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Master's degree in Engineering and Management

Master's Degree Thesis

The development of Additive Manufacturing in China

Academic Supervisor:

Prof. Luigi Benfratello

Graduate:

Rui Rong

S278485

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1. The technological scenario

1.1 3D printing technology introduction

The core idea of 3D printing technology originated in the United States at the end of the 19th century, but it did not have its initial form until the mid-1980s. In 1984, American Charles Hull invented the first 3D printer. China has been researching 3D printing technology since 1991. Around 2000, these processes from laboratory research to engineering and productization gradually. At the time it was called Rapid Prototyping (RP), a physical model before developing a sample. Now there is also a technology called rapid prototyping, additive manufacturing. But for the sake of public acceptance, this new technology is collectively referred to as 3D printing.

Figure 1.1: The first commercialized 3D printer-the SLA-1 in 1988

Picture from 3D Systems Corp, Rock Hill, SC

3D printers are rapid prototyping devices that utilize technologies such as light curing and paper lamination. Its working principle is basically the same as that of ordinary printers. After the printer is filled with "printing materials" such as liquid or powder, it is connected to the computer, and the "printing materials" are superimposed layer by layer through computer control. Finally, the blueprint on the computer becomes a real object. This printing technology is called 3D printing technology.

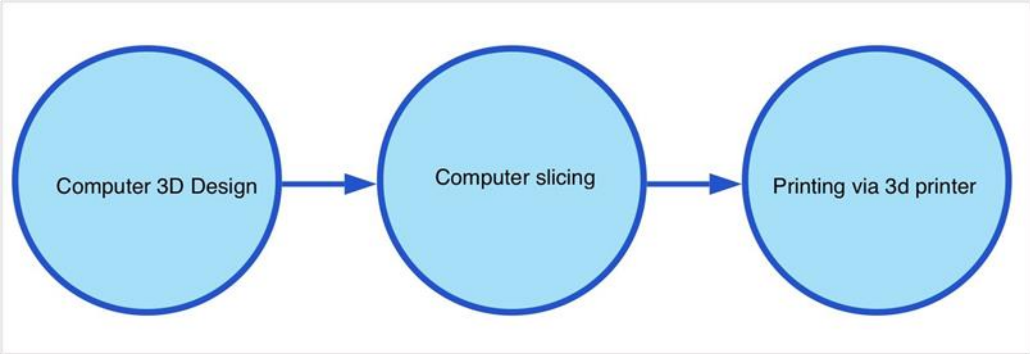


Figure 1.2: 3D printing process

1.2 An essential node in the development of 3D printing

3D printing was born in 1984, when Charles Hull, co-founder of 3D Systems, invented "rapid prototyping" technology, a three-dimensional object that can be 3D digitally modeled. This technology frees humans from a worry: Before putting an item into mass production, you can see what it can look like in advance. Then in 1992, the world's first rapid prototyping machine was built by 3D Systems. The manufactured part looks like a layer upon layer of solid honey, which, while imperfect, at least proves one thing: highly complex parts that can be 3D printed overnight.

The time came in 1999, 3D printing technology was applied in medicine. World's first lab-grown organ implanted in the human body: A young man received a 3D-printed synthetic artificial bladder. This technology opens the way to explore 3D-printed organs. These organs are made from a patient's own cell culture, with little risk of rejection. Wake Forest Institute scientists create a 3D-printed kidney in an animal, and functions include filtering blood and diluting the urine.

Sharing and open source have accelerated the development of 3D printing technology. In 2005, Dr. Adrian Bowyer of the University of Bath founded RepRap Lab, an open-source 3D printing lab that makes 3D printing technology civilian and affordable. In 2006, 3D printer manufacturer and material supplier Objet created a 3D printer that can print multiple materials, allowing materials of different densities to be printed together in a single object at the same time. By 2008, RepRap Labs had launched "Darwin," a 3D printer that could print its own parts, allowing users to share more machines with others. Also this year, someone walked normally with a 3D printed prosthesis for the first time. Prosthetic limbs, including knees, ankles, and feet soles, are printed in one go rather than assembled later. This technology has inspired prosthetics provider Bespoke to offer customized prosthetics with a personal touch.

In 2009, an open-source 3D printer hardware company called MakerBot Industries began selling 3D printers that users could assemble and use easily. Also, this year, bioprinting innovator Organovo printed the first blood vessel using organ printing technology and a 3D bioprinter. In 2011, the first 3D printed plane and the first 3D printed car came out. At the same time, i.Materialise became the first 3D printing service globally to provide 14K gold and sterling silver as materials, which is very helpful for jewelry designers, opening up a whole new, low-cost design option. Immediately after 2012. Doctors and engineers in the Netherlands have 3D printed a jaw and implanted it in an 83-year-old woman to save her from suffering from a chronic bone infection. At the same time, the dental brace manufacturing company Align solved the aesthetic problem of braces by scanning the patient's teeth and printing transparent braces. In this year, Align's turnover was close to 500 million US dollars. After this, 3D printing technology was also used in the field of clothing. In the same year, 3D printing shops also emerged. People can print out the small items they like, such as bracelets, busts and other everyday 3D printing objects. The price is 50 dollars to several hundred dollars.

Figure 1.3: 3D printed mandible

Source: www.nuova-asav.it

1.3 Fundamental

Different types of rapid prototyping systems have different forming principles and system characteristics due to the different forming materials used. But they are all based on the principle of discrete stacking, that is, the method of layer-by-layer manufacturing and layer-by-layer stacking. The basic process is: first use computer software to design a three-dimensional model, then discretize the three-dimensional digital model into surfaces, lines and points, and then stack them in layers through 3D printing equipment, and finally become a three-dimensional object. 3D printing is like building a house layer by layer. The difference is that building a house is done under human operations, while additive manufacturing is performed under computer control.

1.4 Components of a 3D printing system

Printers, new printing materials, printing processes, design and control software are essential components of the 3D printing technology system. The 3D printer is the core equipment of 3D printing. It is a complex mechatronics system integrating machinery, control and computer technology. It is mainly composed of a numerical control system, high-precision mechanical system, molding environment and injection system.

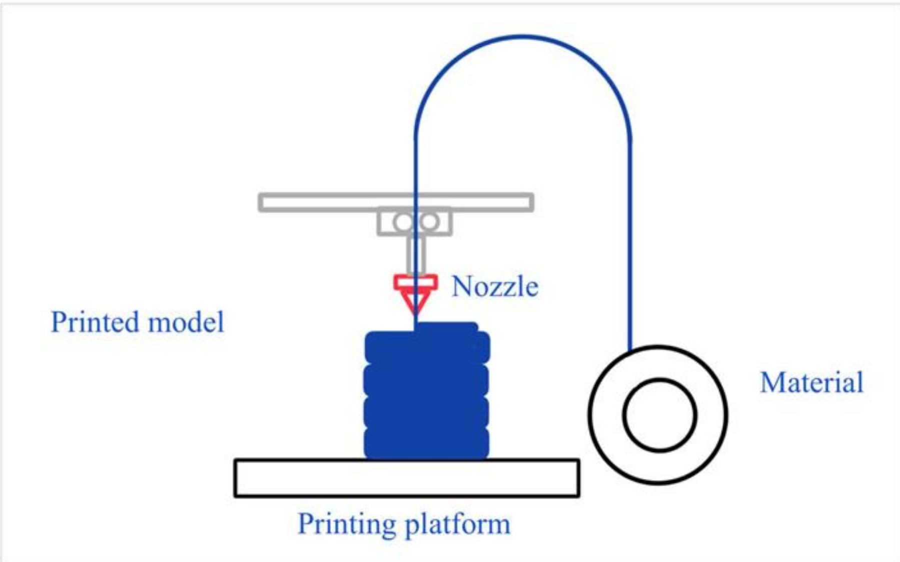


Figure 1.4: The basic structure of 3D printer

1.5 Main technology introduction

1.5.1 Fused deposition modeling (FDM)

Fused Deposition Modeling (FDM) technology uses filamentous PLA, ABS and other thermoplastic materials as raw materials, through the heating and extrusion of the processing head, layer by layer under the computer's control, and finally obtains the formed three-dimensional parts. This technology is currently the most common 3D printing technology, with high technology maturity, low cost, and color printing.

1.5.2 Stereolithography apparatus (SLA)

Stereolithography Apparatus (SLA) is a technology that uses an ultraviolet laser to scan liquid photosensitive polymers (such as acrylic resin, epoxy resin, etc.) layer by layer to realize the solidification of liquid materials and gradually accumulate and form. This technology can make parts with complex structure, high precision of parts and high utilization rate of materials. The disadvantage is that few types of materials can be used for forming, and the process cost is high.

Figure 1.5: SLA 3D Printer

Source: re-fream.eu

1.5.3 Laminated object manufacturing (LOM)

Laminated Object Manufacturing (LOM) uses sheet materials as raw materials, such as paper, metal foil, plastic film, etc., coats hot melt adhesive on the surface of the material. It then cuts and pastes it according to the cross-sectional shape of each layer to achieve the three-dimensional forming of parts. This technique is fast and can form large-sized parts, but it suffers from a severe waste of material and poor surface quality.

1.5.4 Electron beam melting (EBM)

Electron beam melting (EBM) uses an electron beam as the heat source and metal powder as forming material in a vacuum environment. By continuously spreading metal powder on the powder bed and then scanning and melting with electron beam, the small molten pools are made of each other. Fusion and solidification continue to form a complete metal part entity. This technology can form metal parts with complex structures and excellent performance, but the powder bed and vacuum chamber limit the forming size.

1.5.5 Selective laser melting (SLM)

Selective laser melting (SLM) is similar to that of electron beam melting forming technology. It is also a powder forming technology based on powder bed, except that the heat source is replaced by electron beam. Metal parts with complex structure, excellent performance, and good surface quality, but currently this technology cannot form large-sized parts.

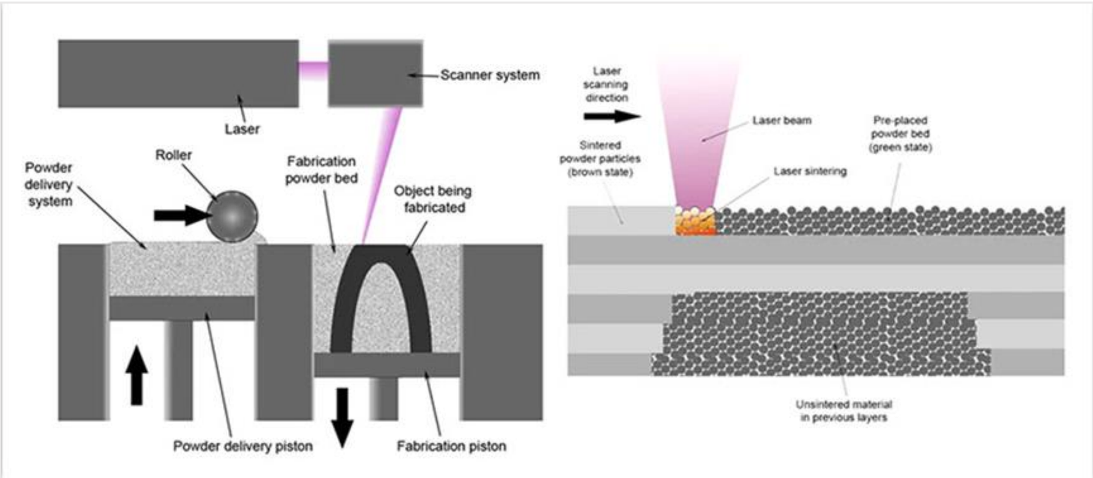


Figure 1.6: How SLM 3D printing works

Source: Spilasers

1.5.6 Laser direct melting deposition (LDMD)

Laser Direct Melting Deposition (LDMD) uses a laser beam as a heat source, and the metal powder is synchronously and precisely fed into the molten pool formed by the laser on the forming surface through an automatic powder feeding device. As the laser spot moves, the powder is continuously fed into the molten pool to melt and then solidify, finally getting the desired shape. This forming process can form large-sized metal parts but cannot form parts with very complex structures.

1.5.7 Electron beam freeform fabrication (EBF)

Electron Beam Freeform Fabrication (EBF) is in a vacuum environment, using an electron beam as the heat source and metal wire as forming material. The metal wire into the molten pool through the wire feeding device and moves according to the set trajectory until the target part or blank is manufactured. This method has high efficiency and good internal quality of the formed parts, but the forming accuracy and surface quality are poor, and it is not suitable for materials with poor plasticity, so it cannot be processed into wire.

2. China's 3D printing development process

2.1 Analysis of the reasons for the development of 3D printing technology in China

In the past few decades, China has gradually become a traditional manufacturing power from the development of the light industry. This has gone through several technical iterations and experience accumulation. However, with global climate change, energy shortage, and the impact of human sustainable development policies, the problems of high energy consumption, high pollution, low efficiency, and a severe waste of materials in traditional manufacturing have been gradually amplified. At the same time, traditional manufacturing has been affected by new technologies and increasing the impact of more personalized user needs, which makes China's manufacturing industry urgently need to find a new direction for technological development.

3D printing is significantly different from traditional machining "equivalent manufacturing" and "subtractive manufacturing" by its unique "additive manufacturing" method. This technology has the characteristics of high efficiency, digital control, low cost of producing small batches of products. Therefore, it has attracted the attention of most manufacturing-based countries globally.

Compared with traditional machining, additive manufacturing technology has the following advantages:

1) Manufacture complex objects at low cost

As we all know, using traditional manufacturing methods, the more complex the shape and structure of the processed items, the higher the manufacturing cost. Therefore, to pursue the lowest investment in production costs, manufacturers often mass-produce standardized components through labor distribution and standardized operation procedures, which are challenging to meet the diversified needs of customers. But for 3D printing, relying on the processing principle of additive manufacturing, without the processing of molds and mechanical equipment, even products with complex shapes will not increase production costs and labor requirements too much. 3D printing reduces the cycle and cost of sample trial production and small batch production, which is conducive to developing new products and developing the personalized and luxury customized products industry.

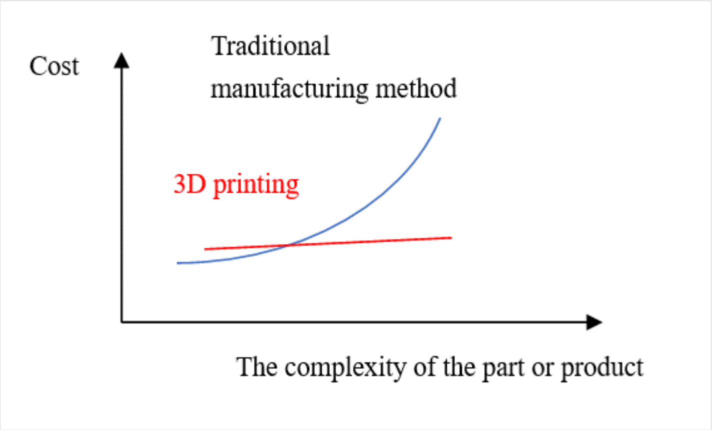


Figure 1.7: The cost advantage of 3D printing in the production of complex parts

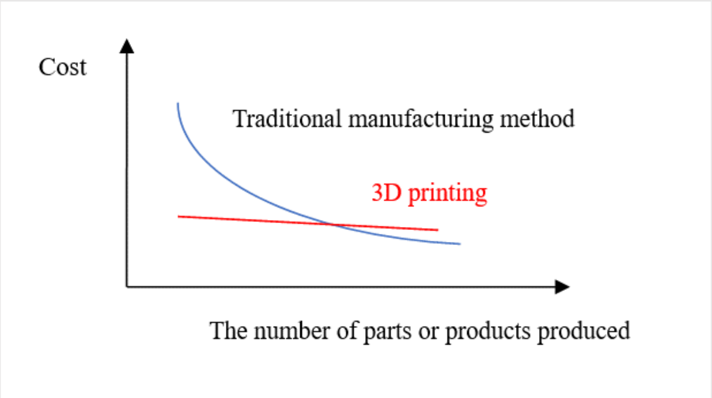


Figure 1.8: 3D printing has advantages for the production of single low-volume parts or products

2) Short production cycle and high precision

3D printing technology can optimize many complicated processes in the production process of traditional manufacturing and processing industry, and directly manufacture complex structures so as to find problems in product modeling and structural design as soon as possible, significantly improving the efficiency of new product research and development and the success rate of production line production. For example, 3D printing does not require a mold opening process, which dramatically saves work time. The characteristics of one-shot molding significantly reduce the workload of auxiliary processing in the later stage, and reduce the steps of entrusting third-party processing, which effectively guarantees the security of confidential data in some confidential fields (such as aviation, nuclear power, military industry, etc.). At the same time, it also reduces the accumulation of errors in the manufacturing process, making products more accurate, especially in high-end precision machinery industries such as automobiles, aircraft, and nuclear power. 3D printing technology can realize the natural and seamless connection of products without parting lines and unnecessary gaps, making the product structure more stable. Its rigidity and strength are significantly higher than traditional manufacturing processes. Compared with traditional production technology, 3D printing technology can increase machining efficiency by 3.5 times, shorten the product development cycle by 30%-90%, and save production costs by 30%-50%.

3) Integrated molding manufacturing of products

Traditional large-scale system production requires the production of different parts first, and then workers or robots assemble and adjust them on the assembly line. The more parts and components the product assembly consumes, the greater the labor and time cost. 3D printing can realize the integrated molding of products. Through layered and sub-regional manufacturing, different parts can be printed with different materials simultaneously, which reduces many intermediate links, eliminates complex assembly processes, and saves human resources material resources. Using traditional methods to manufacture parts, the entire production process generally takes several months, while 3D printing technology may only take days or even hours, significantly improving production efficiency.

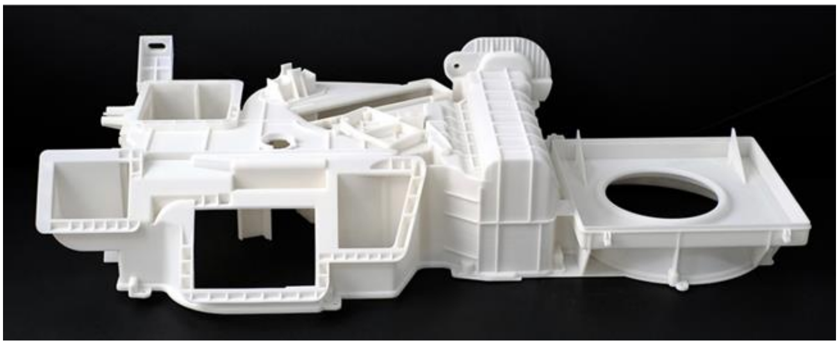


Figure 1.9: 3D integrated printed car air conditioner shell

Source: Farsoon

4) Product variety and personalized design

Traditional mechanical equipment is limited in function, and the types of products produced are also minimal. However, 3D printing technology does not require the purchase of new machinery and equipment nor the training of new professional technicians. The same 3D printer can print countless products of different shapes, can form assembly-free structures and complex porous structures that traditional processes cannot achieve, and realize a personalized customization experience for users. The relationship between designers and products, between designers and users, and between users and products become more harmonious.

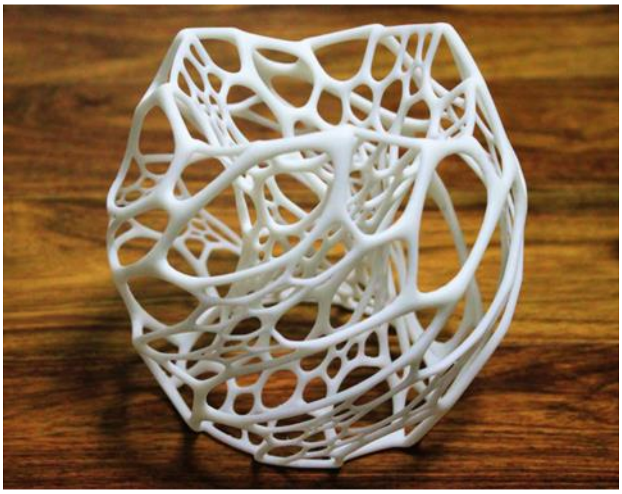


Figure 1.10: Personalized 3D printed artwork
Source: bqi3d.com

5) Product design is not limited by technology and form

Traditional manufacturing technology is limited by tools, technological level, processing methods, etc. The form of manufactured products is also limited. For example, mold-making machines can only make fixed die-cast shapes, and traditional wood lathes can only produce round products. 3D printing technology can break through these limitations and provide designers with more possibilities.

6) The 3D printing machine has strong operability

Traditional handicraft manufacturing requires professional technicians to master skilled professional skills. Even in the age of mass production and computers, many experienced professionals are still required to operate and calibrate the machines. 3D printing has created a new business model. Even if the product is complex, as long as the computer source file is obtained, anyone can produce the product in any environment, and the operation is simple and easy. The low demand for professional skills provides the possibility for ordinary people to manufacture products in remote environments or extreme situations.

7) The manufacturing machine has high portability

Compared with traditional manufacturing machines, the production capacity of 3D printers is more powerful. For example, limited by the physical volume of the machine, traditional injection molding machines can only produce products much smaller than their own volume. At the same time, 3D printers can manufacture products as large as the printing table due to their small size and ease of movement. The advantage of higher portability makes 3D printers expected to become necessary for home or office in the future. At present, the existing home 3D printers on the market are basically the same size as ordinary printers. Of course, some industrial-grade 3D printers are similar to traditional industrial equipment and require particular production environments.

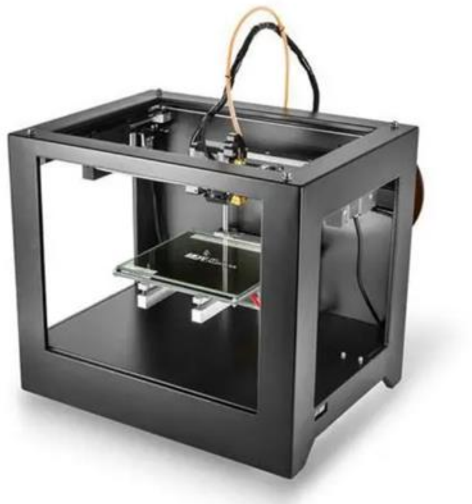


Figure 1.11: Regular 3D Printer

8) The process of producing products is green and environmentally friendly

The traditional metal processing method will cause nearly 90% of the metal raw materials to be discarded, which will easily cause serious waste of resources and seriously endanger environmental health. Another invisible benefit of 3D printing technology is that it can recycle the remaining materials after processing, which effectively alleviates the tension between supply and demand of some non-renewable resources (such as rare earth metals) and dramatically reduces the generation of by-products and waste. At the same time, electronic printed documents are transmitted through the Internet to replace the transportation of raw materials and finished products, allowing factories to produce products nearby, simplifying and eliminating complex production lines and parts supply chains. From the perspective of environmental protection, the carbon emissions of products have been reduced, and the global "resource production efficiency" has been improved. Another significant contribution of 3D printing to environmental protection is its "zero inventory" feature. 3D printing technology allows manufacturers to produce and manufacture products on-demand without establishing a product storage mechanism or even a spare parts inventory, reducing cost investment risks and Waste product waste.

9) Diversified production with multiple raw material combinations

Since today's industrial equipment processes raw materials by cutting, casting, and multi-dimensional processing, it is difficult to simply integrate raw materials of different properties into a very stable new material. With the in-depth research of 3D printing technology on the fusion of various materials, it provides a variety of possibilities for mixing materials with different characteristics, resulting in many material structures with unique properties and functions. It optimizes product performance, helps to achieve lightweight product structure, and further improves the utilization rate of materials.

10) Miniaturization of production models

In the traditional industrial manufacturing process, once the parameters of automatic machinery and equipment are determined, it is difficult to make changes, so it is suitable for the manufacture of a single type of product. 3D printing technology makes the manufacturing system more flexible and inclusive and can be quickly adjusted to suit different printing production tasks. 3D printing technology has the potential to fundamentally change the organizational model of the original production. A computer and a 3D printer can carry out product development and manufacturing. This low-threshold production model has weakened the intensive production advantages of large enterprises and increased the survival opportunities of small and medium-sized enterprises and even individual entrepreneurs. It will transform large-scale factory production into a new model of miniaturization.

2.2 China's additive manufacturing technology policy development

Since the advent of 3D printing technology, countries worldwide have taken 3D printing services as a new growth point for future industrial and enterprise development. The Chinese government and the business community have also attached great importance to it. China started research additive manufacturing technology as early as the 1990s, mainly in universities and research institutes. However, due to the limitations of weak basic conditions such as raw materials and high-end equipment, the early development was relatively slow. After 2008, with the breakthrough of raw material technology, the introduction and development of high-performance equipment, and the improvement of automation control level, additive manufacturing technology has developed rapidly.

The Chinese government-level programmatic document "*National High-tech Research and Development Plan (863 Plan), National Science and Technology Support Plan Manufacturing Field 2014 Alternative Project Collection Guide*". For the first time, additive manufacturing technology has been incorporated into the national high-tech manufacturing technology strategy, aiming to seize the opportunity of a new round of global industrial revolution through government-led top-level design and cutting-edge layout. After that, the release and implementation of a series of policies such as "*National Medium- and Long-Term Science and Technology Development Plan (2006-2020)*", "*Made in China 2025*" and "*Additive Manufacturing Industry Development Action Plan (2017-2020)*" have further strengthened the It strongly encourages and promotes the rapid development of additive manufacturing in China, and clearly stipulates that "by 2020, the annual sales revenue of the additive manufacturing industry will exceed 20 billion yuan (about $3 billion), with an average annual growth rate of more than 30%." In addition, it will also strengthen the construction of additive manufacturing innovation system, critical common technology development, special material research and development, equipment and core device technology, standard specification system and service quality as the critical work in the future.

2.3 Development of 3D printing technology in China

In the late 1980s, China launched the "experimental stage" research on 3D printing technology, developed industrial-level additive manufacturing application services, and carried out applications in critical industrial fields, such as national-level aerospace applications, military machinery and equipment applications, etc. In 1988, Tsinghua University established the Laser Rapid Prototyping Center. In 1991, Huazhong University of Science and Technology established the Rapid Manufacturing Center to study the paper-based layered entity manufacturing technology (LOM). In 1992, Xi'an Jiaotong University established the Institute of Advanced Manufacturing Technology.

In 1993, China's first additive manufacturing company, Beijing Yinhua Rapid Prototyping Abrasives Technology Co., Ltd., was established. In 1994, Huazhong University of Science and Technology successfully developed China's first LOM prototype service based on thin paper. In 1995, Northwestern Polytechnical University proposed the concept of 3D printing technology based on laser cladding technology and carried out related foundation Service Research. In 1996, Wuhan Binhu Electromechanical Technology Industry Co., Ltd. was formally established based on Huazhong University of Science and Technology. In 1997, Xi'an Jiaotong University established Shaanxi Hengtong Intelligent Machine Co., Ltd. and sold the first set of light-curing rapid prototyping (SLA) additive manufacturing equipment in China. In 1998, Huazhong University of Science and Technology began to research SLS service and SLM service. In 2000, Beijing University of Aeronautics and Astronautics aimed at primary national strategic needs such as large aircraft and aero-engines and began tackling critical laser 3D printing services problems. Subsequently, it broke through the laser forming process of related vital components, complete sets of equipment, and application key services for the first time in the world.

In addition, Beijing Longyuan Automatic Forming System Co., Ltd., established by relying on social forces, has developed services based on SLS additive manufacturing equipment since 1993. In May of the same year, China's first industrial-grade additive manufacturing service "Laser Selective Sintering Service (SLS))" was successfully launched, and obtained a Chinese invention patent in 1994. In 1996, the first commercial SLS additive manufacturing AFS-300 solution formed by Beijing Longyuan was sold to the Beijing Institute of Aeronautical Materials and successfully applied to develop new military aviation products. In January 2013, Beijing University of Aeronautics and Astronautics won the first prize of China's National Technology Invention Award for the project "*Laser Forming Technology for Large and Complex Integral Components of Aircraft Titanium Alloy*".

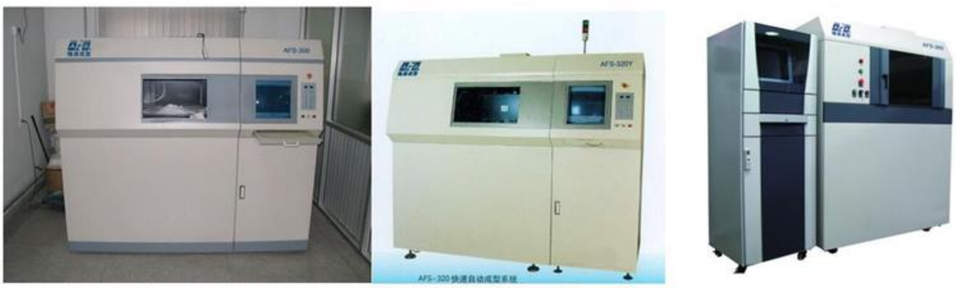


Figure 2.1: The first commercial SLS additive manufacturing AFS-300

Source: cinic.org.cn

China's titanium alloy laser forming technology started late, but the technology has developed rapidly and successfully. In 1985, the United States secretly started research on titanium alloy laser forming technology under the leadership of the Department of Defense and made it public in 1992. China did not start investing in R&D programs until 1995. In the early stage of research and development, the research and development personnel basically followed the United States to study and set up laboratories in many universities and research institutes in China to conduct research. Among them, the achievements made by the AVIC Laser Technology Team are the most significant. Around 2000, the AVIC laser technology team had already begun to invest in the research and development of "3D laser welding rapid prototyping technology", with the continuous support of the state, especially the military. After several years of research and development, it has solved many world technical problems such as "inert gas protection system", "thermal stress dispersion", "defect control", "lattice growth control", etc. It produces products with complex structure, size up to 4m, and performance that meets the requirements of the main bearing structure, which has commercial application value.

At present, China has the technology and capability to use the laser to form complex titanium alloy components exceeding 12 square meters and has invested in the prototype and product manufacturing of several domestic aviation scientific research projects. It has become one of the few countries globally that has mastered manufacturing and applying large-scale main bearing components of laser-forming titanium alloys. Due to titanium alloys' lightweight and high strength, titanium alloy components have broad application prospects in the aviation field. At present, the proportion of titanium alloy components on advanced fighters has exceeded 20%. Laser titanium alloy forming technology completely solves this series of problems. Due to the use of superposition technology saves 90% of costly raw materials, and there is no need to manufacture special molds. It is roughly estimated that the cost of the traditional process is about 25 million yuan to process a 1-ton weight of titanium alloy complex structural parts. In comparison, the cost of the laser 3D welding rapid prototyping technology is only about 1.3 million yuan, and its cost is only 5% of the traditional process.

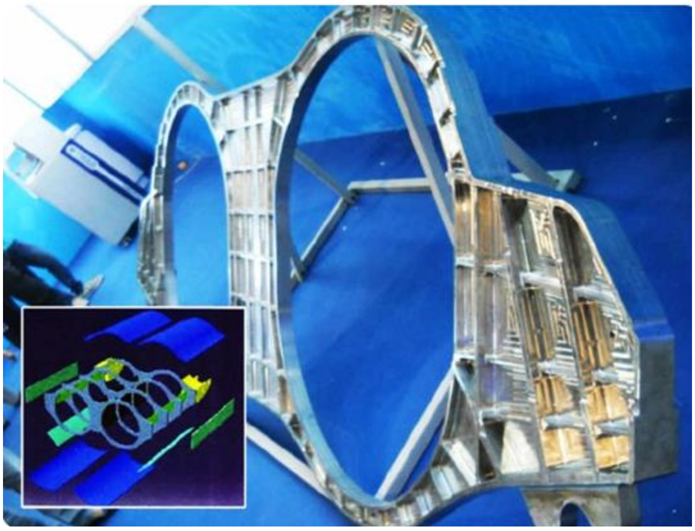


Figure 2.2: Aircraft skeleton produced by 3D printing of titanium alloy in China

Source: Baijiahao

2.4 Development and use of 3D software in China

3D printing equipment needs to rely on digital models for processing, and the generation of digital models requires computer-aided design tools (CAD/CAID three-dimensional modeling software). China's independent CAD software development and application history are relatively early. It has an excellent technical foundation and talent foundation in the basic research of CAD and computer graphics, and the development of large-scale application software systems. These basic research start from the research on the most critical fundamental theories and critical algorithms in CAD systems such as curves, surfaces and geometric modeling. The investment personnel is mainly from industries such as ships and aviation. Some university professors also went deep into research institutes, factories and enterprises to participate in fundamental theoretical research.

In terms of software research and development, China started the basic research of CAD software as early as the 1960s. In 1967, the Chinese ship field first applied computer technology to the processing of curved surfaces. In the summer of 1971, Shanghai established the "Mathematical Stakeout Team”, carried out research on three-way smoothing of hull lines and hull outer sheeting. In 1983, eight departments including the National Science and Technology Commission held the first CAD application work conference in Nantong to discuss the development of China's independent copyright CAD industry. In 1988, Shanghai Ship Technology The institute successfully developed a relatively complete interactive CAD system-DPS. In 1991, the Chinese government began to pay attention to the application and promotion of CAD technology. In 1992, China launched the "*CAD Application Engineering*" program and listed it as the "*95 Program*" focus. The Bai Yulan System (BYL-cad) named after the magnolia flower was listed as an integrated CAD support system by the Shanghai Municipal Science and Technology Commission for development and promotion. Subsequently, many Chinese domestic CAD enterprises were quickly established.

Figure 2.3: DSP system logo

However, after 2000, CAD software entered the three-dimensional era, with higher technical thresholds and longer development cycles. After China joined the WTO, many excellent foreign CAD software entered China to seize the market. At the same time, China's awareness of patent copyright protection was weak, knowledge of the relevant laws of property rights protection is not perfect, and the phenomenon of piracy in the market is severe, which has suppressed the development of China's local CAD software. Later, secondary development based on foreign software became the main form of China's CAD software market, resulting in heavy dependence on foreign software, and it was difficult for Chinese private software development companies to launch independent CAD software. At present, the CAD software in China's 3D printing market mainly includes 3Dexperience, Solidworks, Delcam, Materialise, Autodesk, Adobe, etc., which have been monopolized by European and American companies. In recent years, the Sino-US trade friction has become more serious, and the United States will continue to suppress China's industrial development. In 2013, the ITC organization stopped China from renting IntelliCAD kernels to curb the development of China's domestic CAD software. Afterwards, some Chinese universities were banned from using MATLAB software, which greatly impacted China. The construction and development of China's independent copyright CAD software have become the consensus of Chinese society.

2.5 3D printing equipment manufacturing in China

3D printing equipment is mainly divided into desktop-level and industrial-level, and the price of desktop-level 3D printers is relatively low. Printers with plastic as the primary material are generally priced between \$1,000 and \$4,000, and more expensive photosensitive resin printers are priced around \$5,000. The price of industrial-grade 3D printers is relatively high. The cheapest industrial-grade printers are generally \$30,000, and the price of metal printers is comparable to that of large-scale industrial equipment. One of the main factors restricting the industrialization of China's 3D printing equipment in the early stage of market development is that most of the key components, such as lasers, scanning galvanometers, nozzles, and precision optical devices, rely on imports. The laser market is occupied by international companies such as SPI, IPG, AOC and DPSS, and the market of scanning galvanometers is mainly occupied by German Scanlab.

Figure 2.4: Large-scale industrial 3D printing equipment
Source: zcool.com.cn

Currently, 48% of China’s 3D printing market revenue comes from 3D printing equipment (compared to 37% in Europe and 33% in the US). This figure indicates strong demand for 3D printing hardware in China. In recent years, my country's 3D printing market as a whole has shown a trend of the increasing year by year. More and more companies have entered the field of 3D printing and hope to occupy a place in the entire 3D printing market. In the Chinese 3D printer market, industrial-grade 3D printers are the mainstream, and light-curing equipment occupies the largest market share. Statistics from 3D Science Valley show that the Chinese market occupies a mainstream position in the procurement of high-end industrial-grade 3D printer equipment. More than 44.1% of enterprises use industrial-grade 3D printers with a unit price of more than 100,000 US dollars.

In terms of brand competition, there are many brands in China's 3D printing market, and about half of them entered the 3D printing market after 2016. At present, the mainstream equipment brands in the Chinese market include UnionTecch, EOS, Farsoon, Xi'an BLT, 3DSystems, GE, Stratasys, HP, etc., primarily foreign brands. But foreign brands dominate. Metal 3D printing is one of the critical areas for the rapid growth of the Chinese market. Companies such as BLT, Yijia 3D, Farsoon, and Hanbang Technology have been deeply involved in this field and have been applied in aerospace, automotive and medical fields.

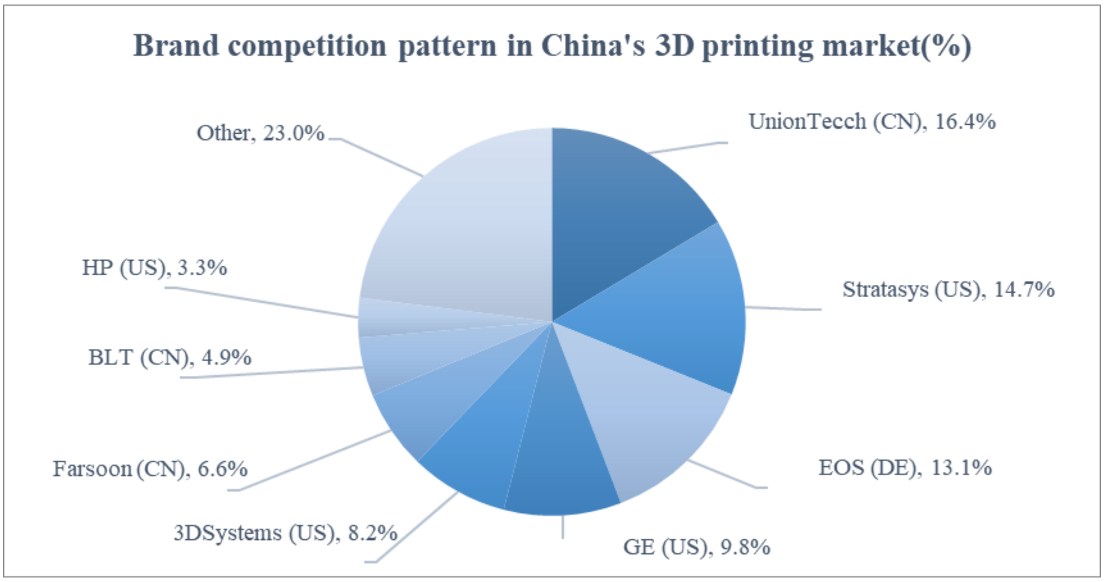


Figure 2.5: Brand competition pattern in China's 3D printing marke

2.6 R&D and production of 3D printing raw materials in China

3D printing materials are an indispensable part of the 3D printing industry, and the technical level of 3D printing materials directly affects the development of the 3D printing industry. In recent years, China has paid more and more attention to the 3D printing material industry at the national level and has basically formed a relatively mature industrial chain. At the same time, at the national level, the "*Action Plan for the Development of the Additive Manufacturing Industry (2017-2020)*", "*The Catalogue of Key Components and Raw Materials for Import of Major Technical Equipment and Products*", "*The Major Projects Supported by the State for Development*" "*Technical Equipment and Product Catalog*", "*Three-Year Action Plan for Enhancing the Core Competitiveness of Manufacturing Industry (2018-2020)*" and other policies that promote the 3D printing material industry. These policies support the development of the 3D printing material industry by formulating industry development goals, financial subsidies, and inclusion in critical areas.

China's 3D printing material market is mainly occupied by large local companies and foreign 3D printing material companies. According to the types of material products, it can be divided into metal powder materials, light-curing resins, wires and non-metal materials. According to the current public information, the global 3D core material-related events from 2019 to 2020 are still dominated by engineering plastics and supplemented by metal materials. From the perspective of global 3D printing material events, foreign 3D material research and development institutions are extensive, covering the military, universities, and enterprises. In contrast, China's 3D printing material research and development are still concentrated in scientific research institutes, and a mature commercial research and development model has not yet been established.

3D metal printing can meet the requirements for structural design, materials and manufacturing processes in product manufacturing. It can significantly reduce the quality of parts while ensuring performance while effectively shortening the manufacturing process of parts. As the application direction of 3D printing technology gradually shifts from the production of samples and molds to the production and application of final products, 3D metal printing technology will develop in the direction of low cost, large size, multi-material, high precision and high efficiency, and the metal printing material will occupy the increasing market share.

2.7 Talent management and training in the field of 3D printing in China

Since the development of China's 3D printing industry, it has gradually grown into a critical industry that can meet industrial production and realize the transformation of China's manufacturing industry. However, while the industry is proliferating, the shortcomings of China's 3D printing technology and talent training have become an important obstacle to industrial progress. At present, almost half of the global 3D printing application market is occupied by the United States, 30% in Europe, and 20% in China. There is still a lack of core design application talents. There is no undergraduate major in 3D printing in China's existing education system, but it is only set up at the postgraduate level. It is necessary to build a comprehensive 3D printing technology education system in the future.

3. 3D printing service industry status and market analysis of China

With the development and improvement of 3D printing technology, the complexity of printing solid workpieces is also increasing. 3D printing technology has gradually been widely used in aerospace, transportation, industrial equipment, electronic products, medical care, education and construction.

3.1 Application scenarios of 3D printing technology

3D printing technology is mainly used in prototype manufacturing, pharmaceutical industry, aviation industry, military and other fields. In addition, in the household, construction and other industries, the application of 3D printing technology has also brought new opportunities for the development of the industry.

- Applications in Industrial Design

Product modeling design can only depict its three-dimensional graphics on the screen through computer software in traditional industrial design. Now using 3D printing technology can quickly produce a 1:1 physical model and conduct an accurate evaluation of the size and appearance of the product, making it more humanized. In developing and designing automotive interior parts, household appliances, and light industrial products, 3D printing has become a very reliable technical means.

- Applications in the automotive industry

In the automotive industry, 3D printing technology is mainly used in automotive parts design, mold design and prototype concept design. The use of 3D printing for parts and prototypes can quickly and intuitively feel the designer's ideas and clearly find the problem, to optimize the product and achieve a benign and fast closed-loop design. At the same time, the design and maintenance of some personalized parts can be directly manufactured and installed. Due to the high cost and low production efficiency of 3D printed metal parts at this stage, it is only used for performance improvement parts of some high-end cars.

Figure 3.1: Divergent 3D showcases new 3D printed supercar
Source: cnbeta

- Applications in the pharmaceutical industry

The application of 3D printing in biomedicine mainly focuses on organ repair and transplantation, construction of soft tissue support, bone or oral and maxillofacial implantation, cosmetic surgery, medical equipment, medical auxiliary equipment, etc. Special orthodontic appliances are printed according to the patient's specific physical defect in joint surgery. In terms of surgery, the patient model can be printed, the preoperative plan can be drawn up, and the optimal surgical method can be summed up to improve the safety and success rate of the surgery. In Maxillofacial, Orthopedics and Oral Dentistry, hearing aids, bone tissue supports, dentures or clear braces can be printed to fit patients' individual characteristics to help patients recover. In the rehabilitation department, comfortable and convenient rehabilitation aids are printed out.

According to the simulated human organ model, in the manufacture of artificial bone materials, heart valves, human heart stents and even human organs, 3D printing has already had many successful application cases using 3D printing technology to print living embryonic stem cells. Tests have shown that these stem cells still maintain the normal differentiation ability of human embryonic stem cells. In addition, 3D printing technology also has critical applications in biopharmaceuticals.

Figure 3.2: Titanium 'lightweight' sternum-rib complex custom-made with 3D printing

Source: tengxun news

- Application in the aviation industry

In the aerospace field, 3D printing is mainly used for complex parts manufacturing, topology optimization manufacturing, integrated design of structural and functional components, manufacturing of dissimilar materials, rapid trial production of engines, and simulated assembly. Using 3D printing technology, Boeing has made about 300 different aircraft parts, and Boeing is currently studying the use of 3D printing technology to print more oversized products such as wings. Aviation giant Airbus is also trying to use 3D printing technology to manufacture aircraft cabins. Currently, 3D printed luggage racks have been used on the Airbus A350. In China's self-developed C919 large passenger plane, 3D printing is used to manufacture aircraft titanium alloy parts.

- Applications in the home industry

In the early days of 3D printing technology, printers with large specifications and single functions were primarily used in large factories and enterprises and were rarely used in homes. After more than 20 years of technological innovation, printers have gradually developed in the direction of miniaturization and portability. In the home furnishing industry, 3D printing has already had some applications, and it has achieved success in printing toys and food. The exploration in the furniture industry is also underway.

- Applications in the construction industry

The application of 3D printing in the field of construction has two aspects: one is to print building models, and companies such as iMaterialise provide services for printing miniature home models. The second is to print each building module and finally splicing into a whole building. Dutch architect Janjaap Ruijssenaars has designed the world's first 3D printed building "Landscape House", which specifically simulates the peculiar "Möbius ring". The designer plans to build the building by 3D printing building modules and splicing them together.

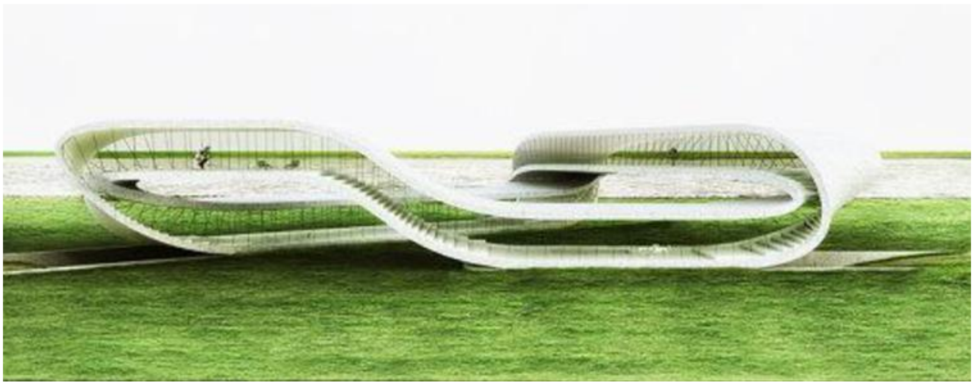


Figure 3.3: The world's first 3D printed building "Landscape House"

Source: 3dprint

- Application in the military field

3D printing is widely used in the military field. China's current fighter jets Jian-15, Jian-16, stealth fighter Jian-20, Jian-31 are widely used in the research and development of 3D printing technology. Rifles and multi-round pistols made with 3D printers have already been born. The US military uses 3D printing technology to assist in manufacturing missile ignition models and uses 3D printing technology to process engines and military satellite parts.

According to the statistics of the application of 3D printing in various industries around the world in 2020, it can be seen that transportation, consumer electronics, aerospace, medical and industrial equipment occupy an important proportion, which also indicates that 3D printing technology is in Both the personal consumption direction and the high-tech field have broad application prospects.

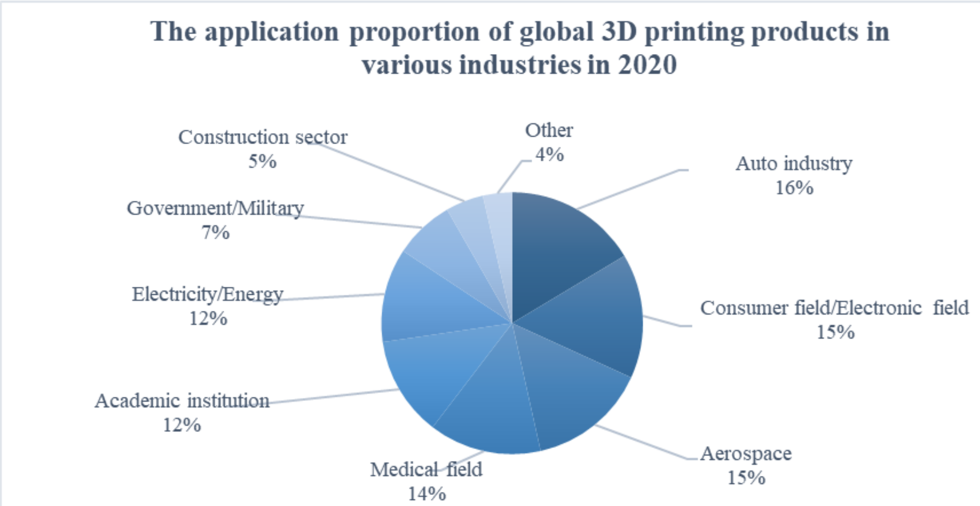


Figure 3.4: The application proportion of global 3D printing products in various industries in 2020

3.2 The impact of 3D printing technology on traditional manufacturing

3D printing has been valued by academia and manufacturing since its inception. Many Chinese academics consider it an essential symbol of the "third industrial revolution". Chinese government departments and scientific research institutions have also held several seminars in recent years to discuss ways to promote the R&D and industrialization of 3D printing technology.

From a technical point of view, 3D printing technology is a new type of processing technology in the development of the manufacturing industry, and it is also incubated based on the existing manufacturing industry. There is no problem of replacing the traditional manufacturing industry. The additive manufacturing technology of 3D printing and traditional numerical control the relationship between the subtractive manufacturing technologies of machine tools is a relationship that complements and complements each other. At present, many 3D printer parts are produced by existing subtractive manufacturing equipment, and then used to make up for the lack of processing capacity of subtractive manufacturing equipment. For example, the machining performance of titanium alloys is too poor, and the cost of machining with machine tools is too high. Using metal 3D printing technology is less difficult to process, moreover, after the metal 3D printing is completed, CNC machine tools are required for finishing.

Additive manufacturing and subtractive manufacturing are both critical production and processing technologies. They are production tools that cooperate with each other. They can only work under the existing manufacturing system. Although the current 3D printing technology has revolutionary significance, it cannot wholly subvert and replace traditional manufacturing technologies.

3.3 The size and distribution of the world 3D printing market

In 2020, in the scale of the global 3D printing industry, the revenue from 3D printing services was about 7.5 billion US dollars, accounting for nearly 60%, an increase of 20% year-on-year, and the global 3D printing equipment sales are 3 billion US dollars, accounting for 24%. Basically the same as the $3 billion in 2019, global sales of 3D printing materials were $2.1 billion, an increase of nearly 10% compared to $1.9 billion in 2019.

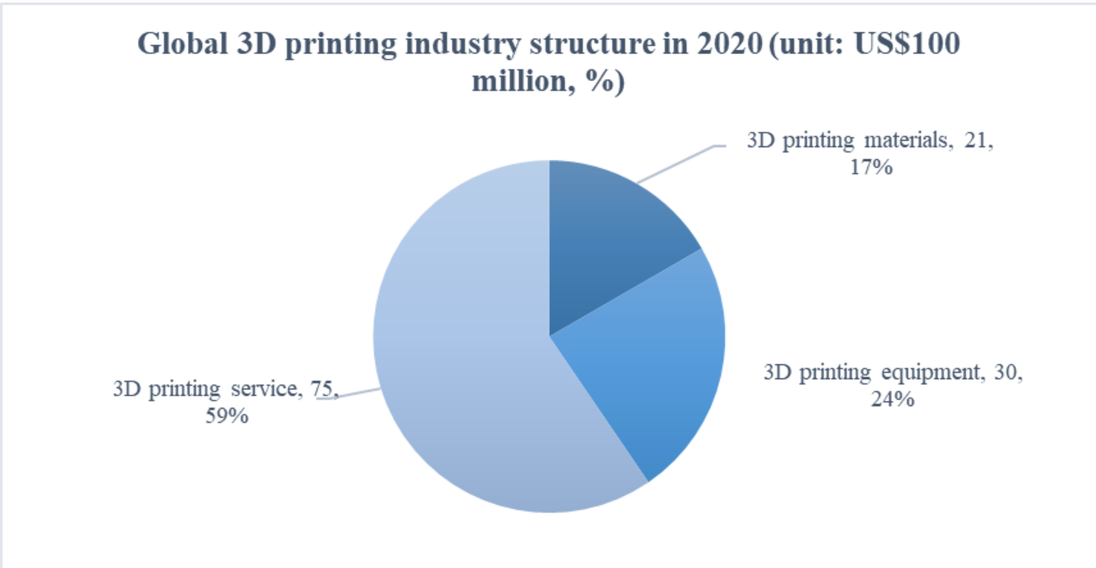


Figure 3.5: Global 3D printing industry structure in 2020

3D printing, including equipment, materials and services, saw an average annual growth rate of 26.1% globally, and it has grown at a double-digit rate for more than 20 consecutive years. This industry has vast untapped potential. From a technical point of view, 3D printing has experienced a "negative profit" introduction period of poor product quality, specializing in R&D and technological improvement. At present, some technologies are relatively mature, sales have begun to rise, market share has continued to expand, and competitors have continued to pour in, which is in line with the characteristics of the growth period. There will be a long growth period in the future, and eventually it will transition to a mature period, reaching the highest output value and total profit.

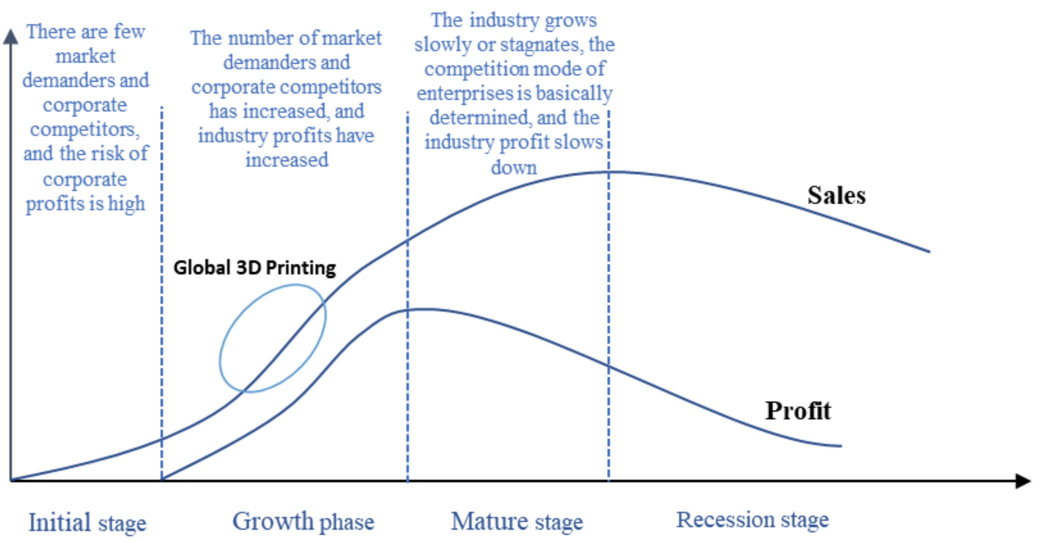


Figure 3.6

From 2014 to 2020, the scale of the global 3D printing market will continue to grow. In 2020, the global 3D printing market will exceed US$15.4 billion and is expected to reach US$34.9 billion in 2024.

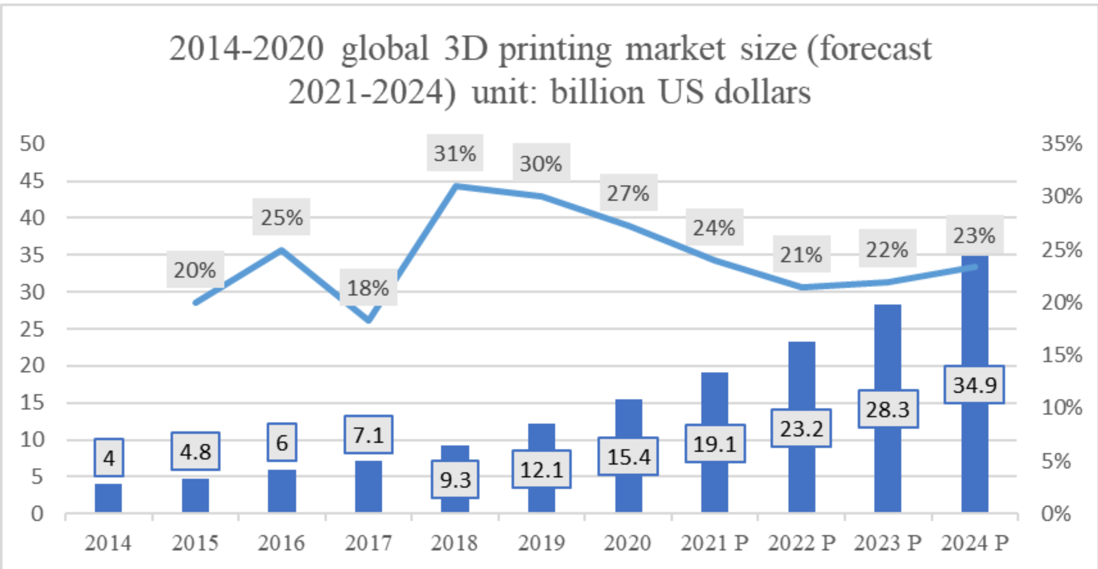


Figure 3.7: 2014-2020 global 3D printing market size (forecast 2021-2024) unit: billion US dollars

At present, the industrial scale of 3D printing in the United States accounts for 40.4% of the global proportion, Europe is second only to the United States, and China ranks third.

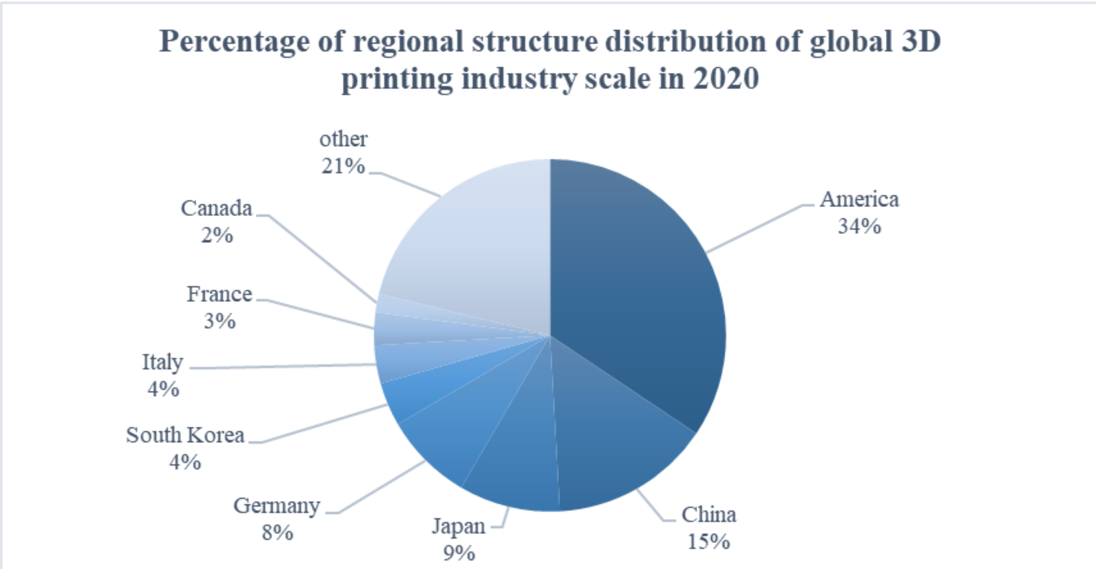


Figure 3.8: Percentage of regional structure distribution of global 3D printing industry scale in 2020

3.4 Macro environment of China's 3D printing market

The rise of China's 3D printing industry is due to the gradual development of 3D printing worldwide and its application in China. Although it started late, the vast market demand has stimulated the development of China's 3D printing industry. The application degree of China's 3D printing market has been deepening in recent years. It has been widely used in aerospace, automobile, shipbuilding, nuclear industry, mold and other fields. In this regard, the analysis method of PEST is used to analyze the development basis of China's 3D printing industry.

- P (Political environment)

In recent years, China has successively issued several related policies that are conducive to the development of additive manufacturing, such as "*Made in China 2025*", "*The 13th Five-Year Plan for Technological Innovation in Materials Field*", "*Additive Manufacturing* Industry *Development Action Plan (2017-2020)* ", "*Additive Manufacturing Standard Pilot Action Plan (2020-2022)* " and other policies have provided a guarantee for the development of 3D printing in China.

- E (Economic environment)

The traditional manufacturing industry urgently needs transformation, and the development of 3D printing is an effective way to intelligent manufacturing. With the increasing demand for 3D printing in traditional industries, it has attracted many companies from China and the world to enter the market.

- S (Social environment)

The increase in labor and raw material costs has made China's manufacturing industry urgently need new production methods to improve efficiency and efficiency. With the increase of labor and raw material costs in China, some manufacturing industries have to seek transformation, which provides a certain market foundation for developing 3D printing materials in China. At the same time, with the development of the economy and the improvement of living standards, consumers are more pursuing personalized needs, and 3D printing technology has apparent advantages in personalized customization.

- T (Technology environment)

The patents related to 3D printing outside China have expired one after another, and the research team can better convert the research results into industrial value. The proliferation of foreign 3D printing technology can promote the accelerated development of China's 3D printing industry.

3.5 China's 3D printing market status

In 2018, the scale of China's 3D printing market reached $2.36 billion, becoming the third-largest market after the United States and Europe. The Asia-Pacific region, including China, is becoming the fastest-growing region for the 3D printing market in the world. In 2020, the total output value of Chinese additive manufacturing enterprises will reach $3.3 billion, an increase of about three times compared with $1.058 billion in 2016. The global additive manufacturing market will grow at a rate of 14.4% by 2026, from $7.97 billion in 2018 to $23.33 billion in 2026. The Asia Pacific will grow at the highest growth rate of 18% and spend $3.6 billion on 3D printing over the next five years. China has provided a lasting impetus for the region's rapid growth.

From 2017 to 2020, the scale of China's 3D printing industry has increased year by year, and the growth rate is slightly faster than the overall global growth rate, so the proportion of China's 3D printing industry in the world is increasing. According to "2019 Global and Chinese 3D Printing Industry Data", in 2019, the scale of China's 3D printing industry was $2.5 billion, a year-on-year increase of 31.1%. According to preliminary statistics, the scale of 3D printing in China in 2020 will exceed $3 billion, about $3.3 billion.

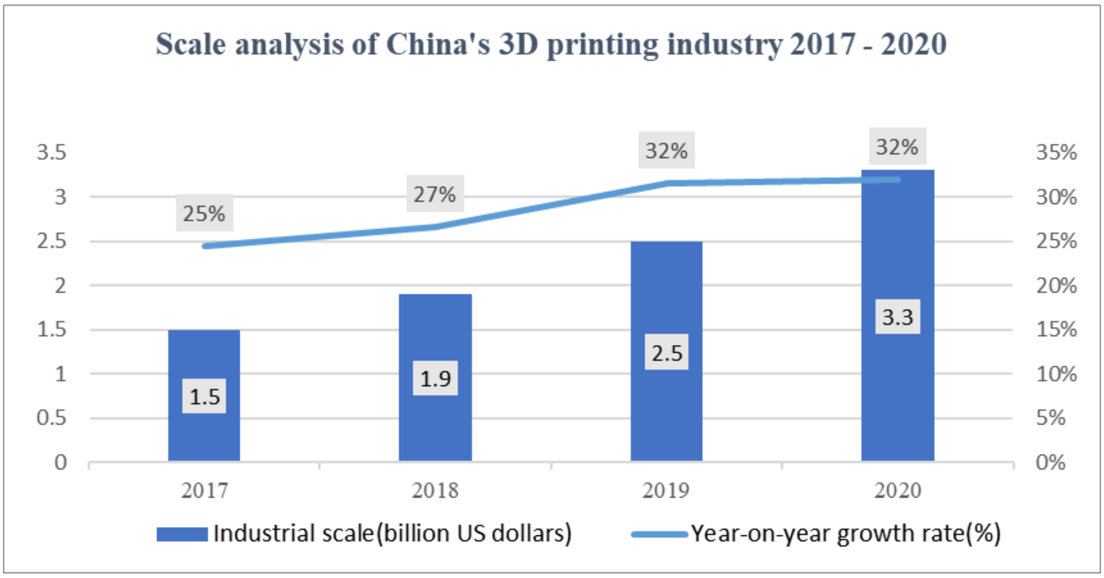


Figure 3.9: Scale analysis of China's 3D printing industry 2017 - 2020

According to the latest data released, in 2020, the scale of China's 3D printing equipment industry is $1.46 billion, accounting for the highest proportion, reaching 44.5%, the scale of the 3D printing service industry is $1.02 billion, accounting for 31%, and the scale of 3D printing materials industry is $800 million, accounting for 24.5%.

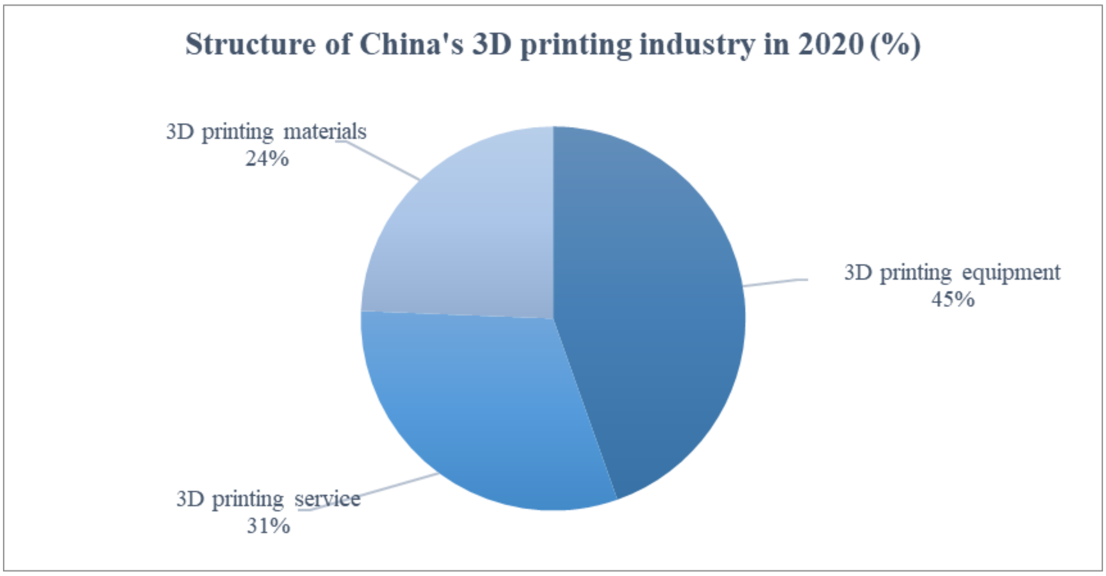


Figure 3.10: Structure of China's 3D printing industry in 2020

In terms of application fields, due to the high requirements on component quality and customization in industrial machinery, automobile manufacturing, aerospace and other fields. Therefore, the application fields of 3D printing in China are mainly concentrated in industrial machinery, automobile manufacturing, aerospace and other fields, the three together account for more than 50%, of which industrial applications account for 20%, aerospace applications account for 18.9%, and automotive applications account for 16%.

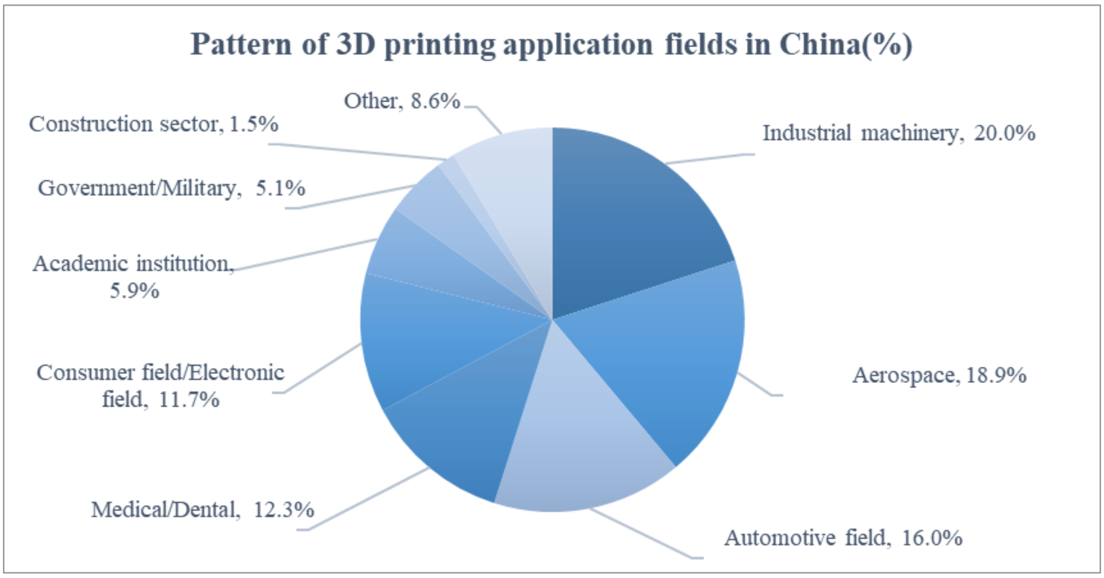


Figure 3.11: Pattern of 3D printing application fields in China

In China's 3D printing material industry structure, commonly used 3D printing raw materials include engineering plastics, photosensitive resins, rubber materials, ceramic materials, metal materials, etc. In terms of material classification, it is mainly divided into metallic materials and non-metallic materials. The currently used metal powder materials mainly include titanium alloy, cobalt-chromium alloy, stainless steel and aluminum alloy, etc. In addition, there are also precious metal powder materials such as gold and silver used for printing jewelry, accounting for a total of 39.3%. These metal materials are basically dependent on imports, and the cost is high. The remaining 60.6% are non-metallic materials, including nylon, PLA, ABS plastic, resin, etc. The non-metallic material industry accounts for the highest proportion. In 2019, the market size of China's 3D printing materials was 650 million US dollars, a year-on-year increase of 26%, of which metal materials accounted for about 40%, corresponding to a market size of about 260 million US dollars.

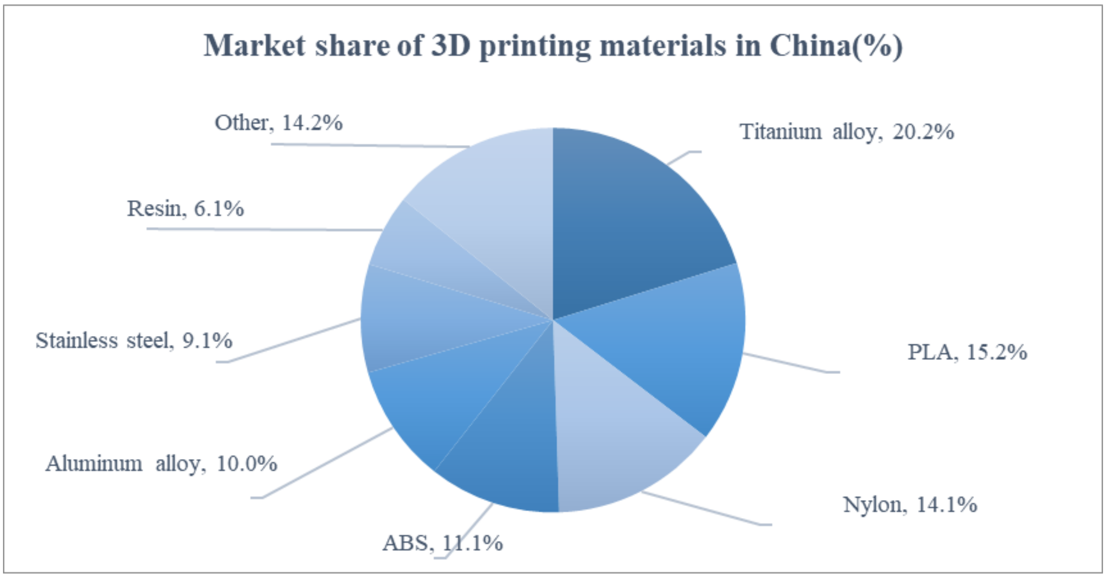


Figure 3.12: Market share of 3D printing materials in China

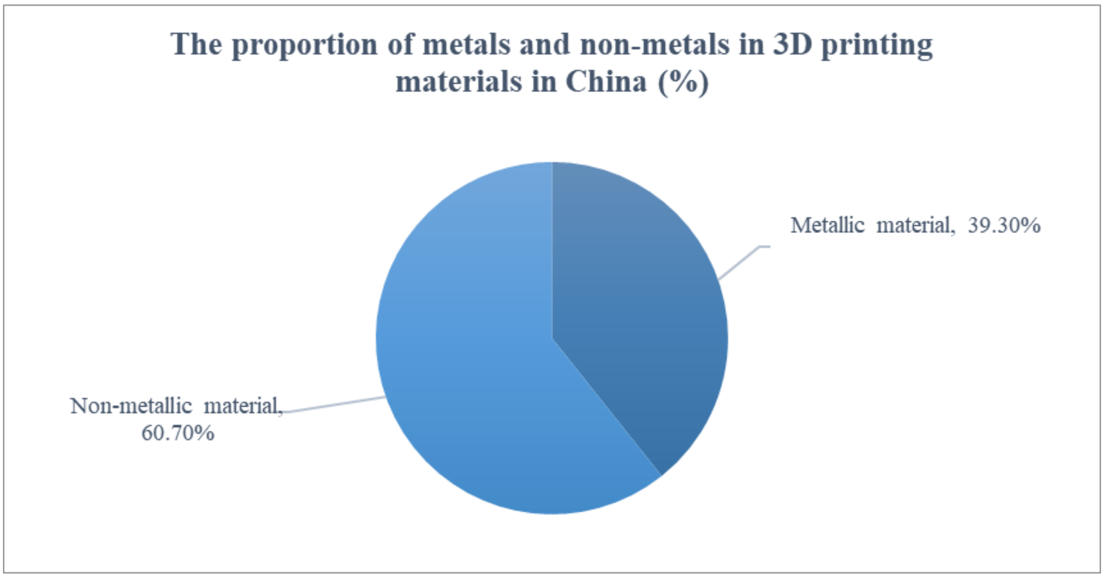


Figure 3.13: The proportion of metals and non-metals in 3D printing materials in China

4. China 3D printing development plan

At present, the commercialization of 3D printing in China is still in its infancy. The development of 3D printing in China is mainly a corporate behavior. Enterprises face problems such as capital and technical limitations and need to choose the development direction of the future industry in time. Comparing the structure of the global 3D printing industry, 3D printing services account for 59.29% of the global additive manufacturing industry. In contrast, in China's 2020 statistics, 3D printing services only account for 31.05% of China's 3D printing industry, there is still a lot of room for development in the scale of the service industry.

Next, on the issue of China's 3D printing development decision-making, the SWOT analysis method is used to analyze the development plan of China's 3D printing market.

4.1 SWOT Analysis of China's 3D Printing Industry

SWOT is an acronym composed of English acronyms for Strengths, Weaknesses, Opportunities, and Threats. SWOT analysis, also known as situational analysis or strengths and weaknesses analysis, is a variety of major internal Advantages, disadvantages, external opportunities and threats, etc., are listed through investigation and arranged in matrix form, and then use the idea of systematic analysis to match various factors to each other for analysis, and draw a series of corresponding conclusions. The conclusion usually has certain decision-making. SWOT analysis is widely used in strategic research and competitive analysis. It has the advantages of comprehensive consideration, intuitive analysis, and easy use. It's a systems thinking.

The SWOT analysis of China's 3D printing industry analyzes the internal factors and external environment of China's 3D printing industry. China's manufacturing industry accounts for a high proportion of the world's industrial structure. China is known as today's "world factory" and occupies a leading position in the world in the field of traditional manufacturing. The following analysis defines the external environment of China's 3D printing industry as the traditional manufacturing industry in China and the 3D printing industry outside China, and following the overall to local thinking, first analyzes the external environment, and then analyzes the internal factors.

4.1.1 Analysis of External Opportunities for China's 3D Printing Industry

- Large market space

Similar to the development process of the computer industry, the price of both equipment and materials in the 3D printing industry basically shows a downward trend, which promotes the development of the 3D printing industry. According to the statistics of Wohlers Associates, an authoritative research institution in the 3D printing industry, the compound annual growth rate from 1993 to 2012 reached 17.7%. From 2012 to 2020, the global 3D printing market continued to grow. In 2020, the global 3D printing market will exceed 15.4 billion US dollars. It is expected to reach $34.9 billion in 2024.

- High-profit levels

Although the price of 3D printing equipment has dropped to varying degrees in recent years, it is still mainly concentrated in the equipment of a single technology, which is generally maintained at a high-profit level. This phenomenon is related to the numerous technical routes of the 3D printing industry, and no one technical route can be applied to all applications. From the perspective of the entire industry development stage, the current overall scale of the 3D printing industry is not large, and then subdivided according to different routes, the market share of equipment in each route is even smaller, it is easier to have a dominant situation, and the price can be well controlled within a higher range.

The profit level of 3D printing materials is higher than that of 3D printers. On the one hand, the technical content required for material manufacturing is high. On the other hand, many printing equipment manufacturers "bundle" equipment and materials and can only use specific materials, so that this market has formed a monopoly situation, and prices and profits have been well controlled. At present, there are more than 100 kinds of materials used in 3D printing equipment, including liquid resin, solid powder, solid filament, etc. In terms of price, the profit of materials is still very high. At the high end, the metal powder material used to make aircraft parts costs as much as $6,400 per kilogram.

- High demand for personalized customization

Diversified, personalized and customized products will become mainstream in the future, and 3D printing is a powerful tool to realize and cater to this trend. It is not difficult to find that many products on the market today lack individuality and are the same. One of the reasons for this phenomenon is the current mass production mode. With the help of 3D printing, companies can provide different products for each customer, combined with advanced production models such as cloud manufacturing, to achieve low cost while satisfying customization.

In the book "Long Tail Theory" written by Chris Anderson, editor-in-chief of Wired magazine in the United States, it is pointed out that the expected market share occupied by the long tail of products with low demand and sales is comparable to the market share of mainstream products. In the 3D printing industry, the benefits generated by the mass and universal customization production model are enough to rival the traditional mass-production model.

- New Possibilities

In recent years, the prices of 3D printing equipment and materials have continued to decline, and the continuous improvement of related technologies and molding quality is very beneficial for the production of formal products with 3D printing. Enterprises can deeply understand the characteristics of 3D printing and identify which parts are most suitable and beneficial to be manufactured by 3D printing. The advantages of 3D printing are especially evident if the production of a part is small, but complex molds and fixtures are required for production, and assembly work or secondary processing work requires a lot of workforces. The full-process digital manufacturing model of 3D printing also enables companies to place production in areas with low labor costs while maintaining the original high-quality level.

The field of 3D printing materials is also worthy of attention. Today, many 3D printing equipment manufacturers will designate printing material suppliers. This situation will also change with the continuous birth of general standards, and the price of materials will become lower and lower.

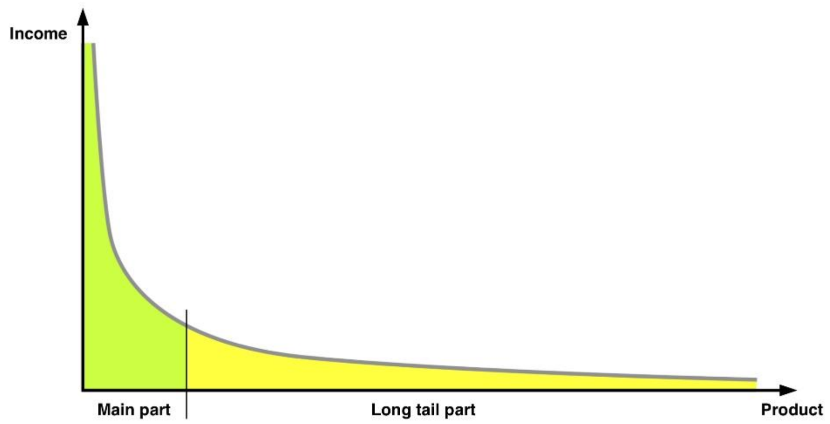


Figure 4.1: long tail model

- New Manufacturing Mode

The 3D printing industry can integrate 3D printers distributed in different locations through cloud computing and the Internet and use the most suitable 3D printers to manufacture products according to the location of customers and their requirements for product materials, volume, and color. A cloud manufacturing model with economies of scale is formed by integrating distributed equipment, which reduces energy consumption and harmful gas emissions, reduces transportation costs and time, and improves equipment utilization, forming a new form of manufacturing. At the same time, with the continuous improvement of the performance of 3D printing equipment and the continuous optimization of related materials, the proportion of 3D printers directly used in formal product manufacturing has increased year by year.

The many characteristics of 3D printing make the threshold for companies to access this field very low. For example, this technology can reduce the manufacturing cost of mold tools, etc., so companies can start manufacturing with less cost and smaller output. The ability to directly create a formal product makes converting a design concept into a product more accessible and efficient than ever for designers. At present, some Chinese companies have begun to provide deeply customized products and services. In the long run, these companies will change the game rules of the market. Those companies that can manufacture in large quantities and at low cost may no longer have an advantage, and these emerging companies have more advantages due to their unique design resources and huge user base.

4.1.2 External Threat Analysis of China's 3D Printing Industry

Like the development of any new technology or revolution, the development of 3D printing will inevitably face many difficulties and challenges. The deep-rooted traditional production methods, the limitations of technology, and the uncertainty of the market will all be reflected in the development of 3D printing.

- Giants monopolize the market

There is no doubt that the United States and Europe are the leaders of the 3D printing industry. Its progressive nature is not only reflected in the field of scientific research, but also practical applications. From the initial industrial prototyping, it has now penetrated various industries. In addition to the constant maturity of the industrial chain, business models are also gradually enriched, from material supply upstream of the industrial chain to printing equipment, supporting software and peripherals in the middle of the industrial chain, to downstream platforms and services. With the continuous advancement and evolution of technology, driven by the market, various business models and corporate strategies have been derived.

There are many 3D printing technology routes, each of which is controlled and dominated by the company that invented the technology or has related patents and has core competitiveness. Therefore, 3D printer manufacturers often use their printing equipment as a carrier through research and development and equipment matching, it has continuously penetrated into the upstream and downstream of the industrial chain and gradually grew into an overall solution provider covering the entire industrial chain. 3D Systems and Stratasys are the founders of SLA and FDM technologies respectively. Through continuous R&D and acquisition, they have formed a parallel situation of consumables, printer equipment and peripheral support, and printing services. Both companies have considerable income in these parts of the industry chain, and relatively balanced, the monopoly formed in consumables makes this part of the gross profit rate much higher than equipment manufacturing and downstream services.

- Changes in the global manufacturing landscape

The traditional competitive advantage of Chinese manufacturing is high quality and low price. With the continuous development of China's economy and the continuous improvement of people's living standards, China's advantages in labor costs will become lower and lower, and the price of products will be challenging to continue to reduce. This will limit the global competitiveness of China's manufacturing industry to a certain extent. The 3D printing digital manufacturing method consumes less workforce, materials, and energy than traditional manufacturing methods. The traditional advantages of China's manufacturing industry cannot be reflected, and the pattern of the world's manufacturing industry will be redistributed to a certain extent.

Although China's 3D printing industry has experienced years of development, it is still in its infancy. From the perspective of the entire Chinese 3D printing industry, there is still a lack of leading companies such as 3D Stratasys in the United States, and some core technologies are also monopolized by prominent European and American corporate giants. The extensive development model of the entire manufacturing industry and the lack of an innovative environment also restrict the popularization and promotion of 3D printing. China still has a long way to go to achieve industrial upgrading and transformation.

- The traditional manufacturing method has a significant influence

As a big manufacturing country, China's traditional advantage is the low-cost mass production mode characterized by standardization, batchization, and serialization. The inherent characteristics of 3D printing technology make this technology suitable for the production of customized and modular products. With natural advantages, enterprises can combine the characteristics of 3D printing to provide users with more competitive choices for the official products to be produced, so that users can get more satisfactory products, and enterprises can enhance their profitability. This is a massive contrast to traditional production methods, whether the 3D printing mode and the traditional mode can form benign mutual cooperation requires the joint action of multiple factors such as enterprises, policies, markets, and technology.

- Transformation of core competitiveness

3D printing has a powerful forming ability and gets rid of the shackles of complex shapes. At the same time, the design ability of parts or products is undoubtedly higher than that of traditional manufacturing methods, and it has also become an important part of core competitiveness. In the field of design, the use of computer-aided design for 3D modeling itself is not new, but computer-aided design for 3D printing is still a new topic. On the one hand, 3D printing will have new process requirements, on the other hand, 3D printing expands the range of molding, complex parts that traditional subtractive manufacturing methods cannot produce can be manufactured by 3D printing and can be designed to reduce weight while maintaining or enhancing mechanical properties. These all require new design methods and the cooperation of new CAD software to complete, and more importantly, most users need to learn and master this new knowledge. At the same time, the currently rapidly developing 3D scanning modeling method also needs Users can master new methods, new ideas, such as reverse engineering modeling, forward and reverse hybrid design, etc. In today's era of more and more emphasis on user experience, it is obviously a challenge to the 3D printing industry to put more demands on users.

- Intellectual property issues

3D printing lowers the threshold of manufacturing. With 3D model files and related printing equipment and materials, manufacturing can be carried out. Combined with the popularity of the Internet and file-sharing platforms, it is straightforward to copy and print products, and it is convenient to copy, share and modify. It also facilitates illegal piracy. The gradual popularity of 3D printing will inevitably be accompanied by an increase in intellectual property issues.

4.1.3 Analysis of the Internal Strengths of China's 3D Printing Industry

- Great market potential

In 2015, the total economic value created by additive manufacturing technology for Chinese society was 3.85 billion US dollars. In 2019, this value rose to 27.3 billion US dollars, a year-on-year growth rate of 710%. At present, the industrial scale of 3D printing in the United States accounts for 34.4% of the global proportion, Europe is second only to the United States, and China ranks third. China still lags behind the US and Europe in advanced manufacturing. Still, China has the most market potential and demand in this technology field, and China's 3D printing market has the opportunity to become the world's largest market in the future.

- Strong government support

In 2013, China's Ministry of Science and Technology listed 3D printing technology as an important research and development field. The government will invest 65 million US dollars in researching and developing 3D printing core technology. The key research areas include: Development and application of laser melting for the manufacture of large aircraft parts Equipment, development and application of large-scale laser melting 3D printing equipment that can be used to manufacture complex parts and molds, research and development of high-temperature and high-pressure bonding equipment for the fusion of complex parts materials and structures, and development and application of 3D printing core technology in the field of customized products. In 2015, "*Made in China 2025*" was put forward, which clarified eight strategic countermeasures, including improving product design capabilities, improving the manufacturing technology innovation system, and improving product quality. At the same time, the "*National Additive Manufacturing Industry Development Promotion Plan (2015-2016)*" jointly issued by the Ministry of Industry and Information Technology, the National Development and Reform Commission, and the Ministry of Finance clarified the development goals and promotion plans of additive manufacturing technology.

- The technical foundation is better

China's 3D printing industry started from Xi'an Jiaotong University, Beijing University of Aeronautics and Astronautics and other universities, with a good theoretical support system, breakthroughs have been achieved in key technologies in some fields, especially in high-end metal laser forming, and there are good research results. With the deepening of market operation, the technology in the past laboratory will have more opportunities to be applied in practice.

- Increased market awareness

At present, in China, 3D printing concept stocks have risen sharply, and 3D printing news is frequently seen on the Internet, TV and other media, which has indeed played an important role in promoting the awareness of 3D printing, and is conducive to attracting various industries to introduce and apply 3D printing technology, and is also conducive to attracting the intervention of capital.

4.1.4 Analysis of Internal Weaknesses of China's 3D Printing Industry

- Lack of educational promotion

For 3D printing technology, the degree of user participation is higher than that of traditional manufacturing methods, which is a manifestation of its degree of freedom, but requires users to have the corresponding ability and creativity, for example, the computer 3D modeling process, whether through CAD software, or Through 3D scanning, user participation is essential, and users need to learn. This is the charm of 3D printing for users who like to research and explore. However, for most ordinary consumers, it will be difficult and prohibitive for them. At present, the entire Chinese manufacturing industry is in the process of moving from "Made in China" to "Created in China". Lack of innovation and creativity is an important factor in the slow progress of this process. The lack of innovation ability and demand will also hinder the promotion of 3D printing. Education and training in the field of 3D printing are essential. However, in the current curriculum system of Chinese universities, subjects such as mechanics, materials, and IT lack 3D printing-related content, and 3D printing is still in the interest of some students and enthusiasts. It is difficult to conduct systematic in-depth research, and creativity cannot be stimulated. For enterprises and users, many enterprises and ordinary consumers still do not know what 3D printing can do. Even if they have purchased equipment, they do not have the knowledge and ability to actually apply the machine, resulting in idle equipment and slow promotion and application.

- Intellectual property protection

The issue of intellectual property protection has always plagued the 3D printing industry. The digital manufacturing method of 3D printing makes it easier than ever to share product designs and manufacture physical objects. Similar to the copyright issues faced by the music field several years ago, files containing 3D model information can also be widely disseminated on the Internet, and both innovators and imitators can launch similar products in the market. The problem of piracy and the licensing model is both a problem facing the industry.

- Low technical level

Design is inherently closely related to manufacturing methods. Architects need to consider the construction method to design houses. Engineers need to consider the advantages and disadvantages of processing methods such as turning, milling, casting, forging, and welding, and then design machines and parts. Designing based on traditional methods is mature for many companies for traditional manufacturing methods. However, how to design machines and parts for 3D printing is a new topic for everyone.

How to better use 3D printing technology is also a problem that needs to be faced, such as the best environmental conditions can be deployed to reduce the deformation of the printed parts, optimize the printing speed, adjust the material properties and so on. Adjusting material properties is more complex, and it should be relatively easy for plastics and even more difficult for metals. Production enterprises need to have a sufficient accumulation of relevant technologies.

The products that can be produced using 3D printing technology are extremely rich and cannot be designed and planned according to traditional manufacturing thinking. In many cases, bold ideas and innovations are required. Whether in the form of the final product or the entire molding process, it is different from the traditional subtractive manufacturing method. It can also verify the performance of all aspects of the product early in the entire product development phase, thereby improving R&D efficiency.

4.2 SWOT Analysis Matrix of China 3D Printing Industry

SWOT analysis method, through matching the external environment and internal factors in the analysis process, formed SO strategy, WO strategy, ST strategy, WT strategy. SO strategy emphasizes leveraging internal strengths to seize opportunities, the WO strategy emphasizes the use of external opportunities to compensate for internal weaknesses, the ST strategy emphasizes the use of internal strengths to avoid or reduce external threats, and the WT strategy is a defensive strategy that strives to compensate for internal weaknesses and avoid external threats.

Based on the external environment and internal factors of China's 3D printing industry, as well as the characteristics of SO, WO, ST, and WT strategies, a SWOT matrix can be made, and according to the specific situation of China's 3D printing industry, an appropriate development strategy can be selected to predict the future development trend.

Through the SWOT analysis in the previous chapter, it is found that the external opportunities of China's 3D printing industry are broad, but they will also be threatened, and internal strengths and weaknesses coexist. Based on this, further strategic analysis is made.

- When there are external opportunities and internal strengths, the SO strategy is adopted to give full play to internal advantages and seize opportunities. China's 3D printing industry needs to make rational use of policy support, take the road of industry-university-research integration, enhance innovation capabilities, improve the level of 3D printing equipment manufacturing and related materials research and development capabilities, and continuously increase market share.

- There are some external opportunities, but some internal disadvantages prevent the use of these external opportunities. It is appropriate to adopt a WO strategy and use external resources to compensate for internal disadvantages. In this case, China should learn from European and American countries and leading companies in the industry, such as 3D Systems and Stratasys. As the world's leading 3D printing industry giants, they continue to rapidly expand their market share through independent innovation, mergers and reorganizations, etc. At the same time, it is possible to carry out extensive cooperation, obtain more excellent support in technology and capital, and accelerate the process of industrial development.

- In a situation where there are external threats and internal strengths, ST strategies are adopted to use internal strengths to avoid or mitigate the impact of external threats and ultimately convert threats into opportunities. Enterprises can choose to provide 3D printing services, create a 3D printing platform as an entry point, take advantage of China's policy and market potential advantages, and avoid the traditional advantages of world giants in 3D printing equipment manufacturing and material research and development. In addition, make full use of China's advantages in the traditional manufacturing field, form a positive interaction with

China's 3D printing industry, and enhance its competitiveness in the new manufacturing mod.

- When there are external threats and internal weaknesses, use the WT strategy to reduce internal weaknesses, avoid external threats, and not face threats head-on. Starting from education and training, improve the industry awareness and technical level, and prepare talents for future development. Relying on China's colossal CAD user base, it combines new design methods and concepts with CAD to form design advantages in the design stage for 3D printing topics, so that China's 3D printing industry can develop as a whole.

Overall, the SO strategy is a strategy adopted in a very smooth situation and belongs to a growth strategy. WO and ST are strategies adopted under normal circumstances, WO is a reverse strategy, and ST is a diversification strategy. WT is a strategy that has to be adopted in the most difficult situations and is defensive. Summarize these strategies and list the SWOT analysis matrix of China's 3D printing industry.

SWOT Matrix	Internal Strength (S) • Great market potential • Strong government support • The technical foundation is better • Increased market awareness	Internal Weaknesses (W) • Lack of educational promotion • Intellectual property protection • Low technical level
External Opportunities (O) • Large market space • High level of profit • High demand for personalized customization • New Possibilities • New Manufacturing Mode • Leverage industrial upgrading and transformation	**SO strategy** • Rational use of policy support to improve R&D efficiency • Innovation-oriented, combining production, education and research to accelerate the process of marketization • Increase investment and increase market share	**WO strategy** • Seek technical cooperation and rapidly improve the technical level • Seek financial support and increase technological innovation • Learn advanced concepts, take the road of integration of the whole industry chain, and expand the influence of the 3D printing industry
External Threat (T) • Giants monopolize the market • Changes in the global manufacturing landscape • The traditional manufacturing method has a great influence • Transformation of core competitiveness • Intellectual property issues	**ST strategy** • Strengthen intellectual property awareness and build unique technological advantages • Promote the popularization of 3D printing and form a positive interaction with traditional industries • Start from relatively low thresholds such as services and platforms	**WT strategy** • Increase capital investment and exchange time for space • Enhance design capabilities and form technical advantages for 3D printing • Strengthen education promotion

Table 4.2.1: SWOT Matrix

4.3 The Chinese Government's Attitude Towards the Development of 3D Printing Technology and Related Policies

Similar to the previous model of promoting many new technologies or supporting industries in China, the initial development and promotion of early Chinese 3D printing technology, especially the development of desktop-level 3D printing, in addition to the advantages of the technology itself, largely stemmed from many government-led projects. China established a roadmap for the development of the 3D printing industry in 2012, aiming to promote the development of the industry from a policy perspective. At the same time, relevant government departments have established the China 3D Printing Innovation and Cultivation Project Organizing Committee, focusing on the promotion and popularization of 3D printing technology in the field of education. The China Trademark Office has set up a separate category for 3D printing to support the development of 3D printing technology from the side.

In 2015, the Chinese government released the "*Made in China 2025*" initiative, which aims to cultivate advanced technology, and 3D printing has become an important promoter of "*Made in China 2025*". In the same year, the Ministry of Science and Technology of China released the "*National Additive Manufacturing Industry Development Promotion Plan (2015-2016)* ", which established the goal of 3D printing innovation and commercialization. In 2016, China released the "*Thirteenth Five-Year Plan*", pointing out that the additive manufacturing method represented by 3D printing has been promoted to the national strategic level. The Ministry of Industry and Information Technology has joined forces with the Ministry of Finance and other departments to actively promote the development of the additive manufacturing industry. The Ministry of Finance of China supports the research and development of qualified additive manufacturing technology, equipment and key components through the national key technology project of "*Additive Manufacturing and Laser Manufacturing*", and studies the inclusion of qualified additive manufacturing in the "*Science and Technology Innovation 2030 Major Projects*" support scope.

Time	Policy
03/2020	***Additive Manufacturing Standards Pilot Action Plan (2020-2022)***
11/2019	***Catalogue of the first batch of application demonstrations of key new materials (2019)***
02/2018	***Guidelines for Review of Injection Technology for Custom Additively Manufactured Medical Devices***
12/2017	***Additive Manufacturing Industry Development Action Plan (2017-2020)***
12/2017	***Catalogue of key components and raw materials imported for major technical equipment and products***
12/2017	***Catalogue of major technical equipment and products supported by the state***
11/2017	***Three-year Action Plan for Strengthening Manufacturing Core Jingzhengli (2018-2020)***
11/2017	***High-end Smart Remanufacturing Action Plan (2018-2020)***
04/2017	***Thirteenth Five-Year Special Plan for Scientific and Technological Innovation in the Field of Materials***
01/2017	***National New Material Industry Development Guide***
10/2016	***Industrial Technology Innovation Capability Development Plan (2016-2020)***
07/2016	***The 13th Five-Year Plan for National Science and Technology Innovation***
05/2016	***National Innovation-Driven Development Strategy Outline***
05/2015	***Made in China 2025***
03/2015	***National Additive Manufacturing Industry Development Promotion Plan (2015-2016)***

Table 2.6: Summary of China's 3D printing industry policies from 2015 to 2020

4.4 China's attitude towards the protection of intellectual property rights and patents in the 3D printing industry

The protection of intellectual property rights and patents can promote the development of science, technology and social economy. On the whole, the construction of China's intellectual property system started late, and there were severe piracy and infringement in the market in the early stage of development. China officially joined the World Trade Organization(WTO) on December 11, 2001, becoming the 143rd member. Before and after joining the World Trade Organization, China's patent law has undergone substantial revisions. In the past few decades, China's intellectual property and patent protection system has become more and more strict, and many achievements have been made in strengthening the construction of the intellectual property system, improving the relevant legal foundation, and building specialized courts and other infrastructure. In recent years, global innovation activities have shown the characteristics of increasingly close cooperation and more internationalization, which puts forward higher requirements for the protection of intellectual property rights and patents.

3D printing is a unique production method. In the early stage of production and processing, engineers need to convert the original design file of the 3D data model of the printed object into a particular format that can be recognized by 3D printers, namely STL (Standard Triangle Language). STL converts the complex details of the original design into an intuitive digital form. After the conversion is complete, the printer firmware can read the STL file and complete the physical printing. 3D printed digital documents can be quickly disseminated through the Internet, and essentially anyone can download and print the entity through their own 3D printer. This model brings difficulties to patent protection and makes the patent law based on the traditional manufacturing model face the challenge.

At present, the copyright protection for 3D printing documents worldwide is being further improved. From a search of China's online academic literature database "CNKI", the keyword search for "3D printing copyright" has more than 200 recent papers and journals, which involve patent protection of 3D printing technology, research on 3D printing copyright issues, discussion on the feasibility of copyright protection of digital files, etc. The Chinese society's emphasis on intellectual property protection can make relevant laws and regulations more perfect in the future.

4.5 The impact of the international environment on the China 3D printing market

During the global outbreak of the new crown epidemic in 2020, medical protective equipment is in short supply in various countries. At this time, 3D printing plays the role of rescue. Creative teams and university institutions in the United States, the United Kingdom and other countries have used 3D printers to make masks, medical face shields, goggles and other epidemic prevention equipment, alleviating the shortage of medical protective equipment in various places. In addition, the epidemic has had a severe impact on the global supply chain. Various factories in North America and Europe have been shut down one after another, and the supply of industrial parts has been dramatically affected. In addition to the supply chain, sales and logistics channels have significantly been affected simultaneously, causing the supply of parts and components of many products to be cut off. 3D printing technology has opened up a new path to solve the supply problem. Data on AliExpress, a subsidiary of Alibaba, China's largest B2C cross-border e-commerce platform, shows that sales of 3D printers on the platform during the epidemic have doubled compared to 2019. These phenomena can make more people realize the application value of 3D printing technology, which is conducive to the popularization of 3D printing technology and accelerates the development of the 3D printing industry.

4.6 The main development direction of 3D printing technology in the future

3D printing rapid prototyping technology has a lot of room for growth in terms of exerting its advantages. It will have a massive impact on people's work, life, and study in the future. The 3D printing industry will also advance in the following aspects.

- Two-type and intelligent printing equipment

In the future, 3D printing equipment will move towards miniaturization and giganticization. Small printing equipment can not only meet the requirements of home and office use, but also can achieve suitable applications in print shops that provide 3D printing services. Giant printers can meet the needs of large manufacturing plants such as aerospace and automobile manufacturers. At the same time, 3D printing is also developing in the direction of intelligence. 3D printing software can realize different response methods according to changes in materials, structure and manufacturing environment and realize intelligent manufacturing.

- Diversification of material

For now, the materials for 3D printing are still limited to a small part, and compared with the types of materials available in traditional manufacturing, 3D printing still has great limitations. However, with the advancement of technology, the basic materials suitable for 3D printing will also be significantly increased in the future, and the hybrid manufacturing of multiple materials will be produced to realize the manufacture of complex objects.

- Integration with the new energy industry

At present, the prime mover of the processing equipment used in the manufacturing industry is mainly driven by electric energy. With the depletion of the earth's natural resources and the pressure of environmental pollution, the trend of new energy replacing traditional energy has become inevitable. The advantages of 3D printing equipment are provides good support for the integration of new energy sources. New energy sources such as solar energy, wind energy, and nuclear energy can be used to provide energy power for 3D printing equipment, realize the energy replacement of the manufacturing industry, and realize "green, low-carbon" manufacturing.

- Internet cloud manufacturing era

With the advancement of the high-tech Internet industry, 3D printing technology and new design will promote the development of the "Internet cloud manufacturing" model, a small-scale and distributed direction. The current large-scale manufacturing model has many disadvantages such as high investment and high risk, and the 3D printing industry will reverse this situation. Numerous small manufacturing enterprises will form a large distributed integrated network comparable to large manufacturing enterprises. Each small business is both independent and interconnected, reducing the risks of traditional industry models. At the same time, cloud manufacturing will also lower the entry threshold for manufacturing and promote technological innovation.

- Manufacturing upgrade and business model innovation

With the promotion of technology and the deepening of multi-field cross-integration, it will surely drive the manufacturing industry to transform into a high-tech-intensive direction, promote the gradual formation of related industrial chains, promote the transformation and upgrading of the manufacturing industry, and at the same time, a brand-new business model will emerge. In the future, the creative model will be sold as a commodity, forming a brand-new business model, which will also promote the manufacturing industry into the era of "manufacturing for all", and open and lead the wave of "intelligent manufacturing for all". Stores can provide small creative 3D printing services, large factories can provide medium and large-scale 3D printing services, and professional companies can provide design services, which can organically combine the ecological industry chain and promote the development and prosperity of new business models. In addition, 3D printing will power innovation and intelligent manufacturing, enhancing the industry's competitiveness.

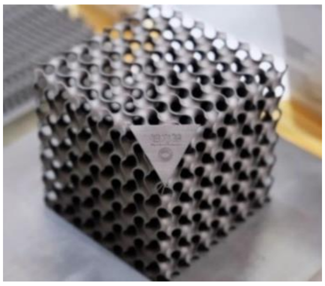
5. Comparison of European American and Chinese 3D printers

At present, the development of China's 3D printer market tends to be prosperous, and more and more local printer brands are emerging, with a wide variety of printers, a wide range of prices, and a massive base of audiences. This chapter summarizes the advantages and disadvantages of 3D printers produced locally in China by comparing the Chinese and European and American brand printers on the market.

5.1 Industrial 3D Printer Comparison

5.1.1 Industrial metal 3D printer

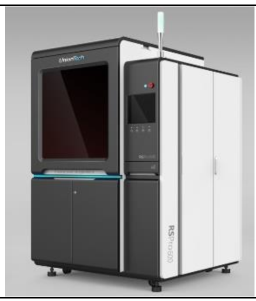
At present, Chinese companies with a relatively high market share of industrial 3D printers include UnionTecch, Farsoon, BLT, etc. The primary services provided are technical support for large metal 3D printing equipment. The following is through BLT's BLT-S320 3D metal Printers and DMP Factory 350 3D Metal Printers made by 3D Systems USA for technology, price and service comparison.

Device model	DMP Factory 350 (US)	BLT - S320 (CN)
Equipment pictures		
Print Technology	SLM	SLM
Laser power type	500 W/Fiber laser1	500W x 2
Wave Length	1070 nm	1060-1080 nm
Build volume (X Y Z)	275 x 275 x 420 mm	250 x 250 x 400 mm
Layer thickness	x=20 μm, y=20 μm, z=20 μm	20 μm~100 μm
Chamber environment	Vacuum chamber	Filled with argon
Working Oxygen Content	<25 ppm	<100 ppm
Typical accuracy	±0.1-0.2% with ±50μm min	Unknown
DMP Monitoring	Included	Included
Software	3DXpert for Metal AM, DMP software suite,	Magics, BP, BLT-MCS,
Powder management	Integrated	Integrated
Types of printing materials	LaserForm Ti Gr1 (A)[2] LaserForm Ti Gr5 (A)[2] LaserForm Ti Gr23 (A)[2] LaserForm AlSi10Mg (A)[3] LaserForm AlSi7Mg0.6 (A)[3] LaserForm Ni625 (A)[3] LaserForm Ni718 (A)[3] LaserForm 316L (A)[3]	Titanium Alloy Aluminum High Temperature Alloy Co-Cr Alloy Stainless Steel High – Strength Stell Die Steel
Equipment size	3580 x 2430x 3230 mm	2750 x 1160x 2185 mm
Equipment weight	4900 KG	3500 KG
Power requirements	400V, 20 KW	380V, 8KW
Application industry	Aerospace, Automotive, Medical	Aviation, aerospace, engine, medical, automotive, electronics, mold, scientific research institutes
Print examples		
Price	575,000 $	2,560,000 ¥ (~402,500 $)

The above comparison shows that the functions of the two printers are similar, the application industry coverage is similar, and the forming size of the equipment is similar. The forming size of the BLT-S320 is slightly smaller than that of the DMP F350. The difference is that the BLT printer is cheaper, 30% less than the DMP price, and has a price advantage. At the same time, BLT-S320 has dual lasers and dual galvanometers. It is mentioned in the introduction on BLT's official website that the equipment efficiency of dual lasers is 30% higher than that of single lasers, which saves parts processing time and reduces costs. 3D Systems also has a dual laser 3d metal printing machine (DMP Flex 350 Dual), but it will be more expensive. In the introduction of the F350 on the 3D systems official website, there is a description of the application of the new technology, "Due to the unique vacuum chamber concept of the DMP Flex 350 and DMP Flex 350 Dual, argon gas consumption is heavily reduced while at the same time showing best in class oxygen purity (<25 ppm). This results in exceptionally strong parts of high chemical purity." The DMP Flex 350 can better isolate oxygen by using a novel vacuum printing chamber, which is beneficial to improving product quality, while the BLT 3D printer uses the traditional argon protection and oxygen isolation method. By comparing the data in the table, the printing accuracy of DMP Factory 350 is higher. Both printers are manufactured in modular form. BLT's official website also lists the supporting auxiliary equipment for BLT-S310, such as powder cleaning machine, powder supply system, vacuum material machine, powder screening machine, etc.. 3D Systems also offers a complete module replacement service. In terms of printing consumables, both printers support a variety of metal materials and have a wide range of application scenarios.

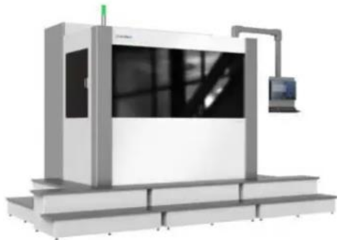
5.1.2 SLA technology industrial 3D printer

In the industrial field, SLA technology is also widely used. Thanks to the precision of SLA technology, many products that require high surface accuracy can be quickly customized through 3D printing, such as dental molds and automotive plastic decorative accessories. SLA is the first commercialized 3D printing technology, invented by 3D Systems' Co-Founder and Chief Technology Officer Chuck Hull in the 1980s. The earliest enterprise to introduce and adopt SLA technology in China is UnionTech. UnionTech has 20 years of experience in the 3D printing industry, currently maintains a large industrial customer base in the field of SLA 3D printing, and occupies more than 60% of the market share in China. The following select a representative 3D printing equipment from 3D Systems and UnionTech to compare product performance, price and service. At present, the representative SLA 3D printing equipment on the official website of 3D Systems is the ProX 800, among the units sold by UnionTech, the RSPro 600 is of similar build volume.

Device model	ProX 800 (US)	RSPro 600 (CN)
Equipment pictures		
Print Technology	SLA	SLA
Build volume (X Y Z)	650 x 750 x 550 mm	600 × 600 × 500 mm
Maximum Part Weight	75 kg	77 kg
Accuracy	0.025-0.05 mm per inch of part dimension	Part size < 3.9 in (100 mm): ±0.004 in (±0.1 mm) Part size ⩾ 3.9 in (100 mm): ±0.1% x L
Layer Thickness	0.01 mm minimum	0.05 mm minimum; 0.25 mm maximum
Operating Temperature Range	20-26 °C	22–26 °C
Software Operating System	Windows® 7 and newer	Windows 7, Windows 10*
Equipment size	1900 x 1630 X 2480 mm	1598 x 1612 x 2121 mm
Equipment weight	1724 kg	1,800 kg
Power requirements	200-240 VAC 50/60 Hz, single-phase	200-240 VAC, 50/60 Hz, single phase
Input Data File Format	.STL and .SLC	STL
Print examples		
Price	270,000 $	205,000 $

Both of these 3D printers use SLA photocuring printing technology, and the print size is similar, and the ProX 800 prints a larger size. By comparing the data in the table, 3D Systems' ProX 800 3D printer prints more accurately, while UnionTech's RSPro 600 3D printer is cheaper, and the RSPro 600 is 24% cheaper than the ProX 800. In the introduction of the official website of 3D Systems, the printing accuracy of the printer is highlighted, and the objects produced can be compared with the traditional CNC process. In the description of the RSPro 600 on the UnionTech website. The description of the RSPro 600 on the UnionTech website reads, "Key components are of top international brands, Panasonic of Japan, Optowave America, Scanlab of Germany." UnionTech can reduce its own R&D investment by purchasing key components externally, thereby reducing equipment prices.

In addition, by querying the product lists of the above two companies, there are other specifications for 3D printers using SLA technology. The current top SLA printer from 3D Systems is the ProX 950, which prints with a maximum side length of 1500mm. UnionTech showcased the latest SLA printer RSPro 2100 at the 2020 formnext connect exhibition, with a printing size of up to 2100mm, which is currently the largest SLA 3D printer in the world. The prices found by these two printers are similar, and the specific data are as follows.

Device model	ProX 950 (US)	RSPro 2100 (CN)
Equipment pictures		
Print Technology	SLA	SLA
Build volume (X Y Z)	1500 x 750 x 550 mm	2100 × 700 × 800 mm
Maximum Part Weight	150 kg	~400kg
Accuracy	0.025-0.05 mm per inch of part dimension	L < 100 mm: ±0.2 mm, L⩾100 mm: ±0.2% x L
Layer Thickness	Min 0.05 mm; Max 0.15 mm	0.1 mm minimum; 0.25 mm maximum
Lase	Solid-state frequency tripled Nd: YVO_4	Solid-state frequency tripled Nd: YVO_4
Wavelength	354.7 nm	355 nm
Operating Temperature Range	20-26 °C	22–26 °C
Relative Humidity	20-50 % non-condensing	< 40 % non-condensing
Software Operating System	Windows® 7 and newer	Windows 7, Windows 10*
Equipment size	2420 x 1730 X 2540 mm	4130 x 2720 x 2770 mm
Equipment weight	2404 kg	5050 kg
Power requirements	200-240 VAC 50/60 Hz, single-phase	200-240 VAC, 50/60 Hz, single phase
Input Data File Format	.STL and .SLC	STL
Price	587,000 $	>550,000 $

It can be seen that the two SLA 3D printers represent the current highest technology of the two companies, and the price of the two printers is close. UnionTech's RSPro 2100 has twice the build volume of 3D Systems' ProX 950, with the longest side length of 2100mm, making it possible to print larger objects. Comparing the data in the table, it can be clearly seen that the printing accuracy of ProX 950 is higher. On the premise of ensuring the basic size, the minimum layer thickness can be 0.05mm, and the printing accuracy can be controlled between 0.025-0.05mm. RSPro 2100 sacrifices printing accuracy because of the enlarged print size. The minimum layer thickness is 0.1mm and the accuracy range is 0.4mm. Comparing the two devices, it can be seen that 3D Systems have better technical reserves in high-end industrial printers, under the premise of similar prices, China's UnionTech uses the technology it has mastered to increase the available size of 3D printing and expand the advantages of its own equipment by sacrificing printing accuracy.

5.2 Consumer-grade 3D printer comparison

5.2.1 Consumer-grade FDM technology 3D printer

In recent years, civilian desktop 3D printing equipment has developed rapidly, more and more people have begun to actively understand and purchase desktop 3D printers, and a large number of printer brands have emerged in the market. At present, the mainstream 3D printing technologies in the civilian market are SLA and FDM. The following select two FMD printing equipment for product performance and price comparison.

MakerBot is a 3D printer production company established in the United States in 2009 and later acquired by Stratasys (US) in 2013. In the current latest sales list, the MakerBot-Sketch printer as an entry model is the lowest price of all MakerBot printers, and it is also the best-selling and best-reviewed printer. China's FlashForge is a private enterprise established in 2011. It mainly sells 3D printers of three types of additive manufacturing technologies: FDM, DLP, and MJP. By product size and technology type, Adventurer 4 printers were selected from the 3D printers on sale as a control group, and the equipment parameters are in the following table.

Device model	MakerBot-Sketch (US)	Adventurer 4 (CN)
Equipment pictures		
Print Technology	FDM	FDM
Build Speed	Max Print Speed: Up to 100 mm/sec	10~150mm/s
Layer Resolution	0.1 – 0.4 mm	0.1~0.4mm
Maximum Build Volume	150 x 150 x 150 mm	220 x 200 x 250mm
Maximum Heated Build Plate Temperature	100 ℃	265℃
Operating Volume	45 dB	56 dB
Print Heads	1 (user replaceable)	1
Nozzle Diameter	0.4 mm	0.4 mm (default) 0.6/0.3 mm (optional)
Ambient Operating Temperature	15 ℃ to 30 ℃, 10% to 70% RH non-condensing	15-30 ℃
Supported consumable types	ABS, PLA, Tough, PVA, SR-30, and PETG	ABS/PLA/PC/PETG/PLA-CF/PETG-CF
Product Dimensions	433.4 x 423.1 x 365 mm	500 x 470 x 540 mm
Product Weight	11.8 Kg	25 Kg
Power Requirements	100-240V AC~ 50/60 Hz, 2.7-1.3A	AC100-240V/DC 24V/13.3A, 320W
Software Bundle	MakerBot Print, MakerBot Connect	FlashPrint, Cura, Slic3r
Operating Systems	Windows (7, 10), Mac OS X (10.12+)	Win XP/Vista/7/8/10、Mac OS、Linux
Price	1,299 $	799 $

Both printers have the same printing accuracy and printing speed through data comparison. The Adventurer 4 produced by FlashForge has a larger build volume and can print larger objects. The Adventurer 4 is also cheaper than MakerBot-Sketch in terms of price. 38.5% less than Sketch. The introduction of MakerBot-Sketch on the MakerBot website is a teaching 3D printer, which can teach students to familiarize and learn the process of 3D printing with the help of systematic online courses. The Adventurer 4 also has teaching and training services for 6-18 year olds about 3D printing design, while the printer is suitable for home printing and office applications.

5.2.2 Consumer-grade SLA technology 3D printer

Compared with FDM technology, Stereolithography (SLA) technology can print objects with a smoother surface, and because the material is a mostly synthetic resin, it can print soft objects. Many people choose Sla 3D printers because of this unique feature. There are many brands of SLA 3D printers in the civilian market. Different manufacturers have extended the Low Force Stereolithography (LFS) based on the original SLA technology by improving the manufacturing process. In addition, the digital light processing (DLP) technology also utilizes light-curing characteristics.

Formlabs is a 3D printing equipment manufacturing company established in the United States in 2011, mainly using LFS 3D printing technology. China's ANYCUBIC company uses DLP technology to produce 3D printers that are cheaper and have good market feedback. Below is a comparison between Formlabs Form 3+ 3D printer and ANYCUBIC Mono X 6K.

Device model	Form 3+ (US)	Mono X 6K (CN)
Equipment pictures		
Print Technology	LFS	DLP
Layer Resolution	0.025 – 0.3 mm	0.01~0.15mm
Maximum Build Volume	145 x 145 x 185 mm	197 x 122 x 245mm
X Y resolution	nothing	5760 x 3600 px (6K)
X Y axis accuracy	0.025 mm	~0.035mm
Z-axis accuracy	unknown	0,01 mm
Optics Engine	1 Light Processing Unit 85 micron laser spot	nothing
Laser power	250 mW	nothing
Wavelength	405 nm	405 nm
Equipment power	220 W	120 W
Touch screen	5.5 inches	3.5 inches
Product Dimensions	405 x 375 x 53 mm	270 x 290 x 475 mm
Product Weight	17.5 Kg	11 Kg
Power Requirements	100-240V AC~ 50/60 Hz, 2.5A	AC100-240V
Software Bundle	unknown	ANYCUBIC Photon workshop
Operating Systems	Windows (7, 10), Mac OS X (10.12+), OpenGL 2.1	ANYCUBIC Photon Mono X 6K
Connection method	WiFi, USB	WiFi, U Disk
Device application	Home Products, Toy Models, Jewelry, Dental Applications, Architectural Models, Automotive fields	Home Products, Toy Models, Jewelry, Dental Applications, Architectural Models
Price	3499 $	689 $

By comparing the data, both printers use synthetic resin as raw material, and use the light-curing technology of LFS and DLP to print items respectively. The build volume of the two printers is similar, ANYCUBIC's Mono X 6K has a larger internal build volume, but the price difference between the two printers is huge, in North America, Formlabs' Form 3+ is five times the Mono X 6K. Because of the different technical paths, the Form 3+ adopts LFS technology to achieve higher printing accuracy, which is one of the highest printing accuracies among desktop 3D printers, and has good stability at the same time. The price of Mono X 6K is lower, and the printing accuracy is not as good as that of Form 3, but the difference is not significant, because the price and consumables are low, so it is very popular in the market and has its own price advantage.

Formlabs also sells other models of printers with larger build volume, higher precision, and more reliable equipment quality. Special printing materials and printing accuracy can be customized for high-end users, but the price is more than 10,000 US dollars. Different types of printers produced by ANYCUBIC are generally inexpensive. There are a variety of printing consumables to choose from on the premise of ensuring essential printing accuracy. At the same time, there are a variety of printers with reduced accuracy but lower prices to choose from which have a good price advantage in entry-level SLA printers.

5.2.3 Multifunction 3D printer

At present, more and more 3D printers on the market are beginning to develop towards multi-function. On the premise of ensuring reasonable prices, they can attract customers by adding more functional operations to meet customers' needs to make personalized and diversified items by themselves. Through transaction data and reviews of online stores, Snapmaker 2.0 F250/F350 printers are becoming more and more popular because of their three-in-one function. Snapmaker was established in China in 2016, is a tech company that develops, manufactures, and sells desktop multi-function 3D printers. Prusa Resear is a Czech-based 3D printing company that produces the Original Prusa i3, which was previously voted the most used 3D printer globally. Next compare the Snapmaker 2.0 F350 3D printing module with the Original Prusa i3 MK3S.

Device model	Prusa i3 MK3S (CZ)	Snapmaker F350 (CN)
Equipment pictures		
Print Technology	FDM	FDM
Maximum Build Volume	250 x 210 x 210 mm	320 x 350 x 330 mm
Build Speed	Max Print Speed: 200 mm/sec	unknown
Layer Resolution	0.05– 0.35 mm	0.05~0.3mm
Max nozzle temperature	300 °C	275 °C
Max heatbed temperature	120 °C	80 °C
Print Heads	1	1
Nozzle Diameter	0.4 mm	0.4 mm
Filament diameter	1.75 mm	1.75 mm
Supported materials	Any thermoplastic including Nylon and Polycarbonate	PLA, ABS, TPU, PETG, wood filled PLA, more being tested
Product Dimensions	500 x 550 x 400 mm	495 x 506 x 580 mm
Product Weight	7 Kg	28.5 Kg
Frame Materia	Aluminum extrusion	Aluminum alloy
Power consumption	PLA settings: 80W ABS settings: 120W	unknown
LCD screen	Monochromatic LCD	5'' screen, Android OS, Quad Core A7 CPU @ 1.1GHz
Wi-Fi connection	Via Raspberry Pi	Smart module
Functional Units	3 thermistors + SuperPINDA, fan RPM sensors	LED Strips, Exhaust Fan, Exhaust Duct
Print medium	SD card	Wi-Fi, USB cable, USB flash drive
Rated Power	240W	320 W
Supported Softwar	PrusaSlicer, Simplify3D, Cura	Snapmaker Luban or third-party software
Price	999 €	1199 €

Analyzing the data in the above table, the Snapmaker F350 is more expensive, but the price of the Prusa i3 does not include shipping. The Prusa website describes the shipping cost in Europe as between 50-100 euros, so the price difference between the two 3D printers is not much. Both printers are desktop printers. The F350 has a larger build volume and can print more oversized items. At the same time, because the overall aluminum alloy material is used, the equipment is more stable and the printing accuracy will be higher. Because of the modular structure, F350 can replace the printing module, replace and install the laser cutting module or the CNC drill processing module, which significantly increases the scope of use of each equipment. Customers can purchase other modules according to their own needs to stimulate more usage scenarios.

5.3 Summarize

China currently has the most enormous manufacturing scale in the world. The economies of scale make products produced locally in China have lower costs than other countries and regions. At the same time, a prominent advantage of China's manufacturing industry is that labor costs are lower than those in European and American countries. With the gradual industrialization of Southeast Asian countries and the development of global manufacturing in the direction of intelligence, this advantage is gradually being lost. China's colossal manufacturing scale allows it to have a more complete industrial chain, allowing manufacturers to purchase at lower costs in the upstream, midstream and downstream supply chains, ultimately reducing product prices.

By comparing Chinese 3D printers and 3D printers of European and American brands, the United States and Europe still master high-end advanced 3D printing technology in the industrial field, and the high-end industrial 3D printers produced have higher printing accuracy. At the same time, enterprises can provide more systematic industrial production services, and higher brand value. European and American companies can increase the price of high-end 3D printing equipment and increase corporate profits through leading technology and services. Industrial 3D printers produced by local Chinese companies mainly rely on price advantages, increase the build volume on the premise of ensuring basic printing accuracy, expand the usage scenarios of printers, and attract user groups by reducing sales prices. At the same time, by setting up R&D centers in Europe and the United States, Chinese enterprises further increase their technological accumulation, improve the quality of after-sales service in Europe and the United States, and enhance their own brand value.

In the civilian desktop 3D printer market, because users have reduced precision requirements for equipment, the advanced printing process in Europe and the United States cannot give full play to the technical advantages. Local Chinese 3D printer equipment companies rely on China's well-established industrial manufacturing chain and lower labor costs to produce 3D printers with the same quality but lower prices. Consumers in the civilian market are more price-sensitive, and Chinese companies have better competitive advantages than Europe and the United States in the field of consumer-grade 3D printers. However, some Chinese companies still need to rely on upstream European and American companies to provide some core spare parts, such as high-power lasers, high-end 3D printing consumables, and software services. This approach can also reduce the R&D investment of Chinese companies in particular fields, reduce product development costs, and ultimately reduce sales prices. In addition, large enterprises in Europe and the United States are choosing to relocate their factories to China or Southeast Asia, where human resources are cheaper due to the increasing cost of local production. This has brought a lot of employment to the local area, the upstream and downstream industrial chains have been improved, and has also cultivated a large number of skilled workers, which has promoted the progress of local industrialization, spawned local companies established using existing technologies, and allowed the market to enter the healthy competition. This further contributes to reducing the production cost of the product.

Bibliography

Guo Lijun, (2013) 3D dayìn hui “yinbao” xin gongye gemìng ma[Will 3D printing "detonate" the new industrial revolution], Zhongguo Shehui Touzi, 1-2

Hereticq, (2013) 3D dayin Jinhua jianzhi [A brief history of the evolution of 3D printing], Wanwu,1

Guo Riyang, (2015) 3D dayin jishu ji chanye qianjing [3D printing technology and industry prospects], Zidonghua yibiao 3, 6-7

Zhou Weimin, (2-2021) Zencai zaizhizao chanye de xianzhuang yu fazhan [Current situation and development of additive remanufacturing industry], Zidonghua yibiao 2, 1-5

Dai Zhengzong, (10-2021) Zencai zhizao chanye fazhan tisu [The development of the additive manufacturing industry is accelerating], Zhongguo caijingbao 5, 1-2

He Canqun, (8-2021) Zengcai zhizao jiqi zai sheji zhongde yingyong yanjiu [Research on additive manufacturing and its application in design], Baozhuang gongcheng 16, 1-3

MásloLibor voestalpine High Performance Metals CZ s.r.o., (2021) Zengcai zhizao jishu: tigao shengchanlv he zhiliang de xinxuanze [Additive manufacturing technology: New options for increased productivity and quality], Jishu qianyan 10, 1-2

Chen xue, (5-2021) Zengcai zhizao jishu de yingyong yu tiaozhan [Applications and challenges of additive manufacturing technology], Guangdong keji, 79-80

Chang Kun, (2021) Jinshu cailiao zengcai zhizao jiqi zai minyong hangkong lingyu de yingyong yanjiu xianzhuang [Research status of metal material additive manufacturing and its application in the field of civil aviation], Materials Reports 3, 3177-3178

Feng Shichao, (2021) Jinshu zengcai zhizao zhuanyong cailiao fazhan xianzhuang [Development status of special materials for metal additive manufacturing], Yanjiu yu tantao 1, 33-34

Zhongguo 3D dayin hangye jiyu baogao (2015) [China 3D printing industry opportunity report], Ipsos, 7

Jihong, (3-2019) 3D dayin fazhan yu zhizao lingyu kexingxing yingyong taitao

[The development of 3D printing and the feasibility application in the field of manufacturing], Tianjin zhiye xueyuan lianhe xuebao, 97-98

Liuzhi, (12-2020) 3D dayin jishu shebei de xianzhuang yu fazhan [Status and development of 3D printing technology equipment], Duanya zhuangbei yu zhizao jishu 6, 10-11

Ding Hanqiu, (3-2020) Zhongguo 3D dayin shichang guancha [China 3D printing market observation], Bussiness school, 70-71

Zhongguo zengcai zhizao shouxiang zengcai fuwu guoji biaozhun zhengshi fabu (2021)[China's additive manufacturing first international standard for additive services officially released], Fenmo yejin gongye 31, 114-115

He Yuanjun, (11-2021) Guozhan CAD ruanjian chongqi zhilu [The road to restart of domestic CAD software], Jisuanji jicheng zhizao xitong 27 11, 3058-3059

Wang Zehua, (2019) 2019 nian zhongguo 3D dayin hangye yanjiu baogao [2019 China 3D printing industry research report], Toubao yanjiuyuan, 23-24

Pan Jiawei, (6-2019) Gongye 3D dayin yingyong fuwu de shichan yinxiao celue yanjiu [Research on marketing strategy of industrial 3D printing application services], Shanghai Academy of Social Sciences 87903, 10-14

Liu Xiaomin, (1-2014) Study on influencing factors of enterprise competitiveness in 3D printing under the third industrial revolution background, Donghua University, 16-21

Cui Guoqiang, The development prospect of 3D printing industry is bright, but there is insufficient talent and technology (7-2018), People, http://finance.people.com.cn/n1/2018/0711/c1004-30139666.html

The world status of China's 3D printing (1-2020), Amreference, http://amreference.com/?p=1119

Analysis of the upstream, midstream and downstream markets of China's 3D printing industry industry chain in 2021 (4-2021), Baijiahao, https://baijiahao.baidu.com/s?id=1697822215989153054&wfr=spider&for=pc

Xifang Wushuo, 100-year history of 3D printing (3-2017), 360doc, http://www.360doc.com/content/17/0305/19/51704_634224282.shtml

The development history of titanium alloy 3D printing technology in China, Baoji Keyuan Titanium Industry Co., Ltd., http://www.ky-ti.com/news/html/?439.html

Li Xiangcai, 3D printing will not impact traditional manufacturing (9-2013), China Securities Network, https://news.cnstock.com/news,gdbb-201309-2744754.htm

The development route of 3D printing industry in various countries in the world, Hui Bo Xin Cai, https://wellsepoxy.com/index.php?m=content&a=newscontent&id=171&catid=66

Status of intellectual property protection in China (2004), Ministry of Foreign Affairs of the People's Republic of China, https://www.mfa.gov.cn/ce/cept//chn/zt/zgzfbps/t95340.htm

China strengthens intellectual property protection to "escort" innovation and development (11-2019), The State Council the People's Republic of China, http://www.gov.cn/xinwen/2019-11/19/content_5453500.htm

3D Systems DMP Factory 350 (2022), 3D Printing https://3dprinting.com/products/industrial-3d-printer/3d-systems-dmp-factory-350/

DMP Flex 350 (2022), 3D Systems https://cn.3dsystems.com/3d-printers/dmp-flex-350?_ga=2.35278374.644360542.1647555824-1875472150.1647385770

BLT S310 (2022), Direct industry https://pdf.directindustry-china.cn/pdf-en/xi-an-bright-laser-technologies-ltd-blt/s310/231801-933647.html

BLT-S310/S320 (2022), Xi'an Bright Laser Technologies https://www.xa-blt.com/equipments/blt-s310/

Understanding China: Manufacturing Giants (2014), Mckinsey China https://www.mckinsey.com.cn/1%E5%B0%8F%E6%97%B6%E8%AF%BB%E6%87%82%E4%B8%AD%E5%9B%BD%EF%BC%9A%E5%88%B6%E9%80%A0%E4%B8%9A%E5%B7%A8%E6%97%A0%E9%9C%B8/

UnionTech's SLA 3D Printer Impresses (2017), Fabbaloo https://www.fabbaloo.com/2017/06/uniontechs-sla-3d-printer-impresses

The RSPro 2100 by UnionTech would be the largest SLA 3D printer in the world (2020), 3D Adept Media https://3dadept.com/the-rspro-2100-by-uniontech-would-be-the-largest-sla-3d-printer-in-the-world/

AnyCubic Photon Mono X 6K review (2022), Space
https://www.space.com/anycubic-photon-mono-x-6k-review

Prusa i3 (2022), Wiki
https://en.wikipedia.org/wiki/Prusa_i3

Original Prusa i3 MK3S+ 3D printer (2022), Prusa Redearch by Josef Prusa
https://www.prusa3d.com/product/original-prusa-i3-mk3s-3d-printer-6/#specs

Snapmaker 2.0 Modular 3D Printer F350/F250 (2022), Snapmaker
https://eu.snapmaker.com/

SLA vs. DLP: Guide to Resin 3D Printers (2022), FormLabs
https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/

Adventurer 4 (2022), FlashForge
https://www.sz3dp.com/product-detail/63