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Finishing of Additively Manufactured Metal Parts by Abrasive Flow Machining

Xuanping Wang[1], ShichongLi[1], Youzhi Fu[1], Hang Gao[1,*]

[1]School of Mechanical Engineering, Dalian University of Technology, Liaoning, China,116023

* Corresponding Email: gaohang@dlut.edu.cn

Abstract

Surface finishing is still a crucial challenge in metal Additive Manufacturing (AM) as the as-built surface roughness is difficult to fulfill service requirements, due to staircase effect, balling effect inherent to AM. Abrasive flow machining (AFM) is a non-conventional finishing technique that offers better accuracy and efficiency for parts with difficult-to-access structures, and the application of AFM to finishing metal parts of AM process is discussed in this paper. The aluminum and titanium grilles by selective laser melting are taken to explore the finishing effect of outer and inner surfaces. The AFM process parameters of abrasive grits sizes, abrasive media viscosity, and tooling designs are optimized to implement effective material removal from the outer and inner surfaces. The results show that the AM grille parts with non-trial internal structures can be finished efficiently and consistently by AFM.

Key words: additive manufacturing, abrasive flow machining, polishing, complex structure

Introduction

The surface roughness of parts additively manufactured by SLM is able to reach Ra 10 μm ~50 μm, while the surface roughness of parts by subtractive manufacturing is usually below Ra 2.5μm. As the inherent "balling effect","powder adhesion" in additive manufacturing lead to the poor surface roughness[1-3], polishing process is inevitable to fulfill requirement of surface quality.

Although blasting, belt polishing, laser polishing, *et al.* are applied in polishing metal AM parts, it is still challenging to polish AM parts with difficult-to-access complex geometries[4]. Abrasive flow machining (AFM) is a polishing process with semisolid abrasive media as cutting tool. The deformable characteristics of the abrasive media enables it to act as a flexible cutting tool to achieve high surface quality for parts with complex geometries[5]. In this paper AFM is taken to polish additively manufactured grille to explore the finishing effect of outer and inner surfaces.

Experimental setup

As shown in Fig.1, the grille is made by aluminium alloy powder through Selective Laser Melting(SLM), on which inclined square holes with 3mm long each side are distributed in equal distance. As shown in Fig.2, there are obviously alloy balls from the SLM process and alloy powders adhered on the grille surface, which results in the poor surface quality with surface roughness Ra 14μm.

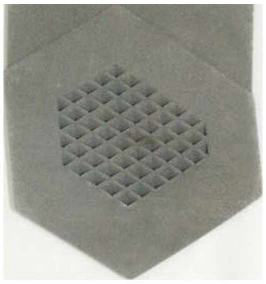


Fig.1. Initial surface of the grille

(a) Outer surface (b) Inner surface

Fig.2. Initial surface textures of the grille

In AFM polishing process, abrasive media act as the continuously deforming cutting tool, composed of polymer, abrasive grits, *et al*. When abrasive media are extruded across the workpiece surface, the active abrasive grits scratch the surface and micro-chips are produced, leading to the material removal. The AFM machine used in the present work is shown in Fig. 3, composed of hydraulic system, electric system, and mechanical system. As the tooling and the flow channel demonstrated in Fig.4, it is optimized to implement polishing the outer surface and inner surface of the grille simultaneously.

Fig.3. AFM system

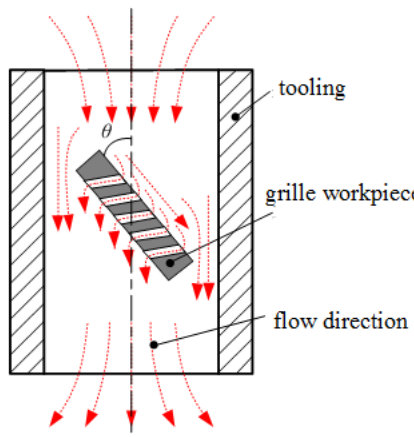


Fig.4. tooling and flow channel for grille polishing

Experimental results analysis

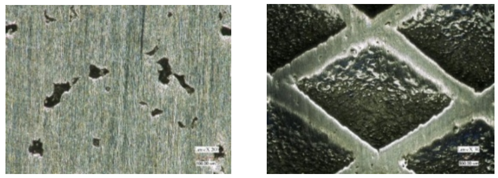
Mesh size and mass fraction of the abrasive media, and the process parameters in AFM polishing are listed in Table 1.

Table 1. Processing parameters in AFM polishing

Media	Pressure /MPa	Cycles	Time /min	Angle /°
SiC24#-80#	2.5	50	23	2

After AFM polishing, the surface roughness is reduced from the initial Ra 14μm to Ra 0.94μm. According to the micro-profiles of outer surface and inner surface provided in Fig.5, the adhered melten balls and alloy powders are all removed with comparison to the initial surface textures in Fig. 2.

It could be concluded from the experimental results that AM parts with non-trivial internal structures can be polished effectively, including outer surface and inner surface.



(a) Outer surface (b) Inner surface

Fig.5. surface textures of the grille after AFM polishing

Conclusions

In this paper abrasive flow machining(AFM) technique is taken to polish additively manufactured grille with square inclined holes with regular arrangement. Abrasive media with hybrid grit sizes are adopted to implement polishing the inner and outer surface of the grille simultaneously. After AFM polishing process, the poor surface resulting from the inherent "balling effect", "powder adhesion" in additive manufacturing is significantly improved, proving that AFM is a feasible way to polish additively manufactured parts with difficult-to-access complex geometries.

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