Design and implementation of dynamic teaching model of diesel engine based on 3D printing technology

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Abstract. In view of the shortage of models of practical installation and teaching AIDS in the teaching and training of traditional naval ship diesel engines, the 3D printing technology is integrated with the educational concept of this course, and a multi-functional diesel engine teaching AIDS model suitable for classroom teaching is designed and manufactured, and its design method and process are expounded. A set of models of diesel engine teaching AIDS are designed and manufactured by using this method and applied in classroom teaching. The teaching effect is good, the learners' enthusiasm is stimulated, and the teaching and training quality is improved.

1. Introduction

3D printing is also called the increase of material manufacturing technology, is a three-dimensional objects by modeling or scanning for the model data, then the model of stratified slice, finally the material "print" made into a 3 d object step by step, the biggest characteristic of this technology is to material, control, information and engineering technology of fusion penetration, is regarded as "third industrial revolution" [1]. 3D printing technology is widely used in industrial manufacturing, medicine, biology and civil consumption. At the same time, 3D printing technology has also had a profound impact on education and talent training models. In the United States and the United Kingdom, 3D printing technology has been widely used in higher education and basic education. Many universities have set up special departments to open 3D printing and 3D scanning equipment to help teachers and students quickly realize innovative designs and ideas. The US has embraced 3D printing as an effective approach to STEM (Science Science, Technology Technology, Engineering Engineering and Mathematics) programs; The Defense Advanced Research Projects Agency's Manufacturing Trial and Extension program is using 3D printing in high schools to stimulate students' interest in design, manufacturing, math and engineering and improve their engineering skills. In 2014, The State Council launched a plan called "3D Printing Innovative Education Seeding", with the aim of providing students with a good environment for innovative learning and fostering their innovative ability. At the same time, local education departments are also actively exploring the application of 3D printing in teaching [2-3]. Some primary and secondary schools in cities such as Shanghai, Nanjing and Qingdao have set up 3D printing practice centers and offered 3D printing courses. The X-Lab team of Tsinghua University helps primary and secondary schools to create 3D creative classroom [4]. Some universities in China have applied 3D printing to teaching, scientific research, innovation practice and competition.
Xi’an Jiaotong University has successfully developed an aircraft bearing part made of titanium alloy by 3D printing technology. Beihang University has applied 3D printing technology to the teaching of mechanical subjects to help students understand complex mechanical principles and structural forms that are difficult to understand through oral teaching and two-dimensional illustrations. This technology has been used to make three-dimensional molecular models in chemistry class, to solve the problem of set surface by printing models with mathematical equations in mathematics class, to print terrain and geomorphology in geography class, to print virus organs and other models in biomedical class, to make bridge models for mechanical experiments in mechanics class, etc. [5]. However, there is little application in Marine engineering professional class, this article will combine ship diesel engine of the main problems existing in the teaching process, the 3 d printing technology and the integration of the course education concept, using 3 d printing design suitable for classroom teaching AIDS, a multi-functional diesel stimulate students study enthusiasm, improve the quality of teaching.

2. 3D modeling of a V-type diesel engine

2.1. Structural characteristics of diesel engine
The main diesel engines of naval ships are V-shaped diesel engines with 6 ~ 20 cylinders. The structure is very compact and has mature connecting rod and fuselage structure. Due to the various internal parts and complex structure of the diesel engine, the matching accuracy between the moving pair is high. The diesel model designed in this paper is a V - shaped 8 - cylinder diesel engine. The diesel engine structure is modeled according to the order of combustor assembly, power transmission assembly, air exchange mechanism, fuel supply device and accessories. First, analyze the structural characteristics; Secondly, considering the mating relationship of parts, the internal complex structure of some parts is simplified to ensure the external shape features; Finally, SolidWorks 3d modeling software is selected to systematically model and assemble diesel engine parts.

2.2. Diesel engine parts modeling
The assembly model of V-type eight-cylinder diesel engine is represented by assembly layer, sub-assembly layer, parts layer and characteristic layer. The assembly layer in the first layer represents the whole diesel engine. Sub-assembly layer contains crankshaft, flywheel, piston and connecting rod, etc., in the second layer, is the result of product decomposition according to function and structure; The sub-assembly layer is further decomposed in the part layer. For example, the crankshaft sub-assembly body has the structure of crank, spindle journal, free end and flywheel end, which reflects the structural differentiation of diesel engine. The feature layer is at the bottom of the layer, which contains various feature relationships such as vertical, coincidence and concentric, and is the concentrated embodiment of specific realization forms of functions [6-7].

Take linkage modeling as an example. The connecting rod of diesel engine is a part of the power transmission assembly. Its main function is to convert the upward and downward reciprocating motion of the piston into the rotational motion of the crankshaft. Therefore, the connecting rod of diesel engine should have sufficient stiffness and strength. First, the structural characteristics of the connecting rod are analyzed. The connecting rod is composed of two large and small bearings and the rod body. Then, the connection and coordination between kinematic pairs are analyzed. The small end is fitted to the piston pin and the large end to the connecting rod diameter on the crankshaft. When setting and modeling the size of the connecting rod structure, the influence of the movement flexibility by the fit clearance of the parts should be fully considered. And then 3d modeling. Finally, the connecting rod, piston pin and crankshaft are assembled to check the assembly quality. According to the assembly situation, the improper size of the connecting rod set during modeling is corrected.
2.3. Assembly of diesel engine parts model

After the modeling of diesel engine parts is completed, the motion relationship between the moving pairs can be checked through the assembly of the parts, such as whether there is any interference phenomenon, whether the motion is flexible, and whether the size setting is reasonable.

The established diesel engine parts model is imported into it, and the assembly is carried out from inside to outside and from top to bottom. Move and rotate the corresponding parts to the appropriate position, and determine the relative position relationship between each part by using the methods of the same axis, tangent, coincidence, etc. Then, a complete assembly can be successfully combined by using each part. In the assembly process, if the phenomenon of position or motion interference is found, the size should be reset in time. Until there is no structural conflict and alarm, it can ensure that the parts of the diesel engine printed by the 3D printer can be assembled into the entity smoothly, and the moving pair can achieve flexible relative motion.

3. Diesel engine parts model slice, 3D printing and assembly

3.1 Diesel engine parts model slice

The production process of 3D printed products is shown in Figure 1. After the 3D model of diesel engine parts is completed, the parts need to be sliced to be used for 3D printing. Since the 3D model data can not be directly recognized by the 3D printer, the 3D printer can not directly print the model through the SolidWorks model. After importing the established 3D model into the computer, it is necessary to use the slicing software to transform the model into the data that can be recognized by the 3D printer, that is, to transform the model into two-dimensional graphic information. Then, with the help of the nozzle of the 3D printer, the graphics are ejected layer by layer to finally form a three-dimensional solid model.

![Fundamentals of 3D modeling](image)

Figure 1. The design and production process for 3D printed finished product

For parts of the diesel engine has a lot of small fine, if not biopsy classification of its parts, it is easy to cause lost and forgotten parts of phenomenon, so before biopsy on diesel engine parts, should be in accordance with the diesel engine structure hierarchy of every parts and components and assembly classifying its principle. The total assembly contains a number of sub-assemblies, each sub-assembly contains a number of parts. According to the above classification method, the V8 engine section model with three levels, the total assembly for all parts assembly after the completion of the diesel engine assembly, assembly containing the crankshaft and camshaft, inter-cooled, exhaust pipe, plunger vice, etc., each assembly consists of below parts, such as the piston by the piston and piston ring. At the same time, because of the excessive number of diesel engine assembly, it is classified according to the diesel engine two mechanisms, five systems in the slicing. Various parts of diesel engine are systematically and completely sliced by this classification.

Slicing is a process of discretizing a 3D virtual model and transforming it into 2d plane data that can be recognized by a 3D printer. Therefore, the efficiency and quality of model forming depend on the slicing algorithm. There are mainly two kinds of slicing algorithms: slicing with fixed thickness and slicing with variable thickness (adaptive slicing algorithm) [8]. The slicing algorithm used in this
paper is the slicing method in Cura with fixed layer thickness. Before slicing, the SolidWorks model file must be converted into the STL file in the standard format of 3D printing.

The basic process of slicing can be roughly divided into: model processing, lamellar information processing, G code compilation, information control and automatic slicing, specific process. For example, after loading a flywheel model into Cura, the software will automatically slice it once the basic parameters for slicing are set. See Figure 2.

Figure 2. Diesel engine components (flywheel) sliced

3.2 3D printing of parts
After the slicing is completed, the G-code file identified by the 3D printer should be exported and imported into the printing control machine through SD card. Then, the file in the SD card should be selected to print on the 3D printer control screen. After the printer nozzle is heated to the specified temperature, the model can start printing by itself. The printer builds the materials needed for printing into three-dimensional space layer by layer. According to the different working principle, the realization method can be divided into two kinds: the first is to spray a layer of glue, and then sprinkle a layer of powder on it, so repeated several times; The second is to melt the material, layer by layer, through a laser or at high temperatures, to form a three-dimensional model. The second approach is used in this article.

3.3 Assembly of printed parts
The v-8 cylinder diesel engine has a complex internal structure. The assembly is as follows: assemble the parts first, then assemble the whole machine; From inside out; Install the main parts first, then the sequence of accessories. Parts in the assembly process, parts and parts between the connection between the screw connection. For some important rolling friction pairs (for example, between the crankshaft and the journal, as shown in the figure), bearings are installed between the shaft and the hole in order to reduce. Before assembly, remove the printed support and polish the surface of the part with a grinding tool. The screw holes of the printed parts may be small due to insufficient accuracy. Before assembly, drill the screw holes to a proper size with a drilling machine.

4. Motion simulation control of diesel engine model
In order to explain and demonstrate the relative motion relationship, working principle and timing relationship among diesel engine parts more directly, the diesel engine model is designed to be assembled, manual and automatic demonstration modes. The automatic demonstration mode uses a motor to drive a 3D printed diesel engine model to simulate the operation process of the diesel engine. The motor is connected and fixed with the output end of the diesel engine. The motor is driven and controlled by Arduino Uno R3 microcontroller, and the PS2 wireless remote control handle is used as the upper computer to realize the remote wireless control of the diesel engine model to start, stop, forward and flip functions. In the choice of motor speed control, considering that the diesel engine model is printed from resin plastic materials, if the motor speed is too high, the piston and the body friction is too severe, serious heat, too high heat may cause damage to the model. In the teaching
demonstration, the crankshaft speed is not too high in order to clearly demonstrate the mating relationship of diesel engine power transmission components. So, in the control of motor speed, set the rated motor speed to 42r/min unchanged. In the design of motion control of diesel engine model, the function of positive and negative rotation of motor is added. The design idea of the circuit is as follows: 12V power supply supplies power to the motor driver board, and 5V power supply supplies power to the single chip microcomputer. Information is transmitted to the wireless receiving module on the Arduino single chip microcomputer through the PS2 wireless handle to control the change of high and low level of the motor power supply module of the drive board, so as to control the rotation of the motor. The design principle and structure are shown in Figure 3, and the 3D printed diesel engine teaching model is shown in Figure 4.

Figure 3. Control the structure of the circuit
Figure 4. V8 diesel engine dynamic model

5. Conclusion
This paper introduces the method and process of using 3D printing technology and stepper motor control technology to construct the model of diesel engine dynamic teaching aid. Solid Works is used for three-dimensional construction. On this basis, slices and prints are made and assembled into a 3D printed diesel engine. After the assembly, a single chip microcomputer is used for motion control to drive the crankshaft of the diesel engine to rotate and drive other moving parts of the diesel engine to move in accordance with the prescribed path. 3D printing teaching model has the characteristics of short research and development cycle, low price, good customization and strong applicability, and can intuitively and clearly show its internal structure. This method can be used for reference in the design and production of other professional teaching AIDS.

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