Research Status and Development Trend of 3D Printing Technology

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Abstract. As the product of Industry 4.0, Intelligent Manufacturing (IM for short), and the enabling technology, i.e. 3D printing technology, has made rapid development in recent years and widely applied in many fields of social life. Moreover, 3D printing technology is a kind of high-tech manufacturing, which is playing a revolutionary role in the industrial development. Therefore, in order to know the study status and development trend of 3D printing technology, this paper systematically analyzes some typical methods and applications in some fields, as well as predicts its development trend in the future based on the brief introduction to the working principle of 3D printing technology.

1. Introduction
The 3D printing technology (also called additive manufacturing (AM for short) or rapid prototyping technology) is the emerging manufacturing technology, which is well promised by the worldwide. The 3D printing technology is based on the digital model file, bonding some adhesive materials together in powder form such as metals or plastics. And then through the layer-by-layer printing method, it is possible for two-dimensional data to transform into 3D materials. The 3D printing technology shows the characteristics of zero-release and zero-waste, because of its various construction forms. Additionally, the 3D printing technology leads to the redesign of some equipment and products, and because of the concept of manufacturing, it gets rid of the constraints of the traditional processing method as well as brings a large space for innovative design [1]. At the same time, 3D printing creates a new production mode, referring to changing the batch manufacturing into personalized customization without much increase of cost and cycle. The technology of 3D printing is entering various fields and plays a key role [2].

2. Overview of 3D printing technology
As mentioned above, the technology of 3D printing is called AM by CAD designing data and adopting the method of material increase step by step to make parts of entities. Compared with the traditional technology of material removal (like machining), it is a manufacturing method of adding materials from bottom to top.

In the late 1980s, with the development, AM was also called material increase manufacturing, rapid prototyping, layered manufacturing, solid free-form fabrication and 3D printing. Different names respectively show the characteristics of the manufacturing technology.
International committee, i.e. ASTM F42, makes a clear definition of AM and 3D printing. AM is the process of connecting materials to make objects according to 3D CAD data. Compared with the subtraction manufacturing, its material is increased in the process of manufacturing. 3D printing is defined as the technology adopting printing head, nozzle or other deposition materials to produce some products, which is commonly used to the AM technology. When it is applied to the particular device, the 3D printer is the additive manufacturing machine with relatively low price or low overall function.

Without using traditional cutters, fixtures and several processing procedures, the 3D printer can adopt 3D design data to make parts into any complex shapes rapidly, which can effectively solve the problem of making parts in the complex structure. With the rapid development of the technology, the 3D printing technology has been widely applied in many fields, such as consumer electronic, automobile, aerospace, medical treatment, military industry, geographic information and artistic design, etc.

3. Research Status of 3D printing technology
The 3D printing technology is firstly appeared in America in the late 19th century, and developed in the 1980s. With the development of intelligent manufacturing, the 3D printing technology has been widely served in the manufacturing of the intelligent vehicle and other areas. Recently, the 3D printing technology has been widely applied in many fields, such as consumer electronic, automobile, aerospace, medical treatment, military industry, geographic information and artistic design, etc.

Since the first 3D printer was invented by Charles Hull in 1986. After that, a great achievement has been made on the 3D printing. In 2000, Zcorp, an American enterprise, cooperating with Rilecen Institute, developed a kind of color 3D printer with the principle of ink-jet printing technology. At the end of the year, an Israeli company, Object Geometries launched the 3D printer Quadra [5] based on the combination of stereolithography apparatus (SLA) and 3D Ink-Jet; In 2010, an American company (i.e. Organoxo) and an Australian company (i.e. Invotech) printed human tissues and organs by using living cells, which was the breakthrough of 3D printing technology in the field of medical.
At present, European countries and America has preliminarily set up a successful business mode of 3D printing technology in the consumer electronics (CE), automobile industry, aircraft industry, medical treatment and other areas. Statistically, among more than 700,000 3D products produced by America in 2012, products in electronic area, automobile manufacturing, medical treatment and industrial machinery industry occupy a large share [7]. Additionally, the 3D printing has been widely used in the customization of personal product gradually. For instance, a lot of foreign companies (like American Quirky) can collect design schemes towards customers by the online platform, and utilize the 3D printing technology to make materials and products for sales, which brings a good benefit.

Compared with the foreign study on the 3D printing technology, the domestic study on 3D printing technology starts later, but due to its huge potential of application in various areas, domestic scientific researchers and industrial experts in bulk pay more attention to it, which leads to the rapid development of 3D printing technology in China. A large amount of research is made, such as the largest 3D printer in the world, which is invented by Huazhong University of Science and Technology through more than a decade. The largest length and width of the machinable components are both up to 1.2 meters. Theoretically, as long as the length and width of the component is less than 1.2 meters, the objects can be printed by this machine. In addition, Xi’an Jiaotong University autonomously developed a nozzle of 3D printer and made great achievements on SLA system and molding materials, which helps its molding accuracy reach 0.2 mm. However, with the overall development, the domestic 3D printing technology still has some disadvantages compared with foreign status, mainly showing in the following aspects:

Firstly, in the aspect of basic study on material science, domestic 3D printing products mainly belong to plastic products and the core manufacturing technology of powdered metals and liquid material is not totally grasped yet.

Secondly, in the aspect of precision machinery and information technology, as for the core parts of 3D printers at the current stage (i.e. laser scanner), because of the limitation of domestic industrial design ability and low automatic controlling system level, there is a large gap of the printer developed independently in terms of process stability and printing accuracy between China and foreign countries, so we need to make further efforts on it [8].

Thirdly, in the aspect of technological development, the level of domestic additive manufacturing technology is equal to that of foreign advanced technology, but in terms of key parts, molding materials, intelligent controlling and application range, domestic level falls behind. The additive manufacturing is mainly applied in modelling, and there is still a large space for improvement in the field of directly making high-performance terminal components.

Fourthly, in the aspect of study on process technology, foreign countries focus more on process controlling, also the theoretical basis of the technology while China depends more on experience and repeated testing to verify the result, which results in Chinese lower level on the key additive manufacturing technology.

4. Typical Application of 3D Printing Technology

4.1 Automobile Industrial Field

With the rapid development of automobile industry, people put forward a higher standard of lightweight design of automobiles, short cycle of design and less manufacturing cost, and the appearance of 3D printing technology makes it possible to meet the demand. On 1st May in 2013, the first automobile made by 3D printing, Urbee 2 was launched, which is opening the door of the application of 3D printing technology in the field of automobile manufacturing.

During the production process of the automobile, thermoplastic high-polymer materials are largely used to produce decorative parts and some structural parts. Compared with the traditional method, the 3D printing technology can shorten the manufacturing time and well perform in making parts with complex structure. At the same time, with the technology of one-step molding, 3D printing can omit a lot of traditional connecting parts and obviously lighten the weight of vehicles for it makes good use
of engineering thermoplastic with low density.

Figure 2. 3D Printing Manipulator

4.2 Aerospace filed

With the development of 3D printing technology, many countries invest plenty of human and material resources in 3D printing technology. At present, the study in the field of aerospace includes two aspects. The first one is the rapid manufacturing of part model and part verification. Aiming at non-metallic materials, using Fused Deposition Modeling, Stereoscopic Lithography, Laminated Object Manufacturing and 3D Printing method. The second one is aiming at the manufacturing of parts of metallic materials and overall structure in a large size, using some techniques including Metal Sintering, Selective Laser Sintering, Laser Rapid Prototyping and Electron-Beam Melting [9].

Different molding techniques have different characteristics [10]. For example, Stereoscopic Lithography shows high accuracy, intensity and hardness, which can also realize color molding, but after molding, its surface is tough. Fused Deposition Modeling has fast molding speed with lower cost, but its accuracy is not high. Selective Laser Sintering is simple with high flexibility and accuracy, which can use various materials (including metal, ceramics and plastics). Laminated Object Manufacturing performs well in model support, low cost and high efficiency. However, the techniques of 3D printing based on adding and accumulation characterize in rapidity, low cost, wide application of materials, high flexibility and high integrated, which shows great advantages compared with traditional techniques [13].

Figure 3. 3D Printing of Aircraft Engine Components
4.3 Civil Engineering Field

During the construction of civil engineering, the applying of 3D printing technology can largely reduce the cost of engineering construction and it is superior in low carbon and environmental protection, the advantages that the traditional construction does not have. At present, after a period of time, 3D printing technology has been maturing. Additionally, 3D printing can help solve the problem of printing the modeling of curved buildings which cannot be solved by other production modes, and it also can eventually print the buildings in lightweight and high intensity. According to the development situation of 3D printing technology, it cannot print buildings in large volume, but it can adopt the printing method of components and then assemble them together [14]. If we need to print a building in dozens of layers, a large 3D printer is required and its problems of intensity should be solved at the same time [15].

![Figure 4. 3D Printing Architectural Model](image)

5. The development trend of 3D printing technology

The 3D printing technology develops rapidly abroad. Although it starts later, it draws wide attention by all sectors of society with the concept of 3D printing appearing.

In the future, the 3D printing technology will be developed with the following aspects [16]:

5.1 Normalization

Normalization is the basic guarantee to select 3D printing materials. Due to the expensive materials for 3D printing, mixed materials are used largely. If normalized materials with low waste and low emission can be used for 3D printing, the variety of the available 3D printing materials will be extended [17].

5.2 Scientific

Scientific is also an important part in the technological process. By internal process monitoring and giving feedback regularly, connection, repeatability and unity between machines can be improved. The good process controlling can reduce the downtime of devices [18].

5.3 Convenience

Convenience makes the operation of 3D printing simpler. At present, CAD tools should be used in 3D printing. If the operation of 3D printing is simpler and more convenient, the technology will be popularized [19].
5.4 Intelligence

Intelligence simplifies the requirements on software functions and processing, such as the material conversion during the forming process and the removal of waste powder after processing. Simplified requirements of 3D printing technology can better popularize it.

Moreover, some 3D printing materials are harmful and environmentally polluted, which are bad for human health. 3D printing will also give rise to information or technology disclosure, so some printing products will threaten national security (like handgun). In the future, 3D printing will develop for environmental security, intellectual property protection and technological protection [20].

6. Conclusion

The technology of 3D printing plays an important role in the development of the industrial. Due to high efficiency and low cost, the 3D printing technology brings a great reform on traditional manufacturing, which can be regarded as a driving force of economic and social development in China. However, there are also some problems of 3D printing to be coped up, such as without guarantee of production quality, high requirement on production technology, hard personnel training and pollution of waste powder, etc. Although the technical bottleneck still exists currently, there is a bright future for the technology, so the whole world attaches great attention to it. In short, the 3D printing technology will create a new era of the national manufacture.

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