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Teaching Practice and Application of ANSYS Simulation Software in the Course of Engineering Mechanics in the Context of New Engineering

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Abstract: In the context of New Engineering, engineering education places greater emphasis on cultivating students' engineering practical ability and digital analysis ability. Engineering Mechanics is highly theoretical and abstract, and traditional teaching is plagued by problems such as insufficient connection between theoretical knowledge and engineering practice. This paper integrates ANSYS simulation software into the Engineering Mechanics course and constructs a closed-loop teaching framework of "theoretical analysis - experimental verification - numerical simulation - result comparison - engineering expansion". Teaching design is developed from the dimensions of teaching objectives, teaching content, implementation process and evaluation system. Taking force analysis of planar structures, beam bending and typical structures of agricultural machinery as cases, students are guided to conduct theoretical calculations, physical experiments and ANSYS simulations to strengthen their understanding of mechanical knowledge and engineering application. Teaching practice indicates that this mode realizes the visualization of abstract mechanical laws, promotes the transformation of students from "being able to calculate" to "being capable of analysis and application", and improves their engineering awareness, digital analysis ability and comprehensive practical ability. The research provides references for the teaching reform of the Engineering Mechanics course in the context of New Engineering.

Keywords: engineering mechanics; numerical simulation; experimental teaching; teaching reform

1. Introduction

With the continuous advancement of the new round of technological revolution and industrial transformation, emerging technologies such as artificial intelligence, digitalization and intelligent manufacturing have constantly reshaped the production modes and technical systems of the engineering field, and put forward new requirements for talent cultivation in higher engineering education [1]. Relevant documents issued by the Ministry of Education of China clearly state that the construction of New Engineering should promote reforms in engineering education concepts, talent cultivation modes, and teaching quality evaluation, and strengthen the cultivation of students' practical abilities, innovative abilities, and problem-solving abilities for complex engineering problems [2].

As an essential professional basic course for engineering majors including mechanical engineering and agricultural engineering, Engineering Mechanics mainly consists of statics and mechanics of materials, which lays a crucial theoretical foundation for students' subsequent study of mechanical design, engineering structures, mechanical principles and other relevant professional courses [3]. The core contents of the course, including force analysis, equilibrium equations, internal force analysis, stress distribution, deformation laws and strength conditions, are highly theoretical and abstract. The traditional teaching mode is dominated by teacher lectures, formula derivation and exercise training, which is effective in cultivating students' theoretical calculation ability. However, when involving engineering problems such as complex structures, spatial force

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bearing and local stress concentration, it is difficult to fully present actual mechanical phenomena merely through theoretical formulas and two-dimensional schematic diagrams [4].

With the development of computer-aided engineering technology, finite element analysis has become a vital technical method for the analysis and optimization of engineering structures. ANSYS can conduct mechanical response analysis of complex structures by establishing geometric models, defining material properties, applying constraints and loads, meshing models and implementing solutions. Relevant teaching resources also take structural mechanics, dynamics and other contents as typical simulation application directions in engineering education. The introduction of ANSYS into the Engineering Mechanics course is not a simple addition of software operation training. Instead, it restructures the logical relationship among theoretical knowledge, experimental teaching and engineering practice with the help of digital tools, enabling students to understand mechanical concepts, verify theoretical laws and complete engineering analysis in real problem scenarios [5].

The First Principles of Instruction proposed by Merrill emphasizes that learning should be centered on real problems and follow a complete process of activating prior knowledge, demonstrating new knowledge, applying knowledge and transferring knowledge. This concept is highly consistent with the ANSYS-aided teaching of Engineering Mechanics. Therefore, based on the talent cultivation requirements of New Engineering, this paper explores the in-depth integration of ANSYS simulation software with the teaching content of Engineering Mechanics, and constructs a collaborative teaching mode integrating theory, experiment and simulation, so as to improve the engineering nature, practicality and comprehensiveness of course teaching [6].

2. Existing Problems

2.1. Abstract Theoretical Knowledge

Engineering Mechanics involves a large number of abstract concepts and mathematical models, such as moment, constraint reaction force, internal force, stress, strain, and bending deformation. In conventional teaching, teachers mainly explain course contents through force diagrams, formulas and two-dimensional structural schematic diagrams. Although students can complete computational exercises in accordance with standard procedures, they lack in-depth understanding of core engineering problems, including "why the model is established in such a way", "how stress distributes inside the structure", and "why the dangerous section appears at a specific position".

Especially in the part of mechanics of materials, stress and strain are internal state variables of structures. Students are unable to directly observe their spatial variations with the naked eye, and relying solely on blackboard writing and static schematic diagrams tends to result in formula-memorization-oriented learning.

2.2. Insufficient Connection between Teaching and Practice

The ultimate goal of Engineering Mechanics teaching is not formula derivation itself, but the application of mechanical theories to understand and solve engineering problems. However, most traditional course cases adopt idealized rod, beam and truss models, which are divorced from the actual mechanical structures that students commonly encounter. In practical engineering, mechanical components usually present characteristics such as complex geometric shapes, multiple load actions and stress concentration, and their force states cannot be fully described by basic theoretical formulas.

Accordingly, course teaching faces a core challenge: how to help students recognize the practical correlation between mechanical formulas and engineering structures without compromising the effectiveness of basic theoretical teaching.

2.3. Partial Segregation between Experiment and Theory

Traditional mechanical experiments assist students in recognizing the force-bearing and deformation laws of materials. Nevertheless, most experiments are conducted on standard specimens. Despite the representativeness of experimental phenomena, they are inconsistent with real engineering mechanical structures. Furthermore, limited by experimental conditions, equipment quantity and classroom teaching duration, students can only observe a small number of typical working conditions, which makes it impossible to carry out continuous analysis on variations of structural parameters, loads and other influencing factors.

ANSYS can effectively complement theoretical calculations and physical experiments. Specifically, theoretical calculations are adopted to establish basic mechanical relationships, physical experiments to acquire real physical responses, and numerical simulation to visualize the internal stress, strain and deformation fields of structures that are difficult to observe directly, so as to realize mutual verification among the three teaching approaches.

2.4. Deficient Engineering Digital Competence of Students

In the context of New Engineering, the solution of engineering problems increasingly relies on digital modeling, numerical analysis and virtual simulation technologies. Students who only possess traditional theoretical calculation capabilities are difficult to meet the requirements for analyzing complex engineering problems. Therefore, it is essential to appropriately introduce engineering simulation tools into the Engineering Mechanics course. This enables students to understand the complete basic process from engineering problem analysis, mathematical modeling and digital model establishment to result evaluation, thereby laying a solid foundation for their subsequent professional courses and engineering practice.

3. Teaching Design of Integrating Ansys into the Engineering Mechanics Course

3.1. General Ideas of Teaching Reform

To address the aforementioned problems existing in traditional teaching, the curriculum teaching reform follows the basic principle of "taking theory as the foundation, experiment as verification, simulation as expansion, and engineering as the carrier". In this reform, ANSYS is embedded into the original teaching process instead of being arranged as an independent software operation module. The overall teaching mode is illustrated in Figure 1.

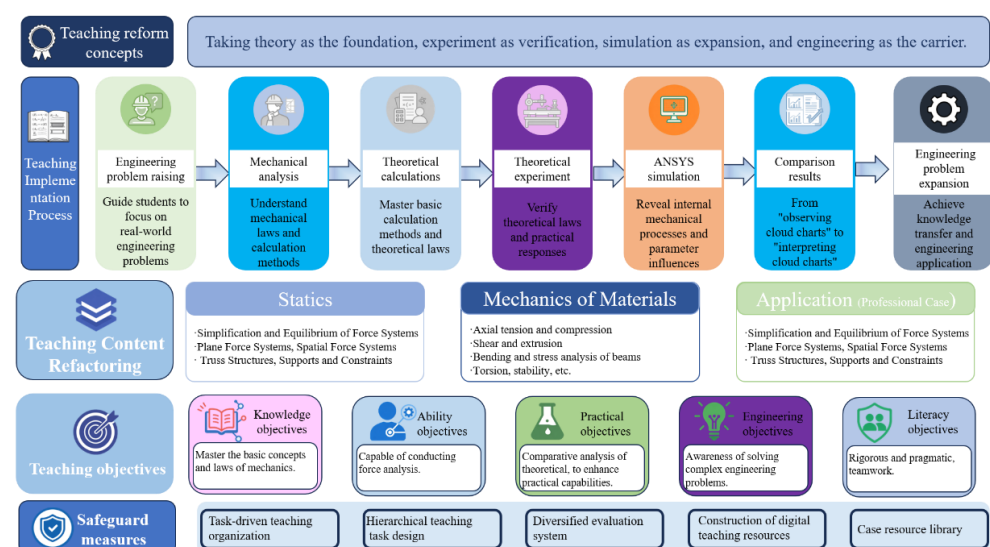


Figure 1. Overall Teaching Model Diagram

This reform constructs a complete teaching chain covering engineering problem raising, mechanical phenomenon analysis, theoretical model establishment, theoretical

calculation, physical experiment, ANSYS modeling and simulation, comparison between simulation and experimental results, error analysis, and engineering problem expansion. In this teaching system, theoretical teaching answers the questions of "what are the mechanical laws and how to conduct calculation", physical experiments verify "whether actual structures follow the same mechanical laws", and ANSYS simulation reveals "the internal structural changes and the influences of parameter variations". Ultimately, students are guided to figure out how to solve practical engineering problems by applying mechanical laws. This teaching mode not only retains the intact theoretical system of the Engineering Mechanics course, but also highlights the characteristics of digital engineering education.

3.2. Teaching Objective Design

The original teaching objectives, which merely focus on knowledge mastery, are expanded into five dimensions including knowledge, ability, practice, engineering application and literacy.

Knowledge objectives: Master the basic concepts, fundamental laws and calculation methods of statics and mechanics of materials, and understand the basic principles of finite element simulation.

Ability objectives: Conduct force analysis and establish mechanical models independently; complete the modeling, meshing, boundary condition setting and result post-processing of basic structures by applying ANSYS software.

Practical objectives: Compare theoretical calculation results, mechanical experimental data and simulation results, and analyze errors and their causes.

Engineering objectives: Transfer acquired mechanical knowledge to practical mechanical structures, and initially form the awareness of solving complex engineering problems.

Literacy objectives: Cultivate rigorous and pragmatic academic attitudes, team collaboration spirits, active inquiry awareness and engineering responsibility awareness.

The above objective setting enables ANSYS to serve as an effective teaching medium for mechanical knowledge learning and engineering ability cultivation, rather than an isolated computer tool.

3.3. Teaching Content Restructuring

According to the curriculum knowledge system, ANSYS application contents are embedded into the typical knowledge points of statics and mechanics of materials. In the statics section, cases such as planar trusses, beam structures and simple mechanical devices are selected to guide students to complete force analysis, constraint setting and structural deformation analysis. In the mechanics of materials section, simulation tasks are designed focusing on axial tension, torsion, beam bending, stress concentration, structural stability and other core contents.

In the comprehensive application stage, engineering objects with professional characteristics are adopted, such as agricultural machinery frames and key load-bearing components of seeders, enabling students to apply basic theoretical knowledge learned in the course to real engineering structures. The progressive teaching arrangement of "basic knowledge - typical structure - professional case" effectively reduces students' cognitive load when confronting complex simulation models directly.

4. Implementation of the Teaching Mode

4.1. Theoretical Analysis Stage: Establishment of Mechanical Models

The teaching process starts from practical engineering problems. Taking simply supported beams or cantilever beams under external loads as typical scenarios, teaching questions are put forward: "Where is the beam most prone to failure under load? Are the stresses consistent at different positions?"

Firstly, students calculate support reaction forces according to static equilibrium conditions, establish the relationship between shear force and bending moment via the

section method, and further solve normal stress and deflection using classical mechanics of materials formulas.

This stage focuses on model establishment and theoretical derivation, enabling students to recognize that ANSYS calculation results are not directly output by software, but derived on the basis of reasonable mechanical assumptions and correct boundary conditions.

4.2. Experimental Verification Stage: Observation of Actual Mechanical Responses

Based on theoretical calculation results, mechanical experiments are carried out. For example, in the beam bending experiment, the displacement and strain changes under different loading conditions are measured to help students obtain authentic physical responses of structures.

Teachers guide students to think deeply about several core questions: Whether the supports in theoretical models are completely consistent with actual supports; whether the actual material properties match the theoretical parameters; whether errors exist in instrument measurement; and whether component manufacturing errors affect practical structural results.

Through the above thinking exercises, students can understand that theoretical models are inherently idealized, and engineering analysis requires full consideration of the differences between model assumptions and actual engineering structures.

4.3. Simulation Analysis Stage: Construction of Ansys Digital Models

After completing physical experiments, students construct digital models corresponding to experimental objects in ANSYS. The standardized implementation process includes eight steps: (1) Establishing or importing geometric models; (2) Setting material parameters; (3) Generating reasonable mesh models; (4) Defining constraints and loads; (5) Solving structural mechanical responses; (6) Acquiring displacement, stress and strain results; (7) Analyzing dangerous structural regions; (8) Comparing simulation results with theoretical calculation and experimental data.

In this stage, teaching emphasis is placed on theoretical principles rather than mechanical memorization of menu positions and software operations, focusing on guiding students to understand why relevant settings are adopted.

Specifically, in terms of boundary conditions, students are guided to analyze the corresponding relationship between actual support forms and finite element models; in terms of meshing, students learn the influence of mesh quality on the reliability of calculation results; in terms of stress cloud diagrams, students interpret the physical causes of stress concentration based on basic mechanics of materials knowledge.

4.4. Comparative Analysis Stage: From "Observing Cloud Diagrams" to "Interpreting Cloud Diagrams"

A common problem in simulation teaching is that students mistakenly regard the generation of intuitive stress cloud diagrams as the completion of structural analysis. Therefore, clear requirements for result interpretation are set in the teaching process. Students are required to answer a series of targeted questions: Where does the maximum structural displacement occur? Are the maximum stress areas consistent with the theoretical dangerous sections? What causes the discrepancies between theoretical calculation and simulation results? Are experimental results completely consistent with simulation data? How do structural responses change with variations in model parameters?

Only when students can fully explain the above problems can they truly grasp the connotation of simulation results and complete in-depth structural analysis.

5. Typical Teaching Case Design

5.1. Case 1: Force Analysis of Planar Truss Structures

In the teaching of statics, planar trusses are adopted as the research object. Traditional teaching mainly calculates the internal force of each member through the joint method

and section method. With the introduction of ANSYS, the teaching process is further expanded and optimized. Firstly, the structural force model is established based on statics principles to calculate the internal force of key members. Secondly, the corresponding structural model is built in ANSYS, with material properties, joint constraints and external loads set reasonably. Thirdly, the axial force and deformation characteristics of each member are obtained from simulation results. Finally, a comparative analysis is conducted between theoretical calculation data and simulation results.

During the teaching process, the magnitude and action position of external loads can be adjusted arbitrarily, allowing students to observe the variation law of member internal forces under different working conditions. The core objective of this case is not to enable students to proficiently operate software buttons, but to help them establish a complete logical connection among force diagrams, theoretical equations, member internal forces and simulation results.

5.2. Case 2: Beam Bending and Stress Distribution Analysis

In the teaching of beam bending in mechanics of materials, cantilever beams are selected as typical research objects. Teachers first calculate the bending moment and normal stress at different positions through theoretical formulas, and guide students to judge the dangerous sections of structures. Subsequently, physical experiments are carried out to observe the actual deformation of beams. Finally, finite element modeling and simulation are completed in ANSYS.

Through simulation cloud diagrams, students can intuitively observe the variations of stress and displacement at different structural positions, transforming the abstract formulas in textbooks into visualized spatial distribution characteristics. For instance, the theoretical calculation formula of bending normal stress is expressed as:

$$\sigma = \frac{M_y}{I} \quad (1)$$

In conventional learning, students merely memorize symbolic meanings and calculation procedures. With the support of ANSYS stress distribution results, students can further understand the physical connotation of the formula: the absolute value of normal stress increases with the distance from the neutral axis on the cross-section, and the maximum stress generally appears at the position farthest from the neutral axis. This teaching method realizes the unification of theoretical formulas, physical significance and engineering phenomena.

5.3. Case 3: Comprehensive Analysis of Agricultural Machinery Structures

To strengthen the professional characteristics of the course, typical agricultural machinery structures are adopted as comprehensive teaching cases. Taking seeder frames and other load-bearing components of agricultural machinery as research objects, this case firstly analyzes the gravity, traction force and working loads borne by components during operation, and conducts overall force analysis based on statics knowledge. On this basis, a simplified structural model is established in ANSYS to analyze the stress and deformation distribution of the structure.

Furthermore, structural dimensions, material parameters and load working conditions can be modified to explore their influences on structural safety. This teaching process realizes the knowledge transfer from ideal beam models in textbooks to practical mechanical structures. It enables students to recognize that basic mechanical knowledge is not isolated theoretical content, but an important theoretical foundation for the design, performance analysis and structural optimization of mechanical equipment.

6. Teaching Organization and Implementation Strategies of Ansys-Based Course Teaching

6.1. Adopting Task-Driven Mode to Replace Simple Software Demonstration

In teaching practice, excessive class hours should not be spent on introducing the ANSYS software interface in advance. Instead, a task-driven teaching mode is adopted. Taking the task of "verifying whether a beam structure meets strength requirements" as

an example, software operations are decomposed into several standardized steps, including geometric modeling, material definition, boundary condition setting, meshing, solution calculation, and result analysis. Students can master software functions naturally in the process of completing practical engineering tasks. This teaching method effectively avoids the disconnection between software operation training and professional knowledge learning.

6.2. Establishment of Hierarchical Teaching Tasks

Considering the individual differences in students' learning foundations, three levels of hierarchical teaching tasks are designed in this curriculum reform.

Basic level: Students complete standard case simulation based on the models provided by teachers, so as to master the basic operation process of ANSYS software.

Improvement level: Students independently adjust and modify load conditions, material properties or structural parameters, and analyze the influence of different influencing factors on structural calculation results.

Expansion level: Students independently select typical engineering structures to establish simulation models, complete theoretical calculation, experimental verification and simulation analysis, and finally form complete engineering analysis reports.

The hierarchical task design ensures the mastery of basic theoretical knowledge and operational skills for all students, while providing sufficient independent exploration space for students with strong learning abilities.

6.3. Incorporating Simulation Assumptions into the Evaluation System

The reliability of finite element analysis results largely depends on the rationality of model establishment. Therefore, the teaching evaluation system should not only focus on the final cloud diagrams and numerical results, but also attach importance to students' explanation and demonstration of model assumptions.

The evaluation indicators cover the rationality of material parameter selection, the consistency between applied loads and actual working conditions, the feasibility of boundary condition settings, the compliance of mesh quality with calculation requirements, and the engineering significance of simulation results.

This evaluation mechanism guides students to establish a correct cognition of engineering simulation: finite element software is not a black-box tool, and the credibility of simulation results depends on the consistency among practical engineering problems, mathematical models and digital simulation models.

7. Reform of Curriculum Assessment and Evaluation Methods

With the integration of ANSYS into curriculum teaching, the course evaluation mode has gradually transformed from the traditional final-exam-dominated assessment to a process-oriented and diversified evaluation system.

7.1. Theoretical Knowledge Evaluation

Students' mastery of basic concepts, physical laws and calculation methods is evaluated through periodic tests, in-class problem analysis and theoretical calculation exercises.

7.2. Simulation Skill Evaluation

Students' comprehensive capabilities in model establishment, boundary condition setting, mesh generation, structural solution and result post-processing are assessed through ANSYS case tasks.

7.3. Comprehensive Analysis Evaluation

This evaluation dimension focuses on examining students' ability to interpret simulation results based on theoretical knowledge, rather than merely submitting software-generated cloud diagrams perfunctorily.

7.4. Engineering Practice Evaluation

Based on comprehensive engineering cases, students' abilities to identify engineering problems, establish mechanical models, conduct analytical analysis and propose improvement strategies are evaluated comprehensively.

7.5. Learning Reflection Evaluation

Students are required to add analyses of error sources and model limitations in experimental and simulation reports to cultivate their reflective thinking awareness. Finally, a multi-dimensional evaluation system covering theoretical knowledge, experimental practice, simulation analysis, engineering application and learning reflection is established.

8. Teaching Practice Effects and Discussion

8.1. Visualization of Abstract Mechanical Knowledge

A large number of knowledge points in Engineering Mechanics are highly abstract. Traditional teaching can elaborate theoretical formula relationships, but fails to enable students to intuitively perceive the spatial distribution of internal structural states. ANSYS can present stress, strain, deformation and other mechanical results in the forms of cloud diagrams, curves and animations, building a clear logical connection between calculation data and structural responses for students.

Accordingly, students' understanding of core concepts including dangerous section, stress concentration and deformation laws is no longer limited to static schematic diagrams in textbooks.

8.2. Strengthened Correlation among Theory, Experiment and Engineering

Theoretical analysis reveals inherent mechanical laws, physical experiments reflect real structural responses, and ANSYS provides digital analysis tools for complex engineering scenarios. Mutual verification among the three teaching approaches helps students distinguish the functional characteristics of different research methods.

Theoretical calculations emphasize basic mechanical laws and mathematical relationships, experiments focus on the authenticity of structural responses, and simulation highlights the analytical capability under complex working conditions. Comparative analysis of the three approaches enables students to deeply understand model assumptions, boundary condition rationality and engineering errors.

8.3. Cultivation of Students' Ability to Solve Complex Engineering Problems

New Engineering talent cultivation focuses on enabling students to solve practical engineering problems with diversified tools, rather than simply mastering various software operations. ANSYS-assisted teaching allows students to experience the complete engineering analysis process of "proposing problems - establishing models - analyzing problems - verifying results - optimizing schemes".

In particular, combined with the professional background of agricultural machinery, the introduction of practical equipment structures into teaching further strengthens students' cognition of professional engineering problems, and realizes effective connection between basic courses and professional courses.

8.4. Transformation of Teachers' Teaching Roles

With the integration of ANSYS into the curriculum, teachers have transformed from pure knowledge lecturers into learning task designers, engineering problem guides and teaching process evaluators.

In addition to elaborating mechanical formulas and theoretical knowledge, teachers need to focus on supervising and evaluating students' abilities to establish reasonable simulation models, interpret simulation results, and identify discrepancies between model assumptions and actual engineering structures. This transformation puts forward higher requirements for teachers' professional knowledge reserve, engineering practical experience and digital teaching competence.

9. Existing Problems and Improvement Directions in Teaching Practice

9.1. Occupation of Theoretical Teaching Time by Simulation Operations

Excessive arrangement of ANSYS teaching content may lead to the problem of prioritizing software operation over mechanical theory learning. Therefore, the teaching principle of "simulation serving theoretical learning" should be adhered to, and only the simulation functions that effectively interpret core mechanical knowledge points are selected for classroom teaching.

9.2. Differences in Students' Computer Foundations

Students with zero foundation may encounter operational difficulties when contacting finite element software for the first time. To solve this problem, a hybrid teaching method combining teacher demonstration, step-by-step operation guidance, standard case templates and hierarchical tasks is adopted to reduce the threshold of software learning.

9.3. Mechanical Acceptance of Simulation Results

Some students tend to regard software calculation results as standard answers and ignore the rationality of model assumptions and boundary conditions. To address this issue, model rationality evaluation is incorporated into the curriculum assessment, fostering students' engineering analysis thinking of verifying model rationality before confirming result credibility.

9.4. Insufficient Integration of Experiment and Simulation

The mechanism of comparative analysis between experimental data and simulation data needs further improvement in subsequent teaching. For example, digital sensors can be used to collect accurate experimental data such as displacement and strain, which are further compared with finite element simulation results to improve the quantification level of curriculum teaching.

9.5. Lack of Systematic Curriculum Resource System

Current ANSYS teaching cases are fragmented, with a single independent case for each chapter. In follow-up teaching reform, a complete case library will be constructed centering on the whole knowledge system of Engineering Mechanics. Basic cases, comprehensive cases and professional cases will be organized hierarchically to form digital teaching resources with distinctive professional characteristics of agricultural engineering.

10. Conclusion

In the context of New Engineering, the Engineering Mechanics course needs to further strengthen the connection between theoretical knowledge and engineering practice. The introduction of ANSYS simulation software effectively reforms the traditional teacher-centered lecturing and student-centered calculation teaching mode, and visualizes abstract mechanical theories through physical experiments and digital simulation.

Centering on the teaching characteristics of Engineering Mechanics, this paper constructs an innovative teaching mode taking engineering problems as the carrier, theoretical analysis as the foundation, physical experiments as the verification means, and ANSYS simulation as the expansion approach, forming a closed teaching loop of "theoretical calculation - experimental verification - simulation analysis - result comparison - engineering expansion".

In teaching practice, typical cases including planar truss structures, beam bending and agricultural machinery structures are adopted to integrate statics and mechanics of materials knowledge with digital engineering analysis methods. This teaching mode enables students to not only master basic mechanical theories, but also initially establish the awareness of engineering modeling and simulation analysis.

Teaching practice verifies that the application value of ANSYS in Engineering Mechanics teaching lies in promoting knowledge understanding, strengthening engineering practice and cultivating digital analysis ability, rather than simply improving

students' software operation skills. In the future, the curriculum case library and multi-dimensional evaluation system will be further improved combined with course experiments and professional case development. Meanwhile, project-based teaching based on real engineering problems will be explored to enable Engineering Mechanics to better play its fundamental supporting role in the New Engineering talent cultivation system.

In general, the integration of ANSYS and Engineering Mechanics is not a simple superposition of traditional teaching content, but an exploration of collaborative reform in teaching concepts, teaching contents, teaching methods and evaluation systems driven by digital technology. This teaching practice provides a valuable reference for improving the engineering nature, practicality and innovation of basic engineering courses.

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