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Review Article

A Review on Powder Bed Fusion Process and Smart Manufacturing Technologies

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Abstract

Powder bed fusion (PBF) processes are laser-based additive manufacturing in which the laser beam scans the selected locations of powder bed at a controlled speed and then it fuses the powder to the solid material by either partial melting in selective laser sintering (SLS) or full melting in selective laser melting (SLM). The aim of this paper is to present a review about PBF showing its way of working, parameters and open issues. In addition, the paper shows the current smart manufacturing that optimize the processes.

Keywords: *Powder Bed Fusion, Smart Manufacturing Technologies, Selective Laser Sintering, Selective Laser Melting*

1. Introduction

S. Sun (Sun *et al*., 2017) stated that powder bed fusion (PBF) processes are laser-based additive manufacturing in which the laser beam scans the selected locations of powder bed at a controlled speed and then it fuses the powder to the solid material by either partial melting in selective laser sintering (SLS) or full melting in selective laser melting (SLM) which is metal-based process that use the laser selectively to melt the powder after layer by layer fabrication as mentioned by S. Shrestha (Shrestha, *et al*., 2019). Smart manufacturing Technologies can be integrated with the process to optimize it.

2. Powder Bed Fusion Process

(Sun *et al*., 2017) illustrated the way of working for laser-based PBF process as shown in the following figure:

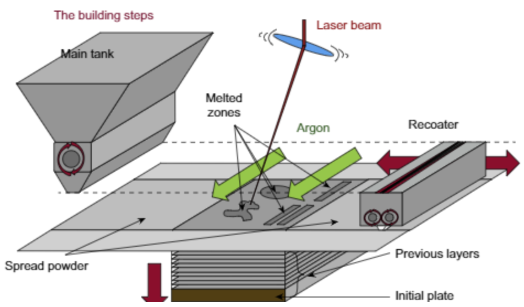

Fig. 1. Powder Bed Fusion Process (Sun *et al*., 2017)

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2.1 Parameters

S. Sun (Sun *et al*., 2017) mentioned that the process parameters for PBF processes are divided into four categories, the first one is laser-based parameters including laser power, wave length, spot size, pulse duration and pulse frequency. The second category is parameters related to scan which are scanning speed, scanning spacing and scanning pattern. The powder related parameters is the third type which includes particle size and distribution, particle shape, powder bed density, layer thickness and material proprieties, the last category is temperature related parameters including powder bed temperature, powder feeder temperature and temperature uniformity.

2.2 Open Issues

S. Shrestha (Shrestha, *et al*., 2019) mentioned that metal-based additive manufacturing has many issues such as porosity, part deformation and cracks, but porosity is the most challenging issue as stated in (Snell, *et al*., 2020), they mentioned that porosity has a significant effect on mechanical properties as it causes structural failures and decreases the strength and Young's modulus when the porosity is increased. In addition, they presented three types of pores gas, keyholes and lack of fusion. Gas pores are the most common type of pore, these pores are the smallest and most spherical of all types of pores and they are connected to trapped gas during melting process or the gas present in metal powder. The second type is keyholes pores that come from an excess in energy input which is a result of high laser power, S. Shrestha (Shrestha, *et al*., 2019) said that bubbles of vapor are trapped within the melt pool causing this type of pore. The third type of pore is lack of fusion pores which are formed due to unmelting some regions because of low energy density which is mostly a result of low laser power. The energy density is a function of laser power, scanning speed, hatch distance and layer thickness, these parameters are the significant factors that affect pores formation as mentioned in S. Shrestha (Shrestha, *et al*., 2019).

3. Smart Manufacturing Technologies

The current manufacturing processes do not allow users to get the advantages of smart manufacturing technologies, integrating them can optimize the processes which is helpful to get cost-effective and high-quality products. (Autodesk) suggested six smart manufacturing technologies that can be used to improve the product performance and maximize the operational efficiency as shown in the following table:

Table 1 Smart Manufacturing Technologies

Technology	Techniques	Benefits
Manufacturing-Led Design	Computer-Aided Design & Computer-Aided Manufacturing (CAD/CAM)	Design and manufacture prototypes
3D Printing (Additive Manufacturing)	Vat Photopolymerization, Binder Jetting Material Jetting, Material Extrusion, Powder Bed Fusion, Sheet Lamination, Directed Energy Deposition and Metal Casting	Create highly complex geometry products
CNC Machining and Probing	Roughing, 2 Axis Vs 3 Axis Milling and Turing	Control the movement cutting tools through generated codes from computer software
Hybrid Manufacturing	Netfabb (Additive) and Power mill (Subtractive)	Create high quality products with less material waste
Simulation	Finite Element Analysis, Computational Fluid Dynamics, Plastic Injection Molding and Generative Design	Predict the product performance and optimize the product design
Robot Automation	Autonomous 3D Printing Robots	Automate large scale additive and subtractive processes

Conclusion

Powder bed fusion (PBF) processes are laser-based additive manufacturing in which the laser beam scans the selected locations of powder bed at a controlled speed and then it fuses the powder to the solid material by either partial melting in selective laser sintering (SLS) or full melting in selective laser melting (SLM) which is metal-based process that use the laser selectively to melt the powder after layer by layer fabrication as mentioned by S. Shrestha (Shrestha, *et al*., 2019). Smart manufacturing Technologies can be integrated with the process to optimize it. This paper presented a review about PBF showing its way of working, parameters and open issues. In addition, the paper showed the current smart manufacturing that optimize the processes.

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