the FEM method is built on the following basic steps:

• Mesh division: The continuous system is divided into a finite number of discrete cells. These cells can be elements of different shapes such as triangles, quadrilaterals, hexagons, or three-dimensional voxels.
• Definition of the FEM model: Determine the geometrical characteristics (node positions, edge lengths, etc.) and material characteristics (material properties, boundary conditions, etc.) of each FEM. FEM modeling usually requires consideration of the physical properties and boundary conditions of the system.
• Definition of approximate solutions: Appropriate forms of approximate solutions (e.g., linear, quadratic, etc.) are defined at each node. These approximate solutions will

provide an approximate estimate of the unknown quantity to be solved at each node.

• Write FEM equations: Using variational principles or weighted residual methods, equations containing FEM approximate solutions are created. These equations are usually obtained by summing the local equations over each element.
• Solving the system of equations: The FEM equations are transformed into a system of linear algebraic equations and solved using numerical methods (e.g., Gaussian elimination, iterative methods, etc.) to obtain a numerical solution.
• Analysis and post-processing: Based on the numerical solutions obtained, the behavior and response of the system are analyzed and post-processed. This includes the calculation of physical quantities such as stresses, strains, displacements, etc., and visualization and interpretation of the results.

2.3 FEM Software Selection

Common FEM analysis software includes ANSYS, ABAQUS, LS-DYNA, COMSOL Multiphysics, SolidWorks Simulation, and Autodesk Inventor Nastran（ Okereke, M., & Keates, S. 2018). ANSYS is a widely used FEM analysis software that provides many rich functions and modules for structural analysis, electromagnetic field analysis, and many other fields. modules for structural analysis, fluid dynamics, electromagnetic field analysis, and many other fields（Madenci, E., & Guven, I. 2015). ABAQUS is a powerful FEM software developed by Dassault Systèmes for structural and multi-physics field analysis and is particularly good at solving complex nonlinear problems （Molnár, G., & Gravouil, A. 2017). LS-DYNA is a FEM software widely used for solving dynamics and high-speed collision problems for automotive, Aerospace, protection, etc (Hallquist, J. 2009, May). COMSOL Multiphysics is a multi-physics simulation software that supports the coupling of multiple physical fields, such as structural mechanics, electromagnetic fields, fluid mechanics, etc (Dede, E. M., Nomura, T., & Lee, J. 2014). SolidWorks Simulation is part of SolidWorks CAD software, which provides structural, fluid, and heat transfer analysis functions that can be easily integrated with CAD models. integrated with CAD models (Kurowski, P. 2013). Autodesk Inventor Nastran is a powerful FEM analysis software developed by Autodesk for structural, heat transfer, and other areas. Users can choose different FEM software according to their needs and budget. When choosing FEM software, the following aspects are usually considered:

- The functionality of FEM software is one of the important factors in the selection. Different software may have different functions and features, including model building, meshing, material modeling, solver options, post-processing functions, and so on. Choosing software that is fully functional and able to meet specific needs can provide richer and more accurate analysis and simulation results.
- Ease of use includes interface design, operating procedures, help files, and tutorials. The software should have an intuitive and user-friendly interface to facilitate learning and use. Ease of use is especially important for beginners and users unfamiliar with FEM methods.
- The chosen FEM software needs to be supported by adequate resources. This includes official documentation, user manuals, forums, technical support teams, and so on. Adequate resource support can help users to solve problems encountered during the use of the software, and provide appropriate technical guidance and assistance.

In this project, ABAQUS software is used as a teaching tool in the Mechanical Manufacturing Processes course. The reason is that in the mechanical manufacturing process, ABAQUS can help students simulate and analyze the stress, deformation, thermal deformation, and other related behaviors of metal materials, to better understand the mechanical and thermodynamic behaviors of the metal processing and manufacturing process. ABAQUS provides a wealth of modeling and solving functions, which can simulate a variety of complex phenomena in the metal manufacturing process, including metal forming, welding, heat treatment, etc. Students can use ABAQUS to construct accurate 3D models, perform mechanical and thermodynamic analyses, and obtain accurate results to gain insights into the behavior and properties of metal manufacturing processes. ABAQUS provides an intuitive, user-friendly graphical interface that makes model creation, loading, and analysis easier for students. In addition, the official ABAQUS website provides a wealth of teaching resources, including teaching cases, training materials, and forum support, which can help instructors and students better teach and learn FEM analysis.

2.4 FEM Model Selection

The rolling process in sheet metal was chosen as the teaching example for this project based on the teaching objectives and course design. Use the flat plate model to perform FEM analysis of the metal rolling process. The flat plate can be used as a basic teaching model to explain simple loading conditions and constraints so that students can learn how to deal with uneven loading, boundary constraints, and other situations (Bhat, A. R. 2009).

By gradually increasing the complexity and learning difficulty of the model, students can gradually develop their modeling and analytical ability and apply what they have learned to more complex and practical engineering problems. This teaching method helps students to understand and master the principles and techniques of FEM analysis (Reddy, J. N. 2019).

2.5 Development of The FEM Model

Using ABAQUS as the FEM software, the rolling process of flat alloy steel is used as a classroom project, and the following is the process of FEM model design, data import, and result analysis.

- Step 1: Create part: roll and slab

Table 1: Alloy steel Property

Mass Density	8E3 (kg/m^3)
Young's Modulus	205e9 Pa
Poisson's Ratio	0.275
Friction Coefficient	0.03
Reduction rate	37.5%

The purpose of the first step is to define the material properties and the properties of the press roll, such as the coefficient of friction, Young's modulus, and other data.

- Step 2: Create an assembly model

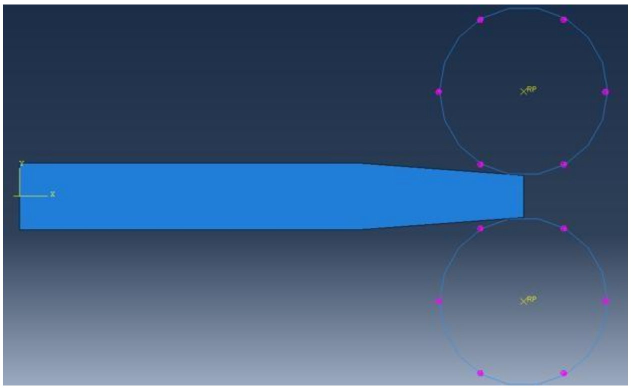

Figure 1: Create an assembly model

The purpose of this step is to create a 2D model of the flat material as well as a model of the press roll, which is defined as rigid since the press roll does not deform.

- Step 3: Create Step

This step aims to localize the flat plate model to plastic deformation and real-time dynamic changes.

- Step 4: Create Interaction

The purpose of this step is to define the "face-to-face" and friction coefficients to enable the system to perform 2D analysis operations. Define the Three friction coefficients as 0.03, 0.05, and 0.07 respectively.

- Step 5: Create Boundary---Roller
- Step 6: Mesh

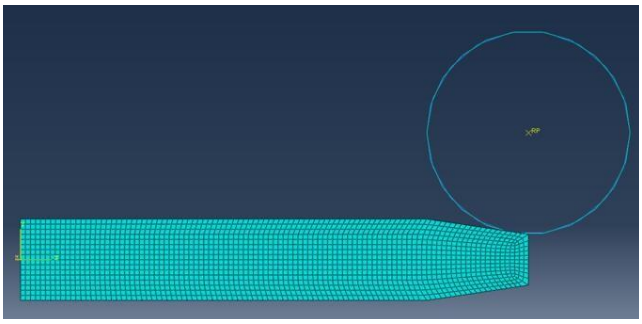

Figure 2: Generating the grid

The purpose of this step is to define the dimensions of the mesh elements and definenodes.

- Step 7: Job

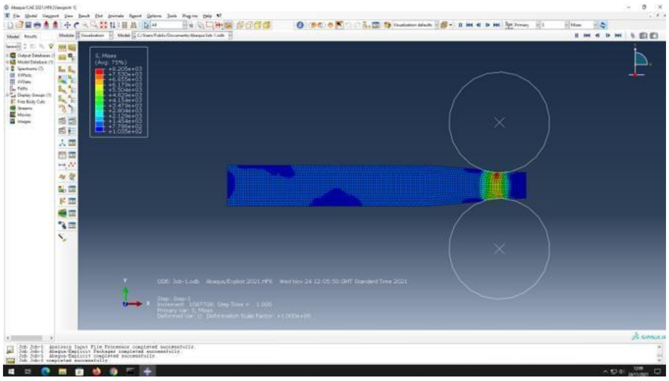

Figure 3: Running simulation

The mises stress distribution inside the slab is demonstrated.

- Step 8: Generating results

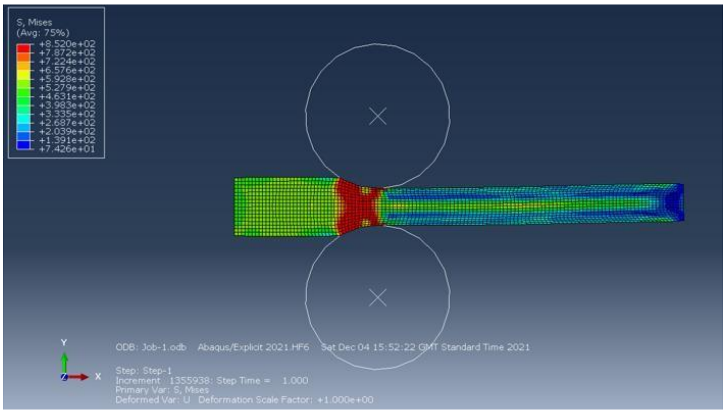

Figure 4: Reduction 37.5%

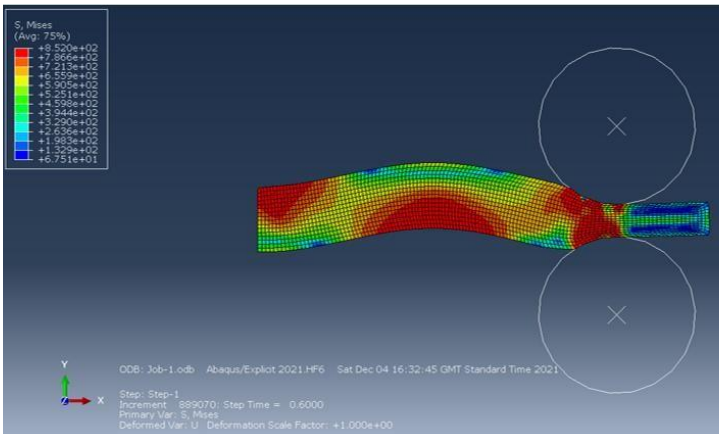

Figure 5: Reduction 50%

Figure 4 and Figure 5 show the effect of the Reduction rate on behaviors in Slab rolling. It can be concluded that at a reduction of 37.5%, the material can complete the rolling processand at a reduction of 50% the material is bent causing the It can be concluded that the material can complete the rolling process when the reduction is 37.5%, and when the reduction is 50%, the material will be bent and the rolling process cannot be completed. Fig. 4 and Fig. 5 are visualized using images and animations to help students understand and interpret the simulation results more intuitively. At the same time, FEA can help students optimize the product design and manufacturing process to make better decisions and optimization schemes.

3. Results and Discussion

3.1 Qualitative Inorganic Analysis

The use of FEMs as a pedagogical tool in the teaching of mechanical engineering processes allows a qualitative analysis of the quality of teaching. The following are some qualitative assessment indicators that can be considered:

- Student understanding and application: The use of FEMs as a teaching tool can help students understand the various analysis and design concepts in mechanical engineering processes and apply them to real-world problems. The quality of teaching can be assessed by observing and evaluating students' ability to understand and apply the concepts when using FEMs for analysis.
- Critical thinking and problem-solving skills: FEM analysis requires students to have critical thinking and problem-solving skills to be able to analyze and evaluate different solutions and select the most appropriate method and parameters. The quality of teaching can be assessed by observing students' decision-making process and problem-solving ability during FEM analysis.
- Practical application ability: One of the objectives of teaching mechanical engineering processes is to develop students' practical application ability so that they can apply the theoretical knowledge they have learned to real engineering problems. The use of FEMs as a teaching tool can provide simulation and analysis of practical problems, and the quality of teaching can be assessed by evaluating students' ability to apply FEM analysis in real cases.
- Learning effectiveness and outcomes: The use of FEMs as a teaching tool can help students gain a deeper understanding of the principles and applications of mechanical engineering processes and improve their analytical and design skills. The quality of teaching and learning can be assessed by evaluating the learning effects and outcomes of students at the end of the course.
- Practicality assessment: To find out students' views and feelings about the use of FEA in practical applications. Whether they think FEA has a future in practical engineering projects, whether they have confidence in the results it produces, and how it can help in the design and analysis of comprehensive engineering projects.
- Instructor guidance and support: Students were asked about their evaluation of the instructor's guidance and support during the teaching process. To find out students' recognition of the level of teacher support in answering questions, providing references, or guiding case studies.

Qualitative analysis of student feedback can help assess teaching effectiveness andimprove teaching methods to provide better teaching experiences and learning outcomes (Gaytan, J., & McEwen, B. C. 2007). It can also help instructors understand students' needs and challenges and target teaching improvements.

3.2 Valuation

Reports, labs, group projects, and presentations may be used in the course as a means of assessing students' understanding and ability to apply FEM analysis (Tam, M. 2014). Students can demonstrate their understanding and ability to apply FEM modeling, solution, and analysis of results by writing an analysis report. The report should include a problem statement, modeling, loading conditions, material properties, interpretation of results, and discussion. The instructor can assess students' ability to synthesize and think independently based on the quality, depth, and logic of the report.

- In the experimental assessment, students are required to use FEM software for modeling, solving, and result analysis. Teachers may give students practical tasks and case studies that require them to solve specific problems in a given environment. The experimental assessment will examine students' practical experimental skills, problem-solving methods, and result analysis skills.
- Group project: Students are organized to work on a group project that requires them to work together to solve a FEM analysis problem or an engineering case. Teachers can assess students' teamwork, communication, and project management skills.
- Presentations: Students can give oral presentations to share their FEA projects, results, and experiences. This assesses the students' ability to express themselves, their presentation skills, and their understanding of the course content.

The combined use of multiple assessment methods above can provide a more comprehensive and integrated assessment of students' learning outcomes and competence development in FEM analysis.

At the same time, attention should be paid to the fairness, accuracy, and trade-offs of the assessment methods to ensure that the assessment results can objectively and effectively reflect the true level of students.

3.3 Advantages

The use of FEM analysis as a teaching tool in mechanical engineering process courses will help students gain a deeper understanding and application of the value and advantages of FEM analysis in the field of mechanical engineering, and improve their analytical and problem-solving skills, as well as their ability to optimize designs and processes. This will provide strong support and preparation for students' future work and research. Compared with the traditional teaching mode, FEM technology has the following advantages:

- Simulating the real situation: FEA can simulate real physical phenomena and processes, and accurately analyze and predict the properties and behaviors of materials through numerical calculations and simulations of their mechanical behaviors and responses of structures. This helps students to understand the key issues and challenges in mechanical engineering.
- Provide practical experience: By actually running the FEA software, students can gain practical experience and familiarize themselves with the use of FEA software, model building, and analysis process. This practice helps students consolidate their theoretical knowledge and develop their ability to apply FEA to real-world engineering problems.
- Optimization of design and process: FEA can help students optimize product design and manufacturing processes. By simulating and comparing different design and process options, students can evaluate the impact of various factors on product performance and manufacturing efficiency to make better decisions and optimization plans.
- Saving costs and resources: FEM analysis can be performed in a virtual environment, reducing the costs and resource consumption of actual testing and manufacturing. By simulating and analyzing on the computer, the feasibility of designs and processes can be evaluated more quickly, potential problems can be detected in advance, and time and cost can be saved.
- Promoting engineering practice: As a commonly used engineering practice method, incorporating FEA into the mechanical manufacturing process course can help students familiarize themselves with and master the analysis tools and methods commonly used in actual engineering. This helps to cultivate students' ability to solve practical problems and make engineering decisions.

3.4 Limitation

FEA as a teaching tool in mechanical engineering process courses also has the following disadvantages:

- Technical complexity: FEA is a complex technique, and for beginners, learning and understanding the principles, modeling, and solution methods of FEA may require a longer time and a higher learning curve. This may increase the difficulty and challenge of learning.
- Software dependency: FEA usually requires the use of specialized software for modeling, solving, and analyzing results. This software may require payment for the purchase or use of licenses and also have certain requirements on computer hardware configuration and system environment. This may introduce software dependency issues and hardware limitations.
- Simplifications or assumptions: To simplify the model and reduce the amount of computation, FEA usually requires some assumptions and simplifications, such as ignoring material nonlinearities, geometric nonlinearities, or contact problems. This may have an impact on the accuracy of the results and these simplifications and assumptions need to be taken into account in practical engineering.
- Parameterization and validation: The results of FEA are affected by several parameters, such as meshing, boundary conditions, and material parameters. Students may not have the experience to accurately set up and validate these parameters at the learning stage, which may lead to inaccurate or misleading results.
- Limitations of physical models: FEA is based on certain physical models and assumptions, and there may be limitations in analyzing some special cases or complex phenomena. Students need to

understand the limitations of the models and analyze and evaluate them in the context of real-world problems when using FEA for teaching process courses.
The above disadvantages do not mean that FEA is not suitable as a teaching tool for mechanical manufacturing process courses, but rather, attention to teaching supplements, and guidance for these disadvantages are needed to ensure that students can properly understand and use the methods and results of FEA.

3.5 Future Work

The future development and research direction of FEM technology in teaching will pay more attention to the interactivity of the teaching process, personalized learning, and the ability to cultivate practical engineering applications. Through continuous innovation and integration of advanced technologies, FEM teaching will better meet the learning needs of students and cultivate more competitive engineering talents. The future development and research direction involves the following aspects:

- Interactive and virtual reality teaching: With the development of virtual reality technology, FEM teaching can more realistically simulate the engineering practice environment. Through the interactive virtual reality teaching platform, students can directly participate in real-time model construction, loading setup, and result visualization to enhance their learning experience and hands-on ability.
- Data-driven learning: Using big data and machine learning technologies, students' data in FEM teaching, such as the modeling process, the solving process, and the result analysis process, can be analyzed. By analyzing students' learning behaviors and performances, targeted feedback and guidance can be provided for personalized teaching to promote students' learning effectiveness and growth.
- Combination of experimental and simulation teaching: The combination of experimental and simulation teaching can provide a more comprehensive and three-dimensional learning experience. By comparing and verifying the actual experimental data with the FEM simulation results, students can deepen their understanding of the FEM method and help them apply FEM technology to solve practical problems.
- High-performance computing and cloud computing: With the improvement of computer hardware level, the application of high-performance computing and cloud computing in FEM teaching will be more widely used. By utilizing the cloud computing platform and large-scale parallel computing resources, the computational process of FEM analysis can be accelerated, and the model-solving efficiency and learning effect of students can be improved.
- Interdisciplinary integration: FEM teaching can be integrated with other disciplines to form a comprehensive teaching program, such as combining materials science, control engineering, sustainable development, and so on. This interdisciplinary integration of teaching can cultivate students' comprehensive application ability and ability to solve practical engineering problems.

4. Conclusion

The above is the application of FEM software in the teaching of mechanical manufacturing process practice, ABAQUS simulation software simulation model force analysis introduced into the teaching of mechanical manufacturing process course is an innovation in teaching methods, with the help of simulation can enable students to deepen the understanding of the course and many abstract concepts, through the practice of the researchto get the following conclusions.

- With the help of software simulation, dry theoretical knowledge can be visualized, due to the convenience of software operation, a variety of cloud diagrams, and animation can be generated directly by the software, these results can be used directly in the classroom but also can be inserted into the multimedia courseware, greatly enriching the teaching resources.

- With the help of FEM simulation, the derivation of complex mechanical formulas is omitted, effectively saving classroom time. As FEM simulation technology is dependent on the theory and practice of mechanics and other disciplines, it should be used as a teaching aid in teaching.
- The auxiliary application of FEM simulation software in lectures enables students to deepen their understanding of theoretical knowledge, makes up for the shortcomings of theoretical and experimental teaching, stimulates students' interest in learning, and improves the teaching effect.

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