

Research on 3D Printing in China: A Review

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Abstract: *To learn research status of 3D printing in China, and explore the future research trend, the literatures were retrieval from China National Knowledge Infrastructure (CNKI) Database by searching for the title keyword "3D printing", "rapid prototyping" and "additive manufacturing". These literatures were analysed as a whole first. Besides, a detailed analysis of research contents about 3D printing in China's economy, health care, intellectual property and the other nine fields was finished. The paper can promote the development of 3D printing industry and related scientific research for China and other countries.*

Keywords: *3D printing; Rapid prototyping; Additive manufacturing; Review*

1. INTRODUCTION

In recent years, 3D printing technology has been applied in more and more fields, which are driving the rapid development of global economy. The Economist magazine points out that 3D printing as a new production mode has made mass production possible, which will cause the big changes in the manufacturing industry, and it will work with other technologies to promote the development of the third industrial revolution [1]. Lots of countries in the world attach great importance to the development of 3D printing industry, especially in the United States, 3D printing is announced as a national strategy by President Obama. In China, 3D printing is also highly concerned by government, enterprises and research institutes. The people's liberation army newspaper noted in 2013 that 3D printing will no doubt rise to China's national strategy [2]. In order to implement the decision and deploy of developing strategic industries by State Council, seize the great opportunities about the new round of technology and industry revolution, China issued "National additive manufacturing industry promotion plan (2015-2016)" in February 2015 [3]. In this context, an in-depth review of 3D printing related research in China should be done to promote the development of 3D printing industry and related scientific research.

2. DATA SOURCE

This paper selects CNKI database as a data source, it covers the CSSCI source journals, the Chinese core journal, theses or dissertations and other important data sources. Retrieved on May 31, 2016. To achieve comprehensiveness of the data retrieval, we took "3D printing", "rapid prototyping" and "additive manufacturing" as keywords and conducted a comprehensive search, a total of 6222 articles were retrieved.

3. RESULT ANALYSIS

3.1. Research Situation on 3D Printing in China

Among of those articles, there are 1150 articles published in 2013, 1156 articles published in 2014, 1701 articles published in 2015 and a little articles published in other years. The whole temporal distribution of 3D printing literature is shown in figure 1. We can find from the figure, although 3D printing has begun to develop since 30 years ago, the number of related literature in China started to appear an obvious growth until 2012. By 2013, the number of literature presents the explosive growth, increasing 1020 articles and 428.99% compared to 2012. During this period, 3D printing researches have been rapid development in China. In contrast, foreign scholars have made a study of 3D printing since 1984 [4-6]. Obviously, China's overall research development is relatively slow.

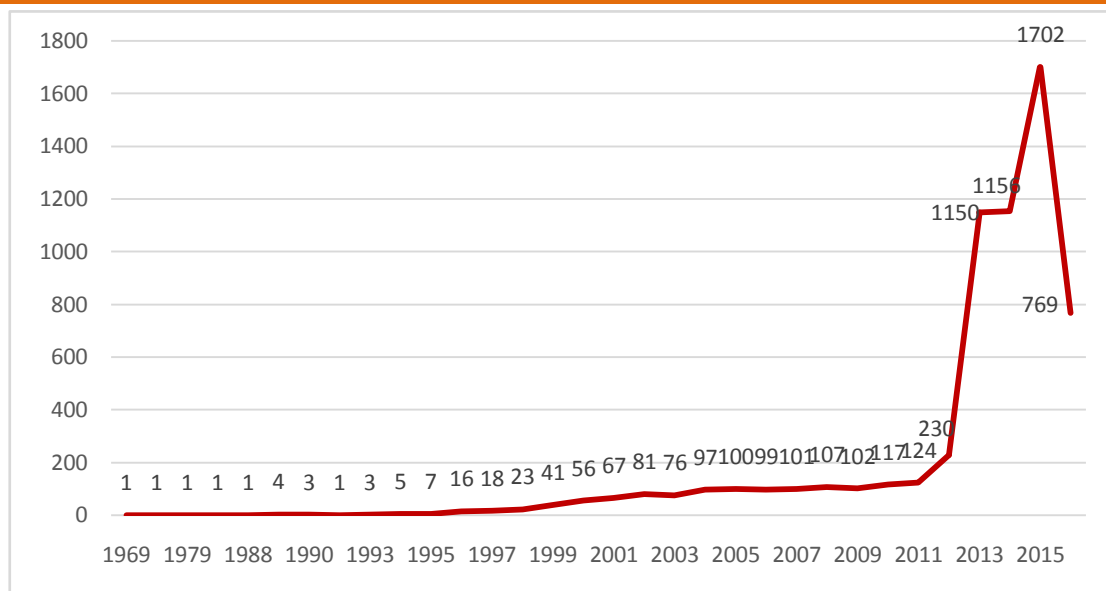


Figure1. Line chart of 3D printing literature statistics number

The research fields of the above literature can be broadly divided into nine major areas such as economy, medical, intellectual property, industry, aerospace, military, architecture, design and education. Studies in the economic field concentrate in prospects, impacts, and countermeasures. The medical field concentrates on 3D printing's applications in various aspects such as human organs, tissue scaffold and medical device. The intellectual property field concentrates on the definition of infringement of intellectual property rights and how to better protect intellectual property rights. The industry field concentrates on the influences of printing metal parts and devices. The aerospace field concentrates on the changes of 3D printing aircraft parts to aerospace industry. The military field concentrates on the firearms, weapons and military equipment of 3D printing. The construction field concentrates on the construction materials and machinery of 3D printing, and its positive influences on intelligent construction. The design field concentrates on the application in jewelry and apparel design. The education field concentrates on how to use 3D printing models and teaching software in the classroom and improve the quality of teaching.

3.2. The Research Fields of 3D Printing Literature in China

3.2.1. Economic field

Wang Xueying thinks the development of 3D printing need to overcome cost and material barriers [7]. Wang Zhonghong points out devising adaptive plans for the development of 3D printing can effectively promote coordinated development between industries [8]. Huang Jian shows the foreign development situation of 3D printing more intuitively by comparing a series of materials enterprises applied [9]. Qin zhiyuan proposes that 3D printing can be subdivided more emerging industries and business models, and create more economic development opportunities [10]. Fan Xinbo points out that 3D printing technology allows designers to design products and achieves zero inventory [11].

3.2.2. Medical field

At present, 3D printing technology has been widely applied in medical. Wang Caimei uses 3D printing to print a personalized orthopedic implants, which provides a more intuitive method for preoperative planning [12]. Wang Fuyou points out that the application of 3D printing can improve the precision of surgical planning for patients and the success rates for surgery [13]. Zhang Yu introduces the sample temperature field and thermal stress coupled field simulation technology by PEEK3D printing to optimize the printing parameters [14]. Fan Lijun notes that the application in high-energy Pilon fractures can effectively reduce the operation time and the amount of patients bleeding, and also can improve the degree of recovery [15]. Liu Fengzhen and Liu Mingxin sum up the application progress in medical field of 3D printing technology, and review the application in medical model, medical devices and tissue function products, living tissues and organs, and other aspects [16].

3.2.3. Industrial field

3D printing technology is changing the traditional manufacturing mode. Qiao Yimin indicates that combining 3D printing technology with the three - dimensional software technology in simulation design of packaging container's shape can effectively accelerate the speed of the product into the market [17]. Yang Yongqiang analyzes the advantages and disadvantages of three kinds of technologies which are SLM/DMLS, LENS, and EBSM, which makes the principle of 3D printing more visualized and concrete [18]. Fu Jun says 3D printing can effectively accelerate the speed of new products development, reduce the cost and risk, and reduce the scrap rate in high-end casts [19]. Zhang Ziyue discusses a new type casting method that combines the 3D printing technology and the traditional investment casting, and has some characteristics including low cost, simple process, high efficiency, and high precision castings [20]. Zeng Yan and Yan Dapeng design components of 3D printer through a rectangular coordinate system, which can control the stability and accuracy of the drive system [21].

3.2.4. Intellectual property field

It is because 3D printing brings enormous challenges for intellectual property rights that there are many people to research on the definition of 3D printing intellectual property rights. Wang Wenmin compares three ways, and draws a conclusion that the printing behavior based on some parameters belong to replication behaviors instead of infringement behaviors [22]. Yang Zhenhui introduces the copyright laws should be set into the original standard of works, and "Remove" rules of copyright law also should be set in the patent law. These initiatives create a free trade market of network and digital copyright for 3D printing [23]. Liu Ping analyses the infringements of 3D printing on trademark, patent protection, copyright aspects, and points that making the copyright of 3D printing models in law and establishing the database of models can realize the effective protection of products' copyright [24]. Chen Chen puts forward the application of 3D printing technology will bring two related legal issues that are how to judge the rationality and legitimacy under theory, and whether the personal printing of "non-production business purpose" is composed of infringement [25]. Zhao Lu thinks that many concepts of patent law need to make change to the development of 3D printing, and patent law under the 3D printing system should be established as soon as possible [26].

3.2.5. Aerospace field

An event has caused people's attention to 3D printing's application in aerospace field. The event is Northwestern Polytechnical University made a 3-meter-long C919 aircraft titanium alloy parts with a 3D printing in 2013 [27]. Shen Zhen thinks general aircrafts made by 3D printing can effectively relieve the tense situation of aerospace materials supplying [28]. Wu Fuyao puts forward that 3D printing has a breakthrough development in manufacturing complex structure and new materials development [29]. Wu Hao thinks that combining with circular economy theory, 3D printing can better improve the malleable cast industries' overall competitiveness in aviation manufacturing field [30]. Luo Chao proposes that additive manufacturing can reduce the overall weight of aircrafts and the aircraft fuel consumptions indirectly. This greatly improves the aircraft carrying capacity [31]. Wang Wensheng points out that the 3D printing can improve the air vehicles inside and outside decoration design, which has important meaning in forming a more reasonable process and method [32].

3.2.6. Military field

In 2013, China fighter-15 and fighter-31 have adopted 3D printing to produce the titanium alloy standing leg of front wheel, which opens the typical applications in the field of 3D printing in military field in China [33]. Jiang Lixin mainly introduces the 3D printer nozzle developed by Xi'an Jiaotong University and the eight sprinkler spray device developed by University of Science and Technology of China [33]. Chen Xiangang points out 3D printing can quickly print out physicals without any molds or under the condition of complex process, which can relieve the pressure on military logistics supports [34]. He Yanfeng points out that although 3D printing is expensive, it can be applied to the rapid manufacturing of war weapons and equipment spare parts in wartime [35]. Guo Jizhou systematically studies the influence of 3D printing technology on the equipment rapid repair capacity and aided maintainability design [36]. Yu Xia analyzes the application trends of 3D printing in military field, combining with development trend of the development of equipment development in the United States [37].

3.2.7. Construction field

The first 3D printing house in Qingdao of China has opened 3D printing application in construction field [38]. Ma Jingwei points out that 3D printing can extend the life cycle of a building, reduce the number of construction wastes and employees in building reduction redundant project [39]. Wang Fangjun thinks 3D printing can make it possible to private ordering. That means that customers can choose the right indoor design according to the characteristic of space [40]. Li Zhiguo uses specific data to indicate that materials of 3D printing have the advantages of high strength, good heat preservation and energy saving effect, and fine seismic effect [41]. You Wan discusses the development status of 3D printing construction technology, reveals the problems of 3D printing in construction field, and thinks those problems should be solved in architectural, building machinery, building materials and building standards and so on [42]. Yang Qianrong introduces the research progresses of 3D printing technology in construction field at home and abroad, and reviews the characteristics of three 3D printing technologies including the existing of 3D- shape technology, contour crafting and Concrete printing [43].

3.2.8. Art and Design field

With the development of 3D printing, people began to explore the application of 3D printing in art and design. Li Lin mentions 3D printing not only can quickly generate complex jewelries, but also can make changes based on deviations in a timely manner [44]. Zhou Aimin thinks universal participations will be the future of product design pattern. That means people can select the appropriate products based on their needs [45]. Zhou Li mentions 3D printing can realize data sharing in the process of fashion design, make changes based on the requirements of customers every time, and avoid the waste of materials [46]. Zhang shan introduces 3D running shoes of Nike and New Balance, which shows the present situation of the application of 3D printing in design field [47]. Tian Hang thinks 3D printing technology can bring about revolution in product design patterns, and expand the designers' imagination space [48].

3.2.9. Education field

In recent years, 3D printing is starting to walk into the classroom, which promotes the development of education. Yang Jie puts forward that 3D printing will help to create the true problem situation, print out the teaching models of complex mechanisms, and enhance the students' ability to analyze and understand [49]. He Juanjuan points out that 3D printing can not only make students more intuitive cognition of three-dimensional geometry, but also improve their creative abilities in the process of making models [50]. Mao Lingyan points out that 3D printing can be used to make teaching tools, and concludes its application with UG software teaching by the structure-flow chart [51]. An Lu thinks that 3D printing technology promotes the development of makerspace of university libraries, and also develops students' innovative thinking [52]. Kuang Xin analyzes 3D printing technology's application in teaching tools, and the importance role in students' learning interest and innovation abilities [53].

4. CONCLUSION AND PROSPECT

In combination with the above research, we believe that: (1) Compared with abroad, the study on 3D printing started late in China, but the research of 3D printing started to develop rapidly since 2013. With the deepening of research, the research on 3D printing is gradually moving towards a rapid expansion period; (2) 3D printing research received wide attentions from scholars in various fields, involving economic, industrial, medical and so on; (3) In recent years, economy and industry have been the focuses of 3D printing studies, but education, medical treatment, design, construction and other areas have not gotten all-round social attention, and some potential areas such as food, environmental protection need be researched more deeply in China; (3) This article focuses only on the present situation of 3D printing research in China. We will extend the scope of the study, and conduct an in-depth analysis of 3D printing's hot spots and frontiers at the next stage.

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