Research on 3D Printing and Its Application in CAD Teaching

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Abstract. 3D printing is a rapid prototyping technology in recent years. Computer aided design (CAD) combining with 3D printing in university is helpful for students to understand the design work. The history and characteristics of 3D printing technology were introduced. The technology and material used in 3D printer was summarized. The application of 3D printing technology in teaching was studied. Combining 3D printing technology and CAD design cases is helpful for students to understand the designed model directly and to master the three-view drawing of objects intuitively. Integrating 3D printing technology into mechanical design competition is an effective means to promote teaching effect. Apply 3D printing into CAD teaching could improve students’ subjective initiative in learning, expand students’ innovative thinking, and improve teaching quality.

Keywords: 3D printing · CAD · Teaching

1 Introduction

3D printing (3DP) is a kind of rapid prototyping technology, also known as additive manufacturing [1]. It is a technology based on the digital model file, which uses adhesive materials such as powder metal or plastic to construct objects by layer printing. The advantages of 3D printing are to save raw materials and realize customized manufacturing, which is an optimal technology to realize green manufacturing.

3D printing is usually realized by digital material printer. It is often used in mold manufacturing, industrial design and other fields to make models, and then gradually used in the direct manufacturing of some products [2, 3]. There are already parts printed with this technology. The technology has applications in bionics [4, 5], biomedical and medical science [6–9], engineering and construction (AEC) [10–12], jewelry, footwear, industrial design [13], architecture, automotive, aerospace, education, geographic information systems, civil engineering, firearms and other fields [14].

Computer aided design (CAD) course is the pre work for manufacturing and printing. The necessary module show is helpful for the design work. So combining 3D printing with CAD courses is a novel teaching method to help teaching and learning work go on smoothly.


2 3D Printing Technology

2.1 3D Printing Technology

3D printing technology is a rapid prototyping technology, which could make adhesive materials into a three-dimensional physical object layer by layer by 3D printer. It is mainly based on the digital model files, and the special adhesive materials are mainly powder metal, wax material, plastic, and so on.

The main principle of this technology is to put the data information and raw materials into the printer through the computer technology. The printer prints the products layer by layer according to the program set by the computer system, and finally presents a three-dimensional physical object.

2.2 Development of 3D Printing

3D printing technology has the characteristics of simple operation and convenience. Through 3D printing technology, objects can be displayed more intuitively, vividly and stereoscopically, which is also more convenient for 3D printing technology than traditional manufacturing technology. With the continuous development of science and technology, the level of 3D printing technology has also been greatly improved. Nowadays, 3D printing technology is more and more widely used. For example, it plays an important role in mechanical manufacturing, industrial design, architecture, biomedicine and other fields.

Compared with traditional printing methods, 3D printing technology has the characteristics of high operation coefficient, cost saving, high production flexibility and automation. Since 3D printing technology has so many advantages and characteristics, it is deeply concerned and valued by experts and industries in society. Table 1 shows the development of 3D printing at home and abroad [15].
Table 1. The development of 3D printing technology

| Time          | Domestic                                                                 | Abroad                                                                 |
|--------------|---------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1984         | Mr. Charles Hull started to develop 3D printing technology                 | Professor Yan Yongnian in Tsinghua University went to USA to study      |
| 1986         | SLA in Hull obtained the 3D printing patent certificate, established 3D systems, became the world’s first company producing 3D printing equipment, and developed STL file format | In 1991, Huazhong University of science and technology established the rapid manufacturing center |
|              |                                                                           | In 1992, Professor Lu Bingheng in Xi’an Jiaotong University went to the United States as a senior visiting scholar. Institute of advanced manufacturing technology was established in 1994. In the same year, Yan Yongnian established the first 3D printing company in China |
| 1988         | Sla-250, the first modern UV curing 3D printing device, was launched. LOM technology and FDM technology were born | Professor Yan Yongnian founded Laser rapid prototyping Center Tsinghua University |
| 1989         | Dechard invented SLS technology of selective laser sintering. Stratasys incorporated |                                                                           |
| 1991–1994    | In 1993, Professor E.M. Sachs in MIT created 3DP printing technology       | In 1991, Huazhong University of science and technology established the rapid manufacturing center |
|              | In 1994, German EOS company launched EO - Sint printing equipment          | In 1992, Professor Lu Bingheng in Xi’an Jiaotong University went to the United States as a senior visiting scholar. Institute of advanced manufacturing technology was established in 1994. In the same year, Yan Yongnian established the first 3D printing company in China |
| 1995–1999    | In 1995, zcorp was authorized by MIT to develop                           | In 1995, Lu Bingheng’s prototype won the support of 2.5 million yuan from the “Ninth Five Year Plan” national key scientific and technological research project. In the same year, Huazhong University of science and technology developed the first LOM Prototype based on sheet paper in China |
|              | In 1996, the media first used the term ‘3D printing’                       | In 1998, Yan Yongnian introduced rapid prototyping technology into the field of life science |
|              | In 1998, optomec successfully developed lens laser sintering technology.   |                                                                           |
| 2000–2006    | In 2000, objet updated SLA technology                                      | In 2001, Huang Weidong of Northwestern Polytechnic University applied for the first batch of innovative patents on the source of laser stereolithography in China |
|              | In 2001, solido developed the first generation of desktop 3D printers      | In 2001, Yan Yongnian developed a rapid prototyping machine for biomaterials |
|              | In 2003, EOS developed DLMS laser sintering technology                     | In 2006, Shanghai private enterprises introduced the laser sintering 3D printer from Binhu Electromechanics |
|              | In 2005, ZCorp successfully developed the first color 3D printer.          |                                                                           |
| 2007–2010    | In 2007, Shapeways, a 3D printing service startup, was founded            | In 2009, the 3D printing equipment from Shi Yusheng’s team in Huazhong University of science and technology entered many enterprises |
|              | In 2008, Objet launched a multi material 3D printer                       | In 2010, Shi Yusheng team developed the world’s largest industrial level rapid manufacturing equipment with working face of 1.2 m × 1.2 m |
|              | In 2010, the world’s first 3D printed car came out                        |                                                                           |
| 2011–2015    | In 2011, the UK developed the first chocolate 3D printer. In the same year, the world’s first 3D printing plane was born | In 2011, Shi Yusheng’s team jointly undertook the EU framework project to produce large and complex titanium alloy casting wax models for aircraft, satellite and Aeroengine Parts for Airbus, ESA and other units |
|              | In 2012, Stratasys became the world’s largest 3D manufacturer. In the same year, Scottish scientists first printed artificial liver tissue | In 2012, China 3D printing technology industry alliance was established. In the same year, China became the only country in the world to master the laser forming technology of large-scale key structural parts |
|              | In 2013, American maker developed the first home metal 3D printer         |                                                                           |
|              | In 2015, American carbon3D company released the technology of continuous liquid interface (CLIP), which increased the speed by 25–100 times |                                                                           |

(continued)
Table 1. (continued)

| Time   | Domestic                                                                 | Abroad                                                                 |
|--------|---------------------------------------------------------------------------|------------------------------------------------------------------------|
| 2016–2019 | In 2018, 3D printing guns will be legal in the United States, and the design drawings of 3D printing guns will also be freely available for download on the Internet. In the same year, Russian astronauts used a 3D bio printer on the international space station to try to print out the thyroid gland of the experimental mouse under zero gravity. In 2019, in the University of California, the spinal cord scaffold mimicking the structure of the central nervous system was successfully made which applied the rapid 3D printing technology firstly, to help the rats recover their motor function. | In 2016, Chongqing Green Intelligent Technology Research Institute of Chinese Academy of Sciences announced that the first 3D printer on orbit in China was successfully developed. The 3D printer can print the largest size of parts up to $200 \times 130 \text{ mm}$. It can help astronauts to make their own parts in weightless environment, which greatly improve the flexibility of space station experiment, reduce the type and quantity of space station spare parts and operating costs, and reduce the dependence of space station on ground supply. |

2.3 Technology and Materials

Ordinary printers used in daily life can print plane objects designed by computers. The so-called 3D printer and ordinary printer work on the same principle, but the printing materials are different. The printing materials of ordinary printers are ink and paper, while 3D printers are equipped with different “printing materials” such as metal, ceramics, plastic, sand, etc., which are real raw materials. After the printer is connected to the computer, the “printing materials” can be stacked layer by layer through the computer control, and finally the blueprint on the computer can be turned into a real object. Figure 1 is a 3D printer which has successfully printed a F1 car.

![Fig. 1. A 3D printer for car](image)

There are many different technologies for 3D printing. They differ in the way that the materials are available and the parts are created with different layers of construction. Commonly used materials for 3D printing include nylon glass fiber, durable nylon
material, gypsum material, aluminum material, titanium alloy, stainless steel, silver plating, gold plating and rubber materials. Table 2 shows cumulative technology and basic materials for different types of technology.

| Types            | Cumulative technology        | Basic materials                                      |
|------------------|------------------------------|-----------------------------------------------------|
| Extrusion        | Fused deposition (FDM)       | Thermoplastic, eutectic system metal, edible material |
| Line             | Electron beam free forming   | Almost any alloy                                      |
|                  | (EBF)                        |                                                     |
| Granular         | Direct metal laser sintering | Almost any alloy                                      |
|                  | (DMLS)                       |                                                     |
|                  | Electron beam melting        | Titanium alloy                                        |
|                  | molding (EBM)                |                                                     |
|                  | Selective laser melting      | Titanium alloy, cobalt chromium alloy, stainless     |
|                  | (SLM)                        | steel, aluminum                                       |
|                  | Selective hot sintering      | Thermoplastic powder                                  |
|                  | (SHS)                        |                                                     |
|                  | Selective laser sintering    | Thermoplastic, metal powder, ceramic powder          |
|                  | (SLS)                        |                                                     |
| 3D printing of   | Gypsum 3D printing (PP)      | Gypsum                                              |
| powder layer     |                              |                                                     |
| nozzle           |                              |                                                     |
| Lamination       | Layered solid manufacturing  | Paper, metal film, plastic film                      |
|                  | (LOM)                        |                                                     |
| Photopolymerization | Stereolithography (SLA)   | Light hardening resin                                 |
|                  | Digital light processing     | Light hardening resin                                 |
|                  | (DLP)                        |                                                     |

3 Application in CAD Teaching

The advantage of 3D printing technology is the directly manufacturing which could take out the data from computer and manufacture the parts directly at once. In some aspects, direct printing can not only improve the efficiency, but also reduce the cost. Replacing the traditional teaching method, the methods combining in teaching and the effects are introduce in the following.

3.1 Combining CAD Design Cases with 3D Printing

Combining CAD design cases with 3D printing technology could help students to understand the designed model directly and to master the three-view drawing intuitively. A
designed example is shown in Fig. 2. This is a part in screw propeller for students to practice designing. If there is a real object printed corresponding the design drawing, it is helpful for students to evaluate the designed parts themselves and improve their designing work furtherly.

![Fig. 2. Example 1](image)

Another designed example is shown in Fig. 3. This is a mobile phone supporter for students to practice using three-dimension software. Through 3D printing, we could observe the shape and surface of objects in all directions and improve the quality by measuring the actual dimensions and precisions of objects to improve the designing. It could also help to solve some problems in CNC manufacturing.

![Fig. 3. Example 2](image)

### 3.2 Integrating 3D Printing into Mechanical Design Competition

Integrating 3D printing into mechanical design competition is an effective means to promote teaching effect. In order to enhance the innovation consciousness of students
and cultivate their practical ability, the school strives to create conditions to support students to participate in all kinds of design competitions.

In the competition of mechanical design, it is often necessary to process some parts. The cost of parts processed by traditional turning, milling, drilling and other methods is relatively high, and the processing time is relatively long. Using 3D printing technology to design these parts is not only cheap and time-saving, but also can improve the competitiveness of the work, reduce the harm of mechanical tools for people, and stimulate the enthusiasm of students to participate in the competition. At the same time, the integration of 3D printing technology into the competition of mechanical design specialty can promote the teaching reform of mechanical related specialty, strengthen the cooperation between school and enterprise, form the connection between specialty and industry, take the opportunity of design competition, combine the competition project and curriculum reform project, refine the connotation of skill competition, lead and deepen the teaching reform and development of mechanical design specialty.

3.3 Effects of 3D Printing Application in Teaching

Taking 3D printing technology as a new auxiliary means of classroom teaching, teachers have mastered the construction method of simple model and the basic use method of 3D printer. Combined with the inquiry teaching method, students can experience the fun of “learning by doing” more excitedly, which is conducive to stimulating students’ enthusiasm and innovative thinking.

**Improve Students’ Subjective Initiative in Learning.** The introduction of 3D printing technology into the classroom can enrich teaching methods, and present abstract concepts, virtual models and designs in the form of materialization in front of students. It can bring strong sense of visual impact and reality, stimulate students’ interest in learning and enthusiasm for practice, and improve their enthusiasm for learning, and make them more active in learning.

**Expand Students’ Innovative Thinking.** 3D printing not only solves the disadvantages of traditional teaching, but also enriches students’ vision and exercises their three-dimensional thinking. This is not only helpful to improve the teaching efficiency of teachers and students’ learning efficiency, but also an important link to expand the development of students’ innovation ability, which is of positive significance to the cultivation of innovative talents.

**Improve Teaching Quality.** According to the needs of teaching, we can set up teaching model resource base. The practical problems in teaching can be solved by designing teaching content or modifying model printing. With the help of new technology, the quality of teaching, and the ability of students’ technical innovation could be improved.

4 Summary

3D printing is a novel manufacturing technology which could transfer the data in computer to the real objects layer by layer by 3D printer. The development of 3D printing
technology is studied. And the material for printing is summarized. Applying the 3D printing technology in teaching is meaningful. Combining 3D printing into design cases and mechanical design competitions are studied for teaching. The application could improve the students’ initiative in learning, expand students’ innovative thinking and improve teaching quality. The teaching application of 3D printing technology deserves further study and discussions.

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