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Development of a high-speed and high-resolution 3D printer by using laser metal deposition technology

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Abstract

A high performance LMD (Laser Metal Deposition) 3D printer prototype is presented here, demonstrating a building speed over 350 cc/ h, a build width as small as 0.3 mm, an accuracy of +/- 30 um, and a maximum building size of 300 mm x 300 mm x 100 mm. The prototype consists of a 6 kW fiber laser, a powder focusing nozzle, an inert gas chamber, a metal powder feeding system with inert gas, and a laser polishing system. A 6 kW fiber laser enable higher building speed than the conventional powder bed fusion. An axial nozzle concentrating the powder stream with a diameter as small as 0.7 mm can improve the accuracy. Inert gas can reduce a content of oxygen in the chamber to less than 50 ppm. Multi-layer parts consisting of multi-materials were built by switching power materials with a metal powder feeding system. The surface of built parts with a roughness, Ra, of 14.1 um was improved to 3.9 um with the laser polishing system. The parts built from Stainless Steel 316L powder satisfied the mechanical properties of JIS G4304.

Keywords: Additive Manufacturing, Laser Metal Deposition ;

1. Introduction

Additive manufacturing technology has been attracting attention as a breakthrough technology in advanced manufacturing. It has, however, technical issues to be solved at the building speed, the building accuracy, and the maximum size of building. Therefore, the Ministry of Economy, Trade and Industry (METI) established a research association, TRAFAM (Technology Research Association for Future Additive Manufacturing), in 2014. TRAFAM’s mission is the development of additive manufacturing systems that will meet the world’s highest standards in the "3D printer technology development for the next-generation

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industry". Toshiba and Toshiba machine belong to this association and have developed a 3D printer prototype by using Laser Metal Deposition (LMD). In this presentation, we describe the features of our prototype.

2. Laser Metal Deposition

The laser metal deposition is a process which uses a laser beam to form a melt pool on a metallic substrate, into which metal powder is introduced through a focusing nozzle with inert carrier gas, as shown Fig.1. The metal powder is deposited through melt and solidification process at the melt pool.

The LMD 3D printer has some advantages, compared with the conventional 3D printer which adopts Powder Bed Fusion. One of advantages is the high potential for improving the building speed depending on the laser power. Second one is the possibility to build multi-material parts with switching the powder source.

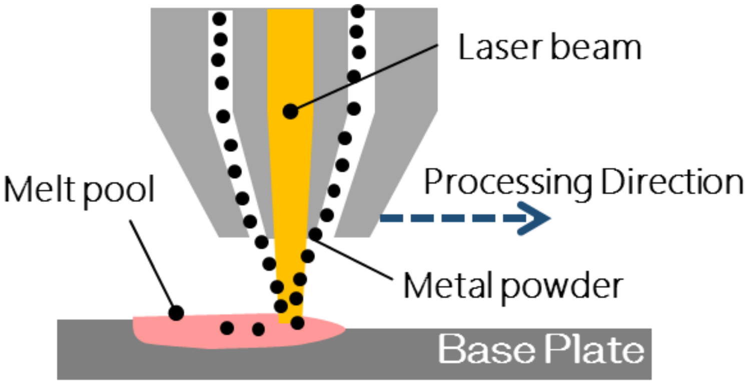

Fig. 1. Schematic of LMD.

3. Feature of LMD 3D printer prototype

Figure 2 shows the outlook of the LMD 3D printer prototype. Maximum building size is 300 mm x 300 mm x 100 mm. The prototype consists of a 6 kW fiber laser, a powder focusing nozzle, an inert gas chamber, a metal powder feeding system with inert gas, and a laser polishing system. A 6 kW fiber laser enable about ten times higher building speed than that of the conventional powder bed fusion. The laser beam introduced into the building chamber through an optical fiber is focused with a focusing optics on a workpiece at a diameter between 0.2 and 3.0 mm. An axial nozzle concentrating the powder stream with a diameter as small as 0.7 mm can improve the accuracy. Inert gas can reduce a content of oxygen in the chamber to less than 50 ppm. Multi-layer parts consisting of multi-materials can be built by switching power materials with a metal powder feeding system. Metal powders including stainless steel, nickel based alloy, aluminum alloy or copper alloy can be used. Figure 3 shows the schematic of laser polishing. The laser polishing improves the roughness of the building surface by utilizing the surface tension, which is caused by re-melting the irradiated surface with a laser on the surface of the building parts.

Fig. 2. Outlook of LMD 3D printer prototype.

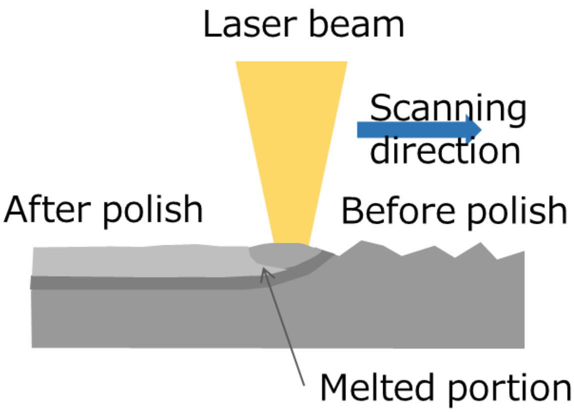

Fig. 3. Schematic of Laser polish.

4. Built parts

Figure 4 shows building processing of a cylinder, which has the diameter of 30mm and the height of 20mm.

Built parts with the present prototype are shown in Fig. 5. A slight overhung figure is shown in Fig.5(a). Laser polish of built parts has also been developed. “As built” surface with a roughness, Ra, of 14.1µm was improved to 3.9 µm by re-melting using laser irradiation as shown in Fig. 5 (b).

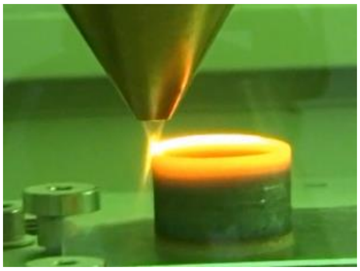

Fig. 4. Building processing of a cylinder.

(a)

(b)

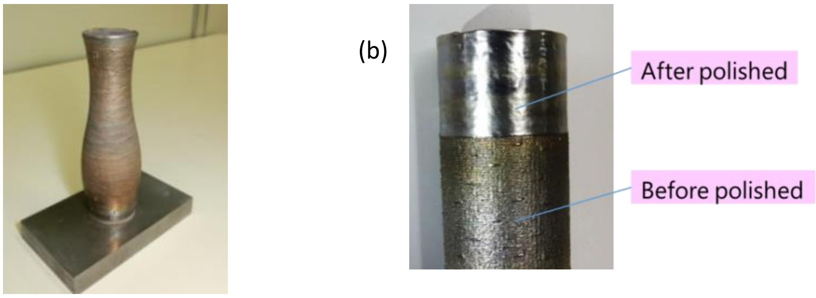

Fig. 5. Parts built with the prototype. (a) A “cup” figure of SUS316L at a height of 60 mm; (b) Laser polished workpiece. Roughness of upper polished surface is 3.9 µm and lower “as built” surface is 14.1 µm.

5. Conclusions

We have achieved a building speed exceeding 300 cc/h, an accuracy of +/- 30 µm, and a maximum building size of 300 mm x 300 mm x 100 mm using a 6kW laser and a powder-focusing nozzle developed fluid dynamics simulation. Laser polishing system has improved the surface roughness of the workpiece from 14.1 µm to 3.9 µm.

Acknowledgements

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References

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