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Exploration of the Application of Digital Twin Technology in Engineering Teaching under the Background of Digital Information—Taking the Professional Course of Materials Forming and Control Engineering at Hefei University of Technology as an Example

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Abstract: *With the increasing proportion of digital and information-based elements in industrial technology and the rapid development of Internet+ education means, the traditional teaching means in engineering teaching have posed a huge challenge, especially in practical teaching courses, the problems of traditional teaching methods have become increasingly prominent, such as the abstraction of micro/nano scale content in practical courses, the lack of practical teaching resources, and the lack of integration of practical teaching and teaching means. This article takes the practical teaching of the professional course belonging to the mechanical material forming and control engineering major as an example. Based on digital twin technology, a concept of virtual simulation practice integrated teaching based on physical experiment big data is proposed, which realizes the teaching mode reform of practical teaching in the engineering teaching process and provides reference and guidance for other courses.*

Keywords: *Digital Twin Technology, Engineering Teaching, Informatization and Digitization, Application Exploration*

1. Introduction

Practical teaching is a very important part of higher education, especially in the new engineering environment with the rapid development of computer technology and the increasing degree of industrial digitization and informatization. In 2012, the Ministry of Education pointed out that effective education should effectively strengthen the practical teaching link[1], and in 2018, it clearly proposed to accelerate the in-depth integration of information technology and education and teaching[2], and then in 2021, the Ministry of Education replied to the "Proposal on High-quality Online and Offline Integration to Promote the Healthy Development of Education", which once again clearly pointed out that it is necessary to fully stimulate the enthusiasm of schools, teachers and students to apply online education and teaching resources, and promote the integrated development of online and offline education. Promote the deep integration of information technology and education and teaching, and develop more equitable and high-quality education[3]. Compared with the traditional multimedia teaching methods, digital twin technology will bring students a more vivid and immersive classroom learning experience, especially for engineering professional courses, which involve a variety of process professional terms and principles in the course teaching process, and it is difficult for students to absorb and understand the course knowledge points through text, pictures and animations. It is of great significance to realize the reform of traditional teaching thinking and methods for cultivating engineering and technical talents.

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2. Problems existing in the teaching of digital twin technology and professional practice

2.1 Digital twin technology

Digital twin technology was first proposed by Professor Michael Grieves of the University of Michigan in United States as a new concept of cyber-physical integration in the field of advanced manufacturing technology, which was named after the "Information Mirroring Model" in the early stage and gradually evolved into the "Digital Twin"[4]. Digital twin technology is a technical means to simulate, verify, predict, and control the whole life cycle process of physical entities with the help of historical data, real-time data, and algorithm models, and digital twin technology, as a new carrier of online and offline integration, will have infinite possibilities in teaching[4-6].

Digital twin technology is an advanced form of 3D digital modeling, representing the future development trend of high-end manufacturing industry, and is also one of the core technologies of intelligent manufacturing, which is suitable for aerospace, electric power, ships, cities, automobiles, and other fields[7].

2.2 Characteristics of the profession and problems in practical teaching

In this paper, the material forming and control engineering of the course "Forging Process and Mold Design" belongs to the mechanical major, which is an engineering major that realizes the purpose of product manufacturing, takes the material as the processing object, takes the molding technology as the means, and takes the process control as the quality assurance measure. The teaching content of this major in our school is mainly composed of four main directions of forging, stamping, casting, welding and forming and five parts of the small direction of polymer resin molding, the specific teaching content involves forming equipment, forming molds, forming processes and principles, etc., and the practical teaching content is mainly composed of metalworking practice, graduation practice, generation practice, course experiment, course design and graduation design, of which production practice and graduation practice are mainly completed in professional-related enterprises.

The content of the material forming and control engineering course mainly includes five parts: casting, welding, forging, stamping and resin molding, and the teaching is carried out with the process, principle, equipment and mold as the point, and the principles involved in the course are difficult to understand and abstract, especially the principles involved in the process at the micro scale, such as the deformation and dynamic recrystallization process of grains in the hot forging process, the formation of microdefects in the casting process, and the holes and fluid movement states in the resin injection molding process. At present, the following problems are found in the process of practical teaching:

(1) There is a lack of teaching resources in the practical teaching links of production internship and graduation internship

At present, most enterprises are reluctant to receive college internship tasks considering safety factors or production schedules, especially in black light factories with a high degree of intelligence, and the internship process is mainly based on visiting and explaining, which leads to the fact that during the internship, some equipment and processes can not be seen or understood, so that the important practice links of production internship and graduation internship are mere formalities. The internship effect and purpose that do not meet the requirements of the practical education link and professional training goals of higher education.

(2) There is a problem of insufficient matching between teaching methods and experimental principles in the course experiment

With the rapid development of multimedia technology, multimedia teaching methods run through the teaching process in the classroom teaching process, such as multimedia teaching auxiliary platforms such as Rain Classroom and Learning APP, but there is still a problem of single teaching method for the practical teaching of engineering majors. The material forming and control engineering major belongs to the mechanical class, and the professional practice teaching courses involve many aspects such as forming technology, mold, process principle, process equipment, etc., and only using traditional multimedia teaching methods to teach will have the problems of poor student acceptance, poor teaching integration and poor mobilization of students' subjective initiative.Take the course of “Forging Process and Mold Design” as an example, during the explanation of the microstructure evolution in the process of cold forging and hot forging, it is difficult to accurately explain the change of microstructure evolution in the forging process, so the teacher is needed to let the students to master knowledge by

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further explanation.

(3) In the process of experimental implementation, there is a problem of insufficient advancement of experimental methods

In addition to having a solid theoretical foundation, it is also necessary to have a certain practical ability. For example, the solidification process of molten metal in casting will involve the nucleation of grains at the microscopic level, the growth and the generation of bubbles, etc., such as the flow state of molten plastic in the gating system and cavity in the resin molding process, which cannot be observed in real time by traditional experimental means.

3. The application status of digital twin technology in teaching

With the rapid development of science and technology and the requirements for scientific and technological talents in the context of new engineering, the importance of practical links in engineering majors has become increasingly prominent, and practical links can improve and cultivate students' hands-on ability and ability to link theory with practice[8-10].

Wang Liyan et al.[10] found that the addition of digital twin technology can strengthen students' learning effect, improve the effect of linking theory with practice, and improve students' comprehensive practical ability, but it does not clearly explain how digital twin technology is implemented in the course. Ou Peipei et al.[5] analyzed the characteristics of digital twin technology and discussed its application in scenarios such as automotive virtual commissioning and production and assembly guidance, which further determined the broad application prospects of digital twin technology and provided reference for the teaching of automotive engineering related courses. Zhang Zhi[10] designed and modeled the cloud classroom based on digital twin technology, and converted the abstract data in learning into image data through the digital twin cloud classroom, so as to improve the teaching quality and learning effect. Shen et al.[11] analyzed the application and progress of digital twin technology in heat treatment, and pointed out that the application of surface digital twin model in industrial workshops has some shortcomings and pointed out that the current digital twin should deal with complex physical models and diversified data processing. Zhang Fan et al.[12] combined digital twin technology with artificial intelligence technology to put forward a new idea of intelligent mine construction based on digital twin + Al, and provided a theoretical reference for the construction of new engineering of intelligent mines in the future by studying the application of digital twin technology in intelligent mines. Wu Qing et al.[13] developed a comprehensive experimental platform for mechanical and electrical courses based on digital twins for mechanical design, manufacturing and automation, which realized the cross-integration of various knowledge points, solved the experimental synthesis between various mechanical and electrical courses, and provided new ideas and new models for experimental teaching.

From the research of many scholars, it can be seen that digital twin technology has slowly moved from simple digital technology to teaching application, combining physical space and virtual space, providing a new way and method to solve the abstract problems existing in the traditional teaching process.

4. Exploration and effect comparison of digital twin technology and engineering courses

4.1 The process of combining digital twin technology with practical course teaching

As a national double-first-class professional construction site[14], the teaching content of the material forming and control engineering major of our university mainly includes four parts: forging and stamping of metal plastic forming, casting of metal liquid forming, welding of metal joining forming and plastic molding of polymer forming. This paper takes the professional course "Forging Process and Mold Design" offered in the second semester of the third year of the major as an example to explore the practical teaching and application of digital twin technology, which mainly teaches the process characteristics and classification of forging, the selection of common materials and equipment for forging, the laws of various forging forming and mold design methods, etc., and the teaching exploration of digital twin technology involves virtual teaching environment design technology, three-dimensional solid modeling technology, three-dimensional animation technology, digital twin virtual simulation technology, etc., so that practical teaching is no longer based on pictures. Simple animations and simple experiments are presented, but students can immerse themselves in the

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experimental process from experimental design, experimental principles to experimental phenomena and results, as a part of the experimental materials, and dynamically reproduce the changes in metal structure and surface friction state involved in the experiment, so as to understand the experimental content more deeply, accurately and efficiently, and achieve the practical teaching objectives of the course. Figure 1 shows the digital twin technology development road map of the "Forging Process and Mold Design" course, which is mainly composed of three parts: experimental content modeling, data transmission, and platform coupling. Experimental content modeling is to convert the process, equipment and molds involved in the course experiments and theoretical calculations into digital models. The data transmission module is to digitally display physical experiments and virtual experiments through VR virtual technology and digital twin technology; Platform coupling is based on the intelligent training platform, which couples the digital twin built based on digital twin technology into the platform, and completes the evaluation and feedback of experimental practice courses.

Taking the flash die chamber experiment teaching in the course as an example, the content model is shown in Figure 2, which mainly includes:

(1) Determine the parameters of forging process, mold and equipment, and complete the experimental design mainly according to the content of the course learned, so as to provide data support for virtual experiments;

(2) Complete the development of three-dimensional models according to process calculations (including the microscopic cellular automaton grain transformation models for microscopic metal internal structure changes, and the macroscopic friction, stress, and strain force algorithm models);

(3) Development of three-dimensional model of the course flash experimental process.

Through the digital twin technology, the physical experiment and the virtual experiment are combined, and the abstract and incomprehensible principle problems in the experimental process are successfully solved.

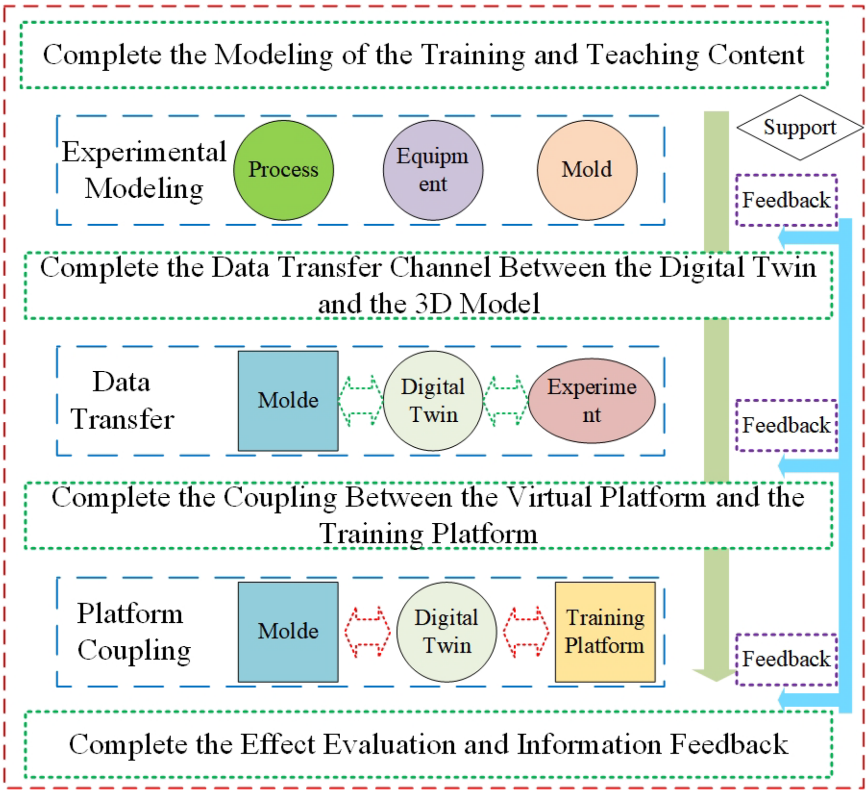

Figure 1: Implementation Flowchart of Digital Twin Technology Experimental

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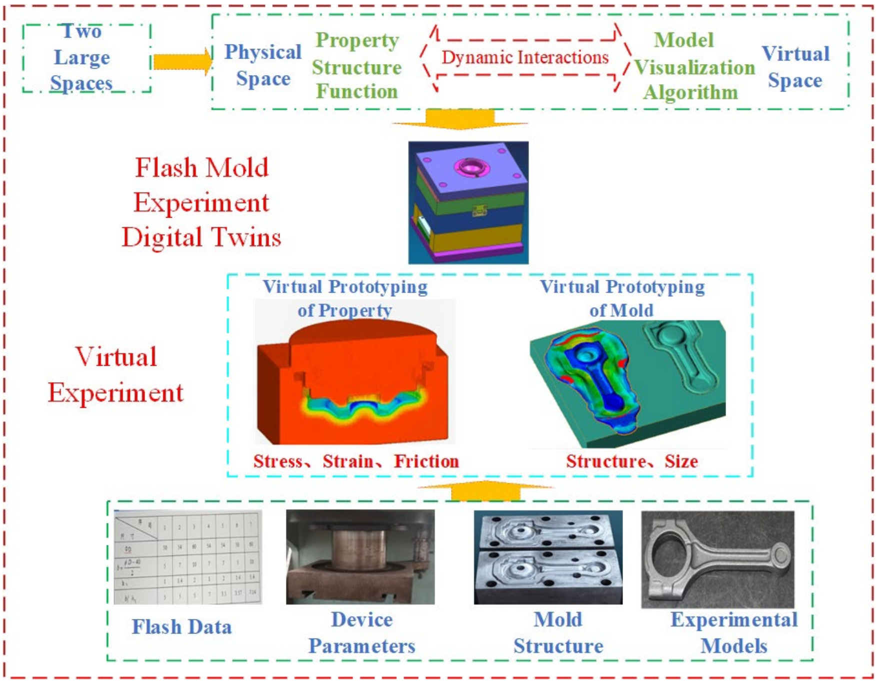

Figure 2: Distribution Diagram of Experimental Content for Flash Die Chamber in "Forging Process and Mold Design"

4.2 Comparison of teaching effects

After the 2021 students of the "Forging Process and Mold Design" course of Material Forming and Control Engineering conducted the experimental teaching of digital twin technology, the statistical data of the questionnaire feedback form of the experimental teaching effect are shown in Table 1, and the histogram is shown in Figure 3, which has a more in-depth understanding of the phenomena involved in the experimental teaching, indicating that the application of digital twin technology in practical teaching is worthy of further exploration and in-depth, and also lays the foundation for the later promotion to the practical teaching of other courses.

Table 1: Feedback Statistics Table for Digital Twin Technology Experimental Teaching Questionnaire

Number of Questionnaires	89		Number of Returns	87
The Name of the Experiment	The Influence of Flash Size on Die Filling and Hammer Forging Film Structure			
Indicators	Process	Theory	Equipment, Mold	Comprehension
Evaluation Methodology	Die Forging Process	Theoretical Basics	Presses, Molds	Analytical Skills
Achievement of Pre-reform Goals	82%	86%	80%	79%
Degree of Achievement of Goals After the Reform	94%	97%	95%	96%

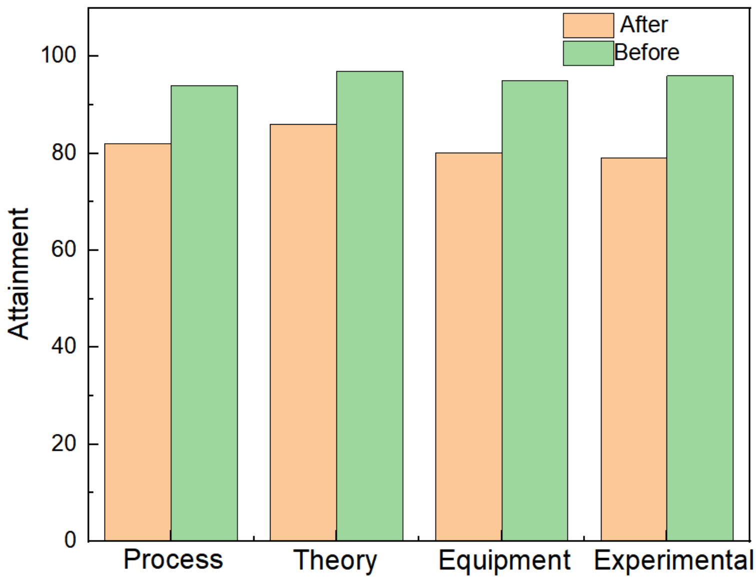

Figure 3: Bar Chart of Teaching Effectiveness before and After Improvement

5. Conclusions and prospects

To sum up, under the background of informatization and digitalization of new engineering, the application of digital twin technology in the process of practical engineering teaching will further improve the teaching effect, and online teaching will become a trend to replace some field internships. This paper explores the establishment of an information platform for the practical teaching of digital twin technology for the course of "Forging Process and Mold Design", which belongs to the material forming and control engineering major of mechanical engineering, which will surely provide reference for the practical teaching of other engineering courses.

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