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Formation and Control of Pore Defects in Metal 3D Printing

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Abstract: In the printing process of 3D technology, the porosity defects caused by relevant reasons are often serious. For this, it is necessary to grasp its formation mechanism and do a good job of quality control in the application process of 3D printing technology, which is of great significance for the wide application of 3D printing technology. This paper gives a brief description of 3D printing technology, focusing on the formation mechanism and control measures of pore defects in metal 3D printing.

1. Introduction

The Additive Manufacturing Technical Committee of American Society for Testing and Materials defines 3D printing as "manufacturing objects by material deposition using print heads, nozzles or other printing technologies". Due to its many advantages, 3D printing technology is widely used in current social production and life.

2. Overview of 3D printing technology (the overview mainly focuses on history, current situation, problems and topics)

3D printing technology is one of the important development contents of emerging industries, which has brought great changes to traditional production methods and lifestyles. 3D printing (3DP) is a kind of rapid prototyping technology. It is a digital model file that using adhesive materials such as powdered metal or plastic to construct objects layer by layer. The technology has a wide range of applications, including in jewelry, footwear, industrial design, construction, engineering, and construction (AEC), automotive, aerospace, dental, and healthcare industries, education, GIS, civil engineering, firearms, and other fields. Grasp the working principle of 3D printing, the software operation of 3D printer and the parameter setting of 3D printer, and can master the use and skills of 3D printing, to ensure the quality of 3D printing. The 3D printing technology of metal parts is the most advanced and potential technology content in the current 3D printing system, and is the development direction of the current advanced manufacturing technology. With the continuous optimization and reform of related technologies, 3D printing technology of metal parts has developed rapidly and has developed in many fields. It is one of the effective technologies in metal parts manufacturing, and is widely used in aerospace, automobile, motorcycle, home appliances and other fields. According to the research report issued by IDC, the global 3D printing market will continue to

expand in 2020, with an overall growth rate of nearly 25% [1].

The 3D printing technology is mainly used for additive manufacturing of desktop level equipment with low cost and simple functions, which can achieve rapid material forming and comprehensive digital processing effect without molds. The products thus processed can meet the needs of infinitely complex geometric structure processing, and can be effectively applied in the manufacturing of many types of materials. With the help of 3D printing technology, effective new product development and personalized manufacturing can also be realized, especially for complex structural parts. Relevant design can promote the effective improvement of product performance.

3. Causes of porosity defects during 3D printing of metal

The principle of metal 3D printing technology mainly includes: complete the preliminary graphic design on the computer, use the selective laser sintering technology, use the high-energy laser to melt the fine particles of plastic, metal or glass powder through the 3D printer, and make them into the desired three-dimensional shape slices. The sintering machine accumulates the slices layer by layer, and finally forms the required parts.

Metal 3D printing mainly relies on laser or electron beam to melt metal powder layer by layer to produce preset parts. Because the metal powder used in 3D printing technology is very small, generally 15 μm to 100 μm, When the metal powder is irradiated by laser or electron beam, the melting of the powder may produce a part of the gasification phenomenon, thus forming the flow of gas, causing the powder around the forming path to be washed away by the gas flow, and some small pores and defects when the adjacent powder is formed [2].

Secondly, in the metal 3D printing process, it is difficult to precisely control the heat distribution during the entire printing process, so there may be unmelted powder in the manufactured parts. In addition, the energy fluctuation of laser or electron beam, the inconsistent powder size, or the sudden change in the structure of the part itself will eventually affect the change of heat distribution, resulting in the appearance of porosity defects in the part. In order to prevent the powder from being oxidized during melting, it is also necessary to fill inert gas or vacuum the forming chamber. However, the concentration of inert gas and the vacuum degree of the vacuum chamber cannot reach 100%, so some of the powder may be oxidized.

To sum up, in the process of metal 3D printing, the internal defects of printed parts are inevitable. What we should do is to control these defects as much as possible, and control the common defect parts, defect size and quantity. This requires that in the process of metal 3D printing, the environment and conditions should be controlled as much as possible to ensure that the impact of various adverse factors is minimized and better printing and forming effect is achieved.

4. Pore defect control method in metal 3D printing process

There are generally two methods to deal with the porosity defects in metal 3D printing. One is to control the defects during printing processing, and the other is to close the generated cavities through post-processing [3].

4.1. Control method during printing

Compared with the post-processing method, it is more important to control the porosity defects in the 3D printing process of metal, so it is necessary to analyze the main causes of porosity in printing. In the process of metal 3D printing, the essence of poor fusion is that complete melting has not been achieved, and porosity is caused by gas overflow in the solidification process. However, the cause of its formation needs to be studied based on experimental materials and printing parameters. As shown

in Figure 1 below, it is some possible influencing factors for poor fusion of metal 3D printing and the formation of pores:

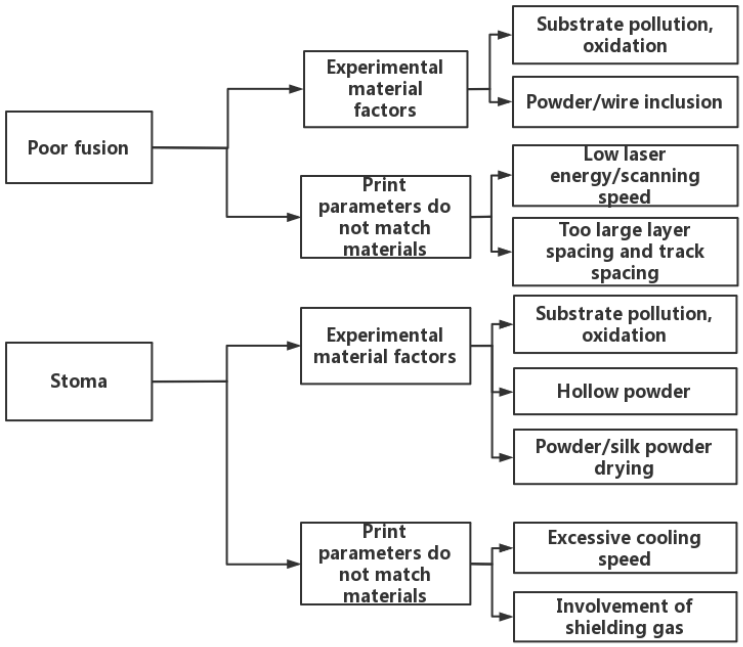

Figure 1: Possible influencing factors of poor fusion and porosity formation of metal 3D printing

In addition to the above mentioned reasons, the actual printing process, defect location and corresponding microstructure should also be considered to eliminate the defects, and the factors of material melting and solidification process in printing should be grasped [4]. It can be seen that there are many influencing factors in 3D printing. It is necessary to grasp the key points of quality control in the processing of specific workpieces and make specific analysis of specific problems.

4.2. Adjust the wall thickness reasonably to improve the printing effect

In some production processes, the 3D printing effect obtained by changing the wall thickness may be surprisingly good. For example, when printing a 1.0mm thin wall, the wall thickness can be set to 1.0, which will achieve a fast and high-intensity printing effect. [5]This works best for 3D prints with high wall thickness and consistency. Adjust the wall thickness for the value of the Wall Thick option on the Basic page. By adjusting the threading behavior, with the proprietary settings of the Simplify3D software, click "Edit Process Settings" to select the Advanced tag to see the settings. The software's "gap fill" is distinctive, a feature that allows the software to fill the gaps inside the thin walls. To open this option, check the "Allow gap fill when necessary" option. If gaps still exist after using this option, you need to check another option. Click the Infill tab to add the "Outline Overlap" (peripheral overlap) setting. This would allow the gap fill to fill more space in the middle of the thin wall. For example, the previous setting had a peripheral line overlap value of 20%, and increasing this value to 30% gave a better printing.

4.3. Post treatment method

For the porosity problem of related parts after metal 3D printing, post-processing methods can also be used to make up for and eliminate the porosity. For metal materials, the hot isostatic pressing technology makes use of the characteristics of extremely low strength and excellent plasticity of metal

materials at high temperatures. The metal in the cavity area will undergo plastic deformation under the effect of external gas pressure, and the metal in the cavity area will contact with each other to produce metallurgical structures that will make the cavity disappear. The post-processing of metal 3D printing is precisely to use hot isostatic pressing technology to achieve pore closure. However, the hot isostatic pressing technology does not have a good effect on the elimination of pores in all metal 3D printed parts.[6] The specific effect is related to the hot isostatic pressing technology. The wall thickness and pore size of the parts also have a certain impact on this. If the process is set improperly, serious consequences will also occur. For example, improper temperature and pressure settings may cause the wall thickness of the parts to be thinner, or even lead to coarse grains of the parts and poor performance of metal materials.

5. Conclusion

With the continuous development and improvement of metal 3D printing technology, its application in the printing of metal parts is more and more frequent. With the continuous improvement of the market requirements for the processing of related parts, metal 3D printing technology will also be applied in more high-accuracy cutting-edge technology fields in the future. This paper analyzes the causes of porosity defects in metal 3D printing, and points out two solutions to this problem. One is the quality control method in the printing process, and the other is the post-processing method after printing. Both methods have their advantages and disadvantages. Since the porosity defect of 3D printing technology is inevitable, we will continue to carry out technical research and development in specific production practices. We believe that with the continuous improvement of metal 3D printing technology, this defect will be gradually improved.

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