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Exploring the combination of engineering training courses and competitions based on engineering drawing-3D printing

Chenghui Lin[1,a], Jian Xu[2,b], Yutao Cao[2,c], Jie Chen[2,d], Yi Tang[2,e], Wangjie Lai[1,f], Shunqi Zhang[1,g,*]

[1]*School of Mechatronics Engineering and Automation, Nanchen Road, Shanghai, China*
[2]*National Experimental Teaching Demonstration Center for Engineering Training, Shanghai University, Nanchen Road, Shanghai, China*
[a]*linchenghui07@shu.edu.cn*, [b]*xujian9977shu.edu.cn*, [c]*539637228@qq.com*, [d]*64776727@qq.com*, [e]*418576337@qq.com*, [f]*635293972@qq.com*, [g]*zhangsq@shu.edu.cn*
[*]*Corresponding author*

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Abstract: 3D printing technology is a kind of additive manufacturing technology that has developed rapidly in recent years, and practical teaching with 3D printing technology as a platform is being adopted by more and more colleges and universities as a new form of practical teaching, and it has also become the educational training goal of many colleges and universities. Based on 3D printing technology, through the cross-teaching of 3D modeling and engineering drawing courses-3D printing practice courses, using the tournament proposition as an example, it makes students have a deeper understanding of design, modeling and manufacturing. This paper proposes teaching methods and practical training contents to explore the combination mode of 3D printing technology and class competition.

1. Introduction

3D printing technology is an innovative production technology that has developed rapidly in the new market of the 21st century, and it plays an important role in many fields with its advantages of being able to manufacture parts with complex structural features and integrated molding of product parts.[1] Therefore, the study of mechanical structure design based on 3D printing can not only make a guide for the development of 3D printing technology and its equipment, but also is a necessary path under the development trend of green and intelligent high-end equipment manufacturing industry in the future.

At the same time, with the continuous development of science and technology and the continuous upgrading of industrial structure, social development and enterprise innovation gradually need a large number of talents with solid professional knowledge and strong practical innovation ability.[2,3] Practical teaching is an important part of a variety of teaching methods in institutions of higher learning, as a supplement and extension of the theoretical teaching content, while with some of the proposition of the competition with each other, to complete the teaching of the prescribed tasks, so that students not only mastered the professional knowledge, but also in the process of improving the hands-on ability to participate in innovation competitions, and ultimately improve the overall ability of students.[4] Therefore, this paper proposes that, based on 3D printing technology, with examples of competition propositions, in the teaching of three-dimensional design and engineering drawing courses, to cultivate the ability of students to quickly land the design as a physical object, the comprehensive training of students in higher education.

This teaching is based on the tournament proposition, which teaches 3D modeling and engineering drawing, leads to the main content of 3D printing, and highlights the characteristics of 3D printing technology through the learning and understanding of modern manufacturing methods.[5] According to the molding process of 3D printing, using modern equipment, combined with hands-on practice. Following the teaching principle of exploring and researching, the teaching means of overall design, data analysis, focusing on understanding, and integrating theory and practice with each other are used to complete the teaching and proving from modeling-data-manufacturing-works. This teaching method from shallow to deep, in line with the students' thinking rules and learning characteristics, reflects the concept of rapid design and production of 3D printing technology, and learns to think independently while learning knowledge, the way of thinking i.e. creativity-geometry-analysis-application.[6]

2. Educational Content

2.1. Examples of Tournament Proposition

According to the proposition requirements of Shanghai “Xinte Cup” Digital Innovation Design Competition, students are instructed to carry out the digital design of a certain mechanical product, according to the demand for the design of a 3D printing technology based on the direction of travel can be freely controlled by the potential energy of the mass of the weight as the power source of the automatic three-wheeled cart, as shown in Figure 1. Automatic trolley on demand design pure mechanical obstacle avoidance control device makes the trolley can automatically avoid the cylindrical obstacles set up on the playing field when traveling. In addition to bearings, screws, keys, pins, washers and other standard parts commonly used parts, as well as 1Kg standard weights, hanging weights of the support rods and wires, the other parts are recommended to use the 3D printing process processing and manufacturing; trolley drive, walking and steering energy is obtained from a unified potential energy conversion of the mass of the weights, and shall not be obtained from other sources of energy to run.

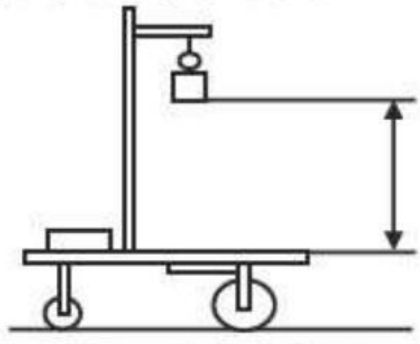

Figure 1: Schematic diagram of carbonless trolley.

2.2. Teaching Arrangement

Situation Analysis: The students are all junior Polytechnic University students, the students have diverse professional backgrounds, but the depth of relevant professional knowledge is insufficient, they only have the foundation of general science knowledge learning, with a certain degree of thinking and logic, taking into account the students' disciplinary backgrounds and application of the ability to cultivate the objectives of the course content arrangement.

2.2.1. Teaching 3D Printing Technology Integrated with Engineering Drawing Course

The integration of 3D printing technology and engineering drawing courses for teaching can solve the problems that can not be seen and touched in engineering drawing courses by virtue of the technical characteristics of 3D printing. Mechanical majors themselves need to link theoretical knowledge with practical situations, and engineering drawing is a course that ultimately applies theory to practice. Therefore, the introduction of more practical content such as 3D printing technology into the drafting course is conducive to enhancing students' interest and increasing the autonomy of learning, thus improving the quality of student learning.

The design phase of 3D printing provides students with the opportunity to design independently, students use 3D modeling software to transform the two-dimensional sketches into three-dimensional models, in this process not only makes the students' ability to read the map has been improved, but also makes the students' spatial imagination to further enhance the students to learn to imagine the three-dimensional model in their minds in the three-dimensional modeling software, which is convenient for correcting the errors and deepening the impression. Of course, the main advantage of 3D printing is that teachers can directly provide a variety of complex structural model parts as teaching aids to students as a reference, students can visualize the structure of the model, and thus more accurately draw the three-dimensional model into a two-dimensional drawing. Teachers can also take advantage of students' interest in 3D printing technology to encourage students to innovate their own modeling, and operate in the classroom to demonstrate how the model designed by the students is manufactured and shaped, which in turn is conducive to the formation of a virtuous cycle by allowing students to discover the joy of practical teaching due to independent exploration.

2.2.2. Cart Structure Design Process

The structural design of the cart is the key to enhance its performance. According to the requirements of the practice program, students implement the project activities step by step in groups of 2 to cultivate students' hands-on practical ability and collaborative and innovative spirit. Through thinking and analyzing, the structure of the cart is determined, and the shortcomings of the 3D printing process, the strength and precision of the 3D printed parts, the length of the 3D printed parts, and the size of the standard parts are also taken into consideration, so as to reduce the number of 3D printed parts by using the standard parts skillfully and adequately, so that all the parts can be printed within the required length of time. This teaching through the establishment of mathematical models on the cart parametric design, reliability design and optimization design, the use of SolidWorks, CATIA, CAD and other software for auxiliary design, gives full play to the role of modern design software in the auxiliary design. Figure 2 shows the design flow of the cart.

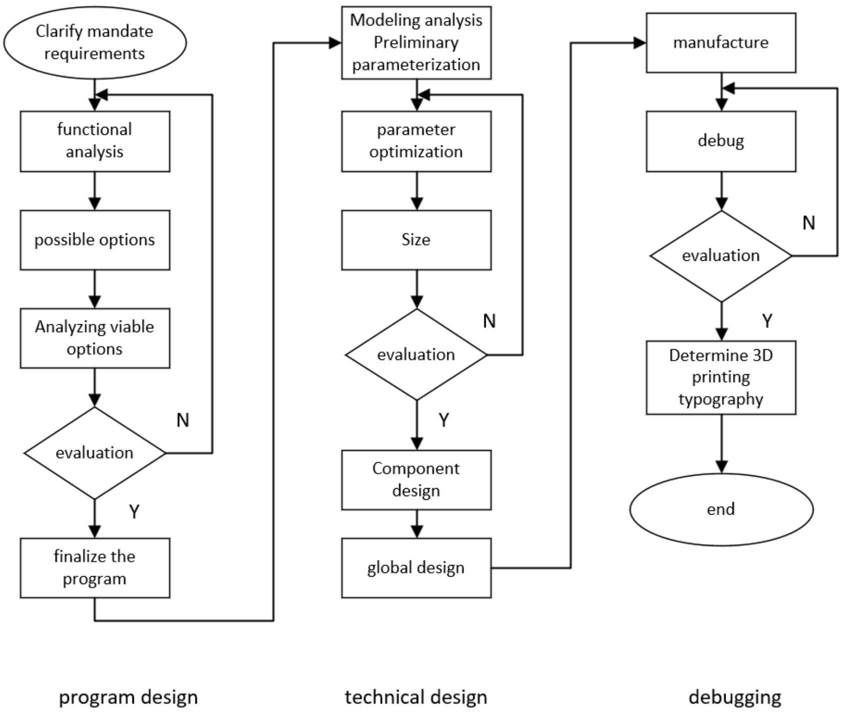

Figure 2: Design flow of the cart

2.2.3. 3D Printing Based Design Solution

In the design, teaching students should take into account the advantages and disadvantages of 3D printing, as well as making full use of standard parts to carry out the structural design of the cart. According to the function of different parts of the carbonless cart, the cart structure can be divided into five parts: energy conversion mechanism, transmission mechanism, steering mechanism, fine-tuning mechanism, driving mechanism, to determine the structural design of each part of the cart.

And students clear design to adhere to the principles: first determine the type and size of the important standard parts, such as bearings, etc., to facilitate the determination of the size of the parts and components of its assembly; standard parts of the size of the standard parts as uniform as possible to reduce the difficulty of assembly, saving assembly time; available standard parts to replace the part of the standard parts instead of as much as possible, such as winding shafts, rear axle shafts, etc. can be used to replace the long cylindrical pins to reduce the number of printed parts and improve the accuracy of assembly; carbon-free trolley. Assembly accuracy; carbonless trolley center of gravity should be low, to prevent the trolley from tipping; the structure is as simple and compact as possible, as far as possible to reduce the number of transmission parts; operation, adjustment should be convenient and flexible; movement does not interfere, and so on. According to the above requirements and principles, the structure of the trolley has a variety of feasible design options, each group of students can analyze and compare, weigh the pros and cons, to determine the best option for the perceived hunger.

The general transmission mechanism is mainly gear drive, pulley drive, chain drive. In order to make the trolley traveling route according to the proposition needs to design the trajectory operation and walking distance as far as possible, the transmission mechanism needs to have a high efficiency of force transfer, mechanical structure is stable, reliable and simple and low total mass and other characteristics. Therefore, the selection of a gear drive to ensure transmission accuracy and transmission ratio.

In order to make the trolley according to the established "S" trajectory, the trolley should be able to control the direction of the cycle swing. General can move according to a specific pattern of institutions: cam mechanism, crank rocker, toothed belt groove, groove wheel and so on. The cam mechanism is complicated in calculation and requires high precision; the toothed belt groove is difficult to meet the long distance traveling; the cam groove is a groove made in the face of the wheel, and the groove is connected to the rocker, which drives the rocker to swing left and right regularly, and drives the steering wheel to rotate regularly, which is large and not easy to be adjusted. After analysis, the choice and design of crank rocker structure to control the direction of movement of the trolley. Crank rocker mechanism is relatively simple, high precision, and easy to adjust.

The drive mechanism has single-wheel drive, two-wheel same-speed drive and two-wheel differential drive. Each group of students can consult the mechanical design manual, and ultimately can choose to use the simpler structure of the single-wheel drive.

Lecture, demonstration, case study, software simulation, on-site practical guidance to inspire initiative. After each group of students have decided on the program, they can show and discuss with each other.

2.2.4. Design Optimization and Instructional Summaries

Compared with the traditional metal carbon-free trolley, the carbon-free trolley molded by 3D printing technology can be optimized in terms of structural design by simplifying the details, integrating the printing of parts and components, adding reinforcement at the place of stress concentration, and punching holes at the place of no need to withstand large stress, etc., which can reduce the time required for 3D printing, lower the difficulty of assembly, and reduce the time of assembly.

In separate lessons, we will explain structural hollowing, hole parts and solid structure design, rounded corners and reinforcement, step design and printing layout and post-processing.

(1) Structural Skeletonization: 3D printing, as an additive manufacturing technology, has great flexibility in printing parts, and is capable of printing parts of various shapes. When designing models, hollowing out less stressed parts or large parts can greatly reduce printing time and save print material.

(2) Hole parts and solid structure design: the design of the trolley has a lot of holes that need to be matched with shafts and bearings, some holes need to be tightened with other parts through the screws and nuts, and some of them need to be solidly connected to the shaft. 3D printed parts are not strong enough, the material is soft and can not be tapped, and when solidly connected to the shaft can not be used to ensure that the fastening of the screw to ensure that solidly connected to the fit, so it is necessary to design a special solidly connected to the holes in which the nut instead of threads, through the screws, the nut instead of the threads, and then the parts are threaded through the screws. Therefore, it is necessary to design a special fixation hole, in which a nut is placed instead of threads, and the nut is threaded with the screw to produce a larger compression force to achieve the effect of fixation.

(3) Rounded corners and reinforcement: When designing the parts, the right angles that are prone to stress concentration are rounded to reduce stress concentration and enhance the strength of the printed parts.

(4) Step design: The design of the trolley needs to use bearings in many places, according to the advantages of 3D integrated printing, the mounting holes of the bearings are designed as step-like holes.

(5) Printing layout and post-processing: 3D printing is layer stacking molding, the adhesion between layers is not strong enough, in the strength of the poor, print parts are prone to fracture in

the direction of the accumulation of layers. Therefore, before printing the parts, it is necessary to analyze the main force direction of the parts, and according to its force situation, choose the appropriate printing direction and placement position to minimize the impact of the inevitable shortcomings of 3D printing molding technology on the performance of the cart. At the same time, placing the model on the 3D printer platform at a reasonable angle also reduces the printing time and saves time and cost.

During the overall teaching process, the teacher gives help and guidance to the students at any time in response to their progress. After the students complete the processing of the part and complete the post-processing, the teacher should organize on-site the students to display and discuss the parts, and make feedback and evaluation of the students' parts completion, the students can taste the joy of success, experience their own sense of achievement, and recognize their own intellectual potential by participating in the group interactive evaluation. At the same time, it also enables the teacher to discover the different highlights of each student and promote communication between teachers and students, thus improving the quality of practical teaching.

2.3. Combination of Classroom Competitions

2.3.1. background

With the growth of the influence and driving effect of the skills competition, the awareness of the competition has gradually penetrated into the daily teaching activities, especially the practical training teaching activities. In order to realize the organic integration of the skills competition and daily practical training teaching, it is necessary to accurately grasp the current situation of the teaching practice of 3D modeling and engineering drawing courses and 3D printing practice courses, and accurately analyze the problems and deficiencies in the current stage of practical teaching, so as to implement the targeted “combination of race and class” curriculum reform.

In the reform, we should pay attention to the guidance of students, take students as the main body, comprehensively use the network teaching method, intuitive teaching method, project teaching method and project (task)-driven method and other diversified teaching methods, to fully mobilize the initiative and enthusiasm of students to learn, so as to improve the efficiency and quality of practical training teaching. At the same time, it is more important to focus on students' teamwork and communication and increase students' participation in the discussion and assessment of works. The direction of reform is proposed for the academic situation and background.

2.3.2. Integration of Competition Tasks into Practical Training Programs

Based on the vocational jobs, following the teaching concept of “project-driven, task-led, product-object, process-oriented”, the rapid development of different types of products is taken as the project, and the tasks are designed according to the actual development process of the products. The teaching content is designed as 4 practical training projects, including 2 basic projects, 1 enhancement project and 1 competition project. Each project is derived from the real workflow of 3D printing, and the selected products cover handicrafts and industrial products, adopting different data scanning methods and different rapid prototyping processes according to the structural characteristics of the products, taking into account the mastery of different theoretical knowledge and the cultivation of practical ability.

Based on the implementation module of the competition project, the content and tasks of the practical training projects are divided, appropriate project carriers are selected, and the degree of each project is gradually deepened, which is both relatively independent and interconnected. Basic project one mainly trains students in forward design modeling and the ability to print products in kind. The second basic project mainly trains students the ability of physical reverse scanning and scanning data processing. Enhancement project requires students to master the common 3D printing software and equipment on the premise of the reverse based on the appearance of the product to carry out a certain degree of innovation and optimization design. The competition projects are selected from the representative topics of 3D printing competitions in recent years to train students' comprehensive application and innovation ability, and at the same time increase the display link to strengthen students' professional skills while cultivating their expression and collaboration ability. The first three projects mainly focus on the single practice of operation skills, while the fourth project emphasizes the comprehensive application of practice and independent innovation and design, and closely follow the development of the industry and competition changes, and timely adjust the project carrier and teaching content with the times.

2.3.3. Integration of The Competition Program into The Curriculum

According to the task module setting of the competition project and the mastery of students' knowledge and skills, the teaching mode of “Setting tasks - Collecting information - Formulating plans - Implementing tasks - Checking effects - Optimizing results - Overall acceptance” is constructed. -Overall acceptance” teaching mode, against the competition standards and job requirements, establish teaching objectives, cultivate students' vocational abilities such as operation of printing equipment, application of simulation modeling software, design of product structure, as well as the awareness of norms, safety, standards, craftsmanship, labor, teamwork and other vocational qualities such as the sense of innovation, innovation consciousness and other vocational qualities.

Classroom teaching mainly adopts project-driven method, case teaching method and demonstration teaching method, and with the help of simulation software, practical equipment, video animation resources, learning platform and other informatization means, it strengthens students' understanding and application ability of reverse engineering, innovative design and rapid prototyping technology through the instruction of important knowledge points and the summarization of the key points of practical operation and experience skills. Especially in the practical session, it is emphasized that students are required to operate in accordance with the standards, so as to gradually cultivate students' awareness of standard operation and standards, and gradually meet the standard operation requirements of the competition. The main content of 3D printing is guided by simple and at the same time meaningful questions.

2.3.4. Micro-Project Setup

(1) Turning scientific research projects into micro

Combined with the teaching content, we have an in-depth understanding of the contents of some major courses of sophomore mechanical majors with strong fundamentals and practicality and the students' professional level ability, collect and screen the scientific research projects and competitions of mechanical majors on campus, make appropriate modifications of the project contents, delete some contents that are not in line with the majors or are too difficult, and turn the projects that are in line with the students' professional learning ability into micro-projects and design them into micro-projects or transform them into teaching cases. The projects that meet the students' professional learning ability are transformed into micro-projects, and the projects are designed and transformed into micro-projects or teaching cases.

(2) Specialized course knowledge project

Combined with the practice of professional courses, such as “Mechanical Design and Principles” for mechanical majors and “Ergonomics” for industrial design majors, and other main courses, the typical products and typical institutions in the project-based transformation teaching, etc., the improved products or institutions as micro-projects. Improved products or organizations are used as micro-projects. For example, the shape modeling of mechanical products, the design of transmission mechanism, furniture and electronic product design and development, etc., and through the rapidity of the 3D printing process, we can get the part samples in a hurry, which is very helpful for the verification of design and function.

2.3.5. Introduction to Teaching Examples

In the fall semester of this year, several students used what they had learned while attending classes to do a digital design project and participated in the Shanghai Xinte Cup Digital Design Competition, and the final physical model diagram is shown in Figure 3.

Project name: Carbonless cart based on S-route

Project members: five sophomore students, who studied 3D design and engineering drawing and 3D printing technology for engineering training during the semester

Project content: (1). The Carbonless Cart demonstrates the concept of carbonless, and focuses more on energy utilization than other model carts, the only source of energy is gravitational potential energy, which is truly environmentally friendly and carbonless. (2). The carbon-free cart changes the traditional rigid rod pendulum mechanism into a crank rocker mechanism, which makes the weight of the cart in the reduction of at the same time, in the process of S-shaped steering movement to control the process of turning is easier to realize the differential speed, more convenient and labor-saving, and easier to control the cycle of the cart over the obstacle columns. (3). The front and rear wheels of the carbonless trolley are 3D printed, and the chamfered garden angle is added to reduce the contact area with the ground, which lowers the friction coefficient with the ground, and can make the running speed of the trolley become more smooth and fast. (4). According to adding digital debugging system, the blind debugging way of carbonless cart becomes digital and visualized, and the controllability and adjustability of carbonless cart is improved.

Figure 3: Carbonless cart

Finite element analysis was done on the most important stress part of the trolley, the trolley base plate, and the results are shown in Figure 4.

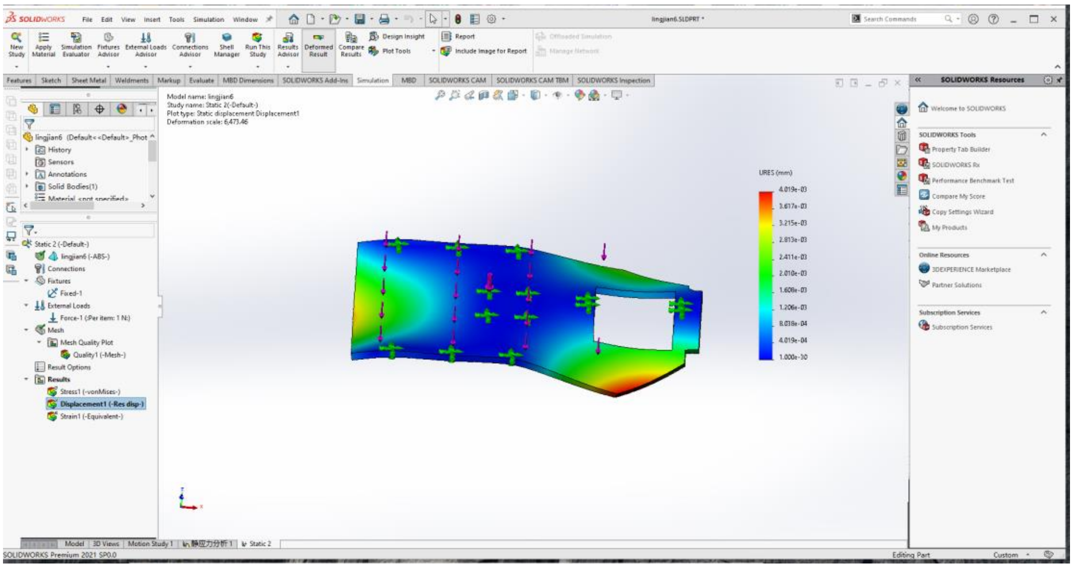

Figure 4: Finite element analysis of cart base plate

2.3.6. Project Results

By completing the tasks of the practical training project, students not only mastered the professional knowledge and skills, but also familiarized with the implementation process of the competition project. Students with solid theoretical mastery stood out in the competition through intensive training, while the competition further deepened the results of practical teaching. The project participated in the Shanghai Third Xinte Cup Digital Design Competition, and after a round of elimination, it was scored in the final round by online defense and on-site modeling, and finally won the second prize. And better employment opportunities were obtained for several students with excellent competition results, which greatly stimulated the students' motivation to participate in the competition.

3. Conclusions

Engineering practice teaching is one of the important ways to cultivate the comprehensive ability of students in colleges and universities, 3D printing technology as a platform for practical teaching as a new form of practical teaching is being adopted by more and more colleges and universities, using 3D printing technology will be students and students, students and teachers, as well as the students and the specialty of the organic combination of students, so that students from individual learning into a collaborative discussion, so that the teacher from the traditional mode of imparting knowledge to the mode of asking questions and skillful guidance, fully creating an atmosphere of inquiry and cooperative learning. The teacher will change from the traditional mode of imparting knowledge to the mode of asking questions and skillfully guiding, fully creating a cooperative learning atmosphere of inquiry.

This paper proposes a “learning by doing” practical course that combines the integration of mechanical structure design and 3D printing. Through the independent learning of the whole process of 3D CAD design and 3D printing of the competition project objectives, students can gain a profound perceptual experience, so that they can comprehensively understand the real value of the high-speed development of the 3D printing industry, thus enabling a new generation of students to devote themselves to science. This will enable a new generation of students to develop a passion for science, engineering and design, and create a group of student engineers.

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