Journal of Materials, Processing and Design (2021) 5: 31-36
Clausius Scientific Press, Canada

DOI: 10.23977/jmpd.2021.050106
ISSN 2516-0923

Preliminary Study on Additive Manufacturing Scheme of Hydraulic Manifold Block rapid-solidifying SLM Forming

Chunlei Luo*, Zihao Mao

Central South University, Mechanical and Electrical Engineering, Hunan Province, 410083, China

*Corresponding author: 1874687359@qq.com

Keywords: Hydraulic manifold block, Selective laser melting, rapid-solidifying

Abstract: **[Purpose/significance]** In traditional manufacturing process, hydraulic manifold blocks are drilled into blank to form their complex flow channel structure This processing technology is complicated and the efficiency is low. Selective laser melting (Selective laser melting, SLM) is a kind of additive manufacturing technology. Compared with traditional processing technology, it is not sensitive to the complexity of the processed parts. It is especially suitable for machining parts with complex internal structure such as hydraulic manifold blocks. **[Method/Process]** Therefore, this article proposes an additive manufacturing scheme for rapid-solidifying SLM forming of hydraulic manifold block, introduces the materials required for SLM forming, the method of rapid-solidifying SLM forming, and analyzes the application effect of the new scheme in the additive manufacturing of hydraulic manifold block. **[Result/Conclusion]** The results show that the rapid-solidifying SLM is insensitive to the internal pore structure of the integrated block, and can accurately design and optimize the complex porous structure of the integrated block. Compared with other additive manufacturing technologies, the forming accuracy is higher. The microstructure and comprehensive mechanical properties of the post integrated block are better, and it has a very broad development prospect.

1. Introduction

In the traditional integration hydraulic manifold block processing, the blank is usually drilled to form the flow channel, for some complex flow channel place also need to add the drilling process, which makes the hydraulic integration block processing is very complex, and in the process of drilling the hole intersecting burr is difficult to remove. The traditional manufacturing technology is approaching its limit by subtracting part of the material from the original block [1].

The additive manufacturing technology adopts the principle of discrete accumulation to melt the powder material to form a solid body through the three-dimensional model of the part, and is insensitive to the complexity of the part. Compared with the traditional casting process, additive manufacturing technology can form parts without molds. The more complex the parts, the more significant the forming efficiency. Therefore, using additive manufacturing technology to manufacture hydraulic valve block solves many problems in the process of traditional hydraulic

manifold block processing, which is a very suitable and promising processing technology.At present, the additive manufacturing technology of hydraulic valves at home and abroad mainly includes two technologies: laser cladding and selective melting. The laser cladding technology has a small forming size limited by space, and can also repair damaged components with high performance, but the forming accuracy is low. The selective melting is completed in an airtight container without oxygen, which can inhibit the oxidation of alloy elements at high temperatures. The selective melting is completed by electron beam or laser, which can achieve higher forming accuracy and mechanical properties [2].

Selective laser melting (SLM) is a technology that uses metal to be completely melted under the action of a laser beam, and then rapidly cooled and solidified. Compared with other additive manufacturing technologies, it uses laser as a heat source and has high forming accuracy and compactness. Good advantages have obvious advantages in forming parts with complex internal structures [3]. Rapid-solidifying is an important means to tap the potential properties of high-strength aluminum alloys. By rapidly solidifying the completely molten molten pool formed in the SLM process, materials with rapid-solidifying structure characteristics and special physical, chemical and mechanical properties can also be directly obtained [4]. The rapid-solidifying selective laser melting technology is to rapidly solidify the molten pool after the SLM forms the molten pool. It combines SLM and rapid-solidifying technology to obtain a hydraulic manifold with higher forming accuracy and better mechanical properties after forming. Therefore, the author tried to research the application of the rapid-solidifying SLM forming additive manufacturing program in the hydraulic manifold block to improve the comprehensive mechanical performance of the hydraulic manifold block.

2. New solutions for additive manufacturing of hydraulic manifold blocks

2.1 Material

Lightweight is the eternal pursuit of the development of hydraulic systems, and light-weight and high-strength materials are the basis for lightweighting. High-strength aluminum alloy (super hard aluminum alloy) materials are widely used in various fields due to their light weight, high strength, oxidation resistance and excellent corrosion resistance. The yield strength of 7075 aluminum alloy commonly used in hydraulic integrated valve blocks is about 503MPa, far exceeding the commonly used stainless steel. The density of aluminum alloy is 2.7kg/m3, which is only about 1/3 of that of steel. Using super-hard aluminum alloy powder as the raw material for hydraulic valve blocks can achieve a weight reduction of more than 78% [5].

2.2 Method

Selective laser melting (SLM) is a kind of additive manufacturing technology. It uses laser as a heat source. It has the advantages of excellent performance, high precision, fine structure, and good density. It can form almost any geometrical part, especially suitable for Parts with complex internal structure have obvious advantages in the process of forming hydraulic valve blocks. The principle of SLM is to iterate through the steps of powder laying -- laser sintering -- substrate descent -- powder laying again", powder laying layer by layer, and finally complete the whole forming of parts.

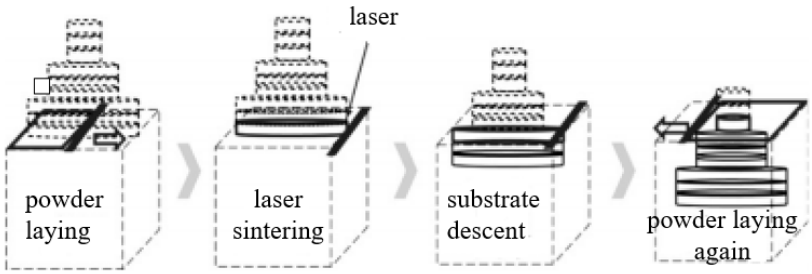


Figure 1: SLM forming principle

At present, SLM technology is mainly used for forming typical materials such as steel, aluminum alloy, and titanium alloy, and has a certain technical foundation. It has gradually developed into a manufacturing technology that can take into account both forming accuracy and high-performance forming [6]. However, the interaction between aluminum alloy powder and laser in the SLM forming process is very complicated. The aluminum alloy has good thermal conductivity, which is easy to cause oxidation and element burnout, and the reflectivity of the laser exceeds 90%. It is difficult to form hydraulic manifold blocks with aluminum alloy as raw material. The strength of the formed hydraulic manifold block cannot meet the requirements of the hydraulic system is also a problem that must be faced in the SLM formed hydraulic valve block [7].

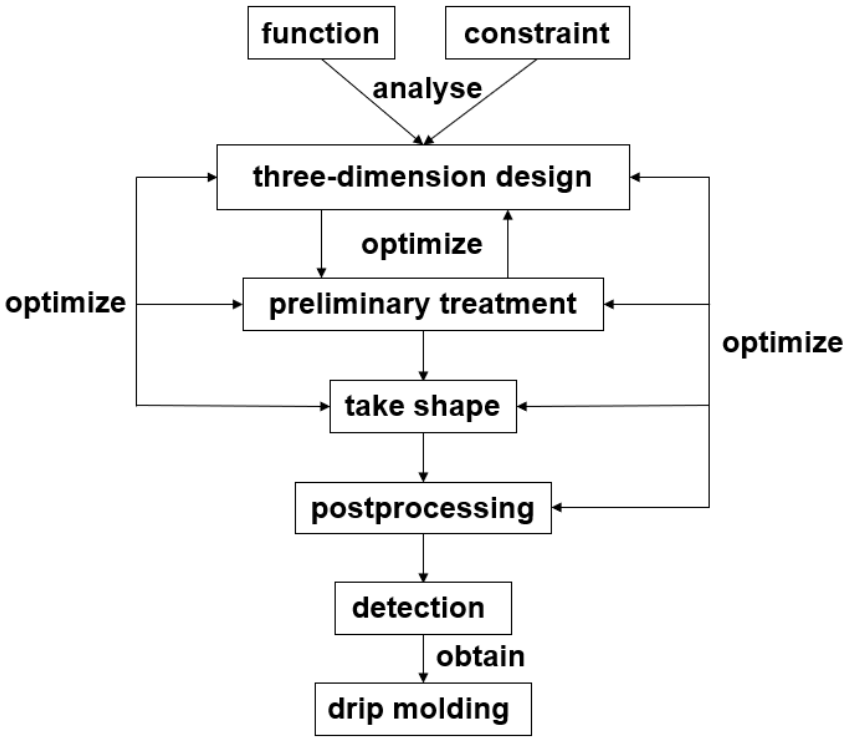


Figure 2: High-strength aluminum alloy hydraulic integrated valve block manufacturing flow chart

To solve the above problems, it is necessary to introduce the rapid-solidifying SLM technology. Rapid-solidifying SLM is a process of "rapid heat and rapid cooling". After the molten pool is formed by laser melting, the rapid-solidifying method is used to make the cooling rate of the molten pool very fast, which will refine the grains and reduce componen segregation. All help to improve the strength and corrosion resistance of the alloy. This method of rapid-solidifying can dig out the

properties of aluminum alloys to a large extent and create conditions for improving the microstructure and mechanical properties of super-hard aluminum alloys. Laser rapid melting in the SLM process-rapid solidification is the fastest rapid cooling solidification method that can achieve solidification coolant so far. It can not only directly improve the microstructure of super-hard aluminum alloys, but also quickly melt high-strength aluminum in lasers. Alloying elements are added during the alloying process to obtain a material with fine uniform and rapid-solidifying non-equilibrium microstructure characteristics and the designed excellent properties [8].

In summary, this article uses super-hard aluminum alloy powder as the material, adopts the rapid-solidifying SLM technology to form the hydraulic valve block with the required oil channel shape and size, and improves the strength of integrated hydraulic valve blocks by adjusting the process parameters and post-treatment during forming.

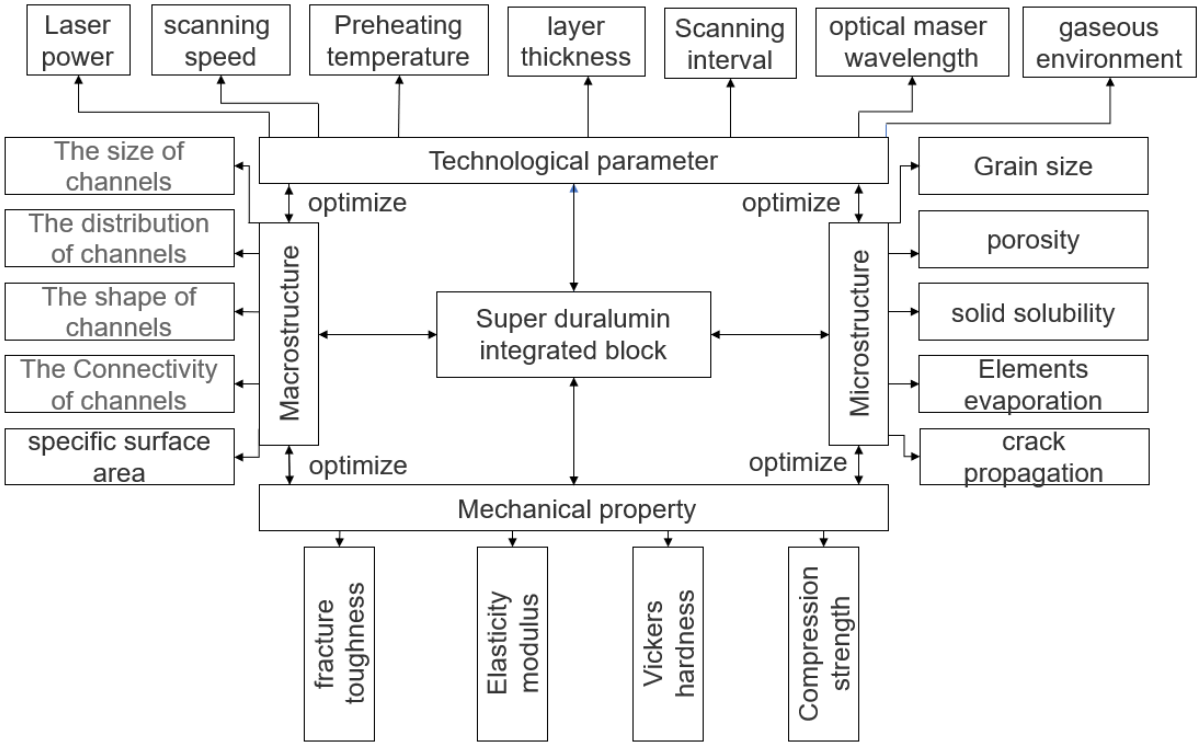
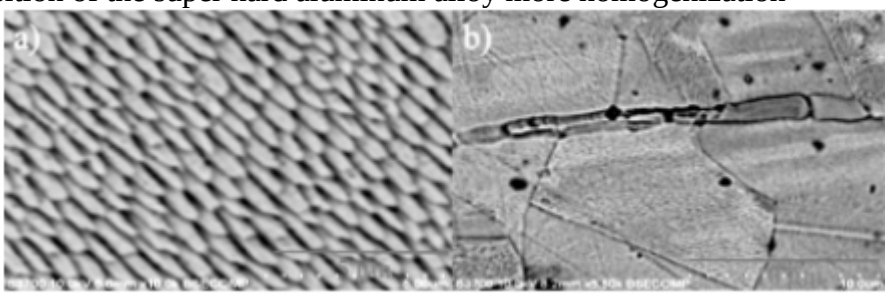


Figure 3: The overall framework of the research scheme for additive manufacturing of high-strength aluminum alloy hydraulic integrated valve blocks

3. Effect analysis of the new scheme

The rapid-solidifying of selective laser melting can form almost any geometrical parts, which has great advantages for the formation of hydraulic valve blocks with complex internal structures. After forming the molten pool in the SLM process, it undergoes rapid solidification, so that the liquid-solid phase transformation of the superduralumin powder molten pool occurs at a high degree of undercooling, forming a non-equilibrium solidification structure, and has the following characteristics: 1) Fine grains change. Larger undercooling shortens the time for crystal nucleus growth during solidification, and the grain size is much lower than that of conventional superduralumin. 2) Segregation decreases. The faster the cooling rate, the smaller the distance between the dendrites and the finer the second phase, and an alloy with uniform microstructure can be obtained. At the same time, fine and dispersed precipitated phase is formed at the grain boundaries and within the grains, which improves the mechanical properties of the alloy. 3) The

solution limit is enlarged. Increasing the solid solubility of the alloy will help to form new fine metastable phases, and make the alloy to dispersion strengthening. At the same time, it can also increase the solid solubility of impurity elements, form a phase structure with a wide range of components, reduce the harmful effects of impurities and the activity of the microcouple cells, and make the composition of the super hard aluminum alloy more homogenization



(a) SLM forming parts (b) Ordinary comparison piece

Figure 4: Metallographic structure under scanning electron microscope

FIG. 4 shows the metallographic structure of the SLM forming part and that of the ordinary forming part under scanning electron microscope. It can be seen that the SLM forming part has smaller grains and more uniform alloy composition in microstructure, and the hardness and Young's modulus of the forming part are larger than those of the traditional contrast material [2]. In addition, as a rapid prototyping technology, SLM is insensitive to the pore structure inside the manifold, and can accurately design and optimize the complex porous structure of the manifold.

4. Conclusions

The hydraulic manifold block is the main component of the hydraulic integrated system. In traditional manufacturing, the efficiency of hydraulic manifold block and forming hydraulic system has reached the bottleneck. As a rapid prototyping technology, SLM can accurately design and optimize the complex porous structure of the integrated block. It is a key technology to break through the existing manufacturing bottleneck of the integrated block. Compared with traditional manufacturing solutions, the new solution of rapid-solidifying selective laser melting technology to manufacture integrated blocks greatly improves the manufacturing efficiency of integrated blocks. Compared with other additive manufacturing technologies, the forming precision is higher, and the microstructure and mechanical properties of the integrated block after forming are better. and it has very broad prospects for development.

References

[1] Yin Xuan, Cheng Jinzhao, Zhao Huijuan. Channel design of hydraulic manifold block oriented to additive manufacturing [J]. Technology and Innovation, 2018(15): 134-135.

[2] Zhang Lei, Zhu Yi, Yang Huayong. Lightweight design and forming of hydraulic complex runners based on additive manufacturing [J]. Hydraulics and Pneumatics, 2018(11): 1-7.

[3] Yang Yongqiang, Chen Jie, Song Changhui, Wang Di, Bai Yunchao. Current Status and Progress of Laser Selective Melting Technology of Metal Parts [J]. Progress in Laser and Optoelectronics, 2018, 55(01): 9-21.

[4] Li Peiyong. Progress in the preparation of high-performance high-temperature aluminum alloys and their composites by rapid-solidifying/powder metallurgy technology [J]. Aviation Manufacturing Technology, 2020, 63(07): 64-78+85.

[5] Wang Xubao, Qu Bo. Lightweight design of aviation aluminum alloy bracket based on SLM process [J]. Mechanical Design, 2018, 35(10): 50-53.

[6] Tian Jie, Huang Zhenghua, Qi Wenjun, Li Yajiang, Liu Jianye, Hu Gaofeng. Current Status of Research on Laser Melting of Metal Selected Areas [J]. Material Guide, 2017, 31(S1): 90-94+101.
[7] Gan Wukui, Peng Jingui, Li Shihao, Xia Wenqiang, Wang Zhitai, Xu Zhifeng. Selective laser melting precision forming of aluminum alloy and its application in aviation [J]. Aviation Manufacturing Technology, 2019, 62(16): 53-63.
[8] Deng Yanbo, Zhao Rongtao, Feng Ji, Kong Lingjun, Han Zhengqian, Li Shihai. Application of Rapid-solidifying Technology in Aluminum Alloy [J]. Science and Technology Information, 2012(25): 476-477.