Simulation for Additive Manufacturing
11th –13th October 2017
Munich, Germany

Laser command generation for direct energy deposition with time-domain thermal conductivity simulation analysis

Ryo Koike[1], Shintaro Arano[1], Yasuhiro Kakinuma[1], Yohei Oda[2], Makoto Fujishima[2], and Tojiro Aoyama[2]

Department of System Design Engineering
Keio University, 3-14-1 Hiyoshi, Kouhoku-ku, Yokohama, Japan
koike@sd.keio.ac.jp

DMG Mori Seiki, Co., Ltd.
2-35-16 Meieki, Nakamura-ku, Nagoya, Aichi, Japan
yo-oda@dmgmori.co.jp

Key Words: *Direct Energy Deposition, Thermal Conductivity, Laser*

Direct energy deposition (DED) is an additive manufacturing (AM) process where focused thermal energy is used to fuse materials by melting as they are being deposited as shown in Fig. 1. DED attracts much attention from aerospace and automobile industries because of its applicability to complex shape production with high efficiency. In terms of laser AM technologies for metals, many researchers evaluate mechanical properties of the produced parts. For example, the strength of the components manufactured in DED is often analyzed in terms of density, and several researchers take experimental approaches to reduce the void inside them [1]. The relation between the microstructure and its mechanical characteristics is also investigated for superalloys, such as Inconel 625 [2] and Ti-6Al-4V [3]. Most of these studies indicate the necessity of laser power modification in metal AM process to enhance the specific strength and obtain a proper metal structure.

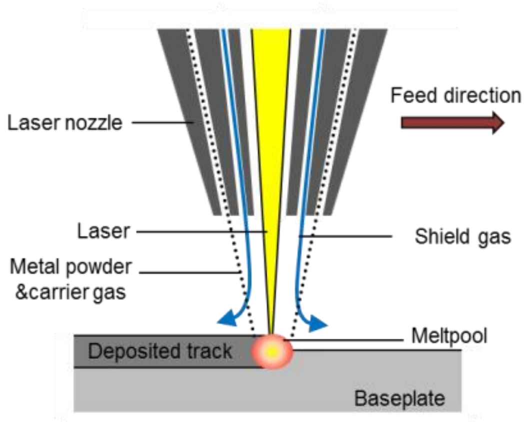

Fig. 1 Schematic of direct energy deposition (DED) process.

On the other hand, shape accuracy is also an important factor in the manufacturing industry in terms of reliability. Although DED provides high production efficiency comparing powder bed fusion (PBF), it is difficult to enhance shape accuracy in DED. A simulation can ensure shape accuracy by predicting the produced shape from the production conditions; thus, an accurate time-domain simulation is proposed for PBF [4]. However, in case of DED, the dynamic movement of metal powder and large heat supply render process analysis difficult.

Considering the shape of deposited past strongly depends on the meltpool size in DED, the meltpool temperature should be kept constant and overheating must be avoided. From this viewpoint, a laser command optimization is proposed in this paper to maintain the meltpool temperature in DED based on a thermal conductivity simulation. A laser power command is a pre-requisite for the proposed method. Therefore, the deformation due to overheating can be avoided only with a feedforward

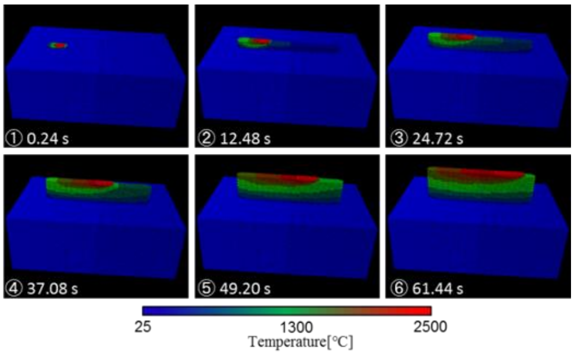

Fig. 2 Temperature distribution simulation result for DED using a constant laser power.

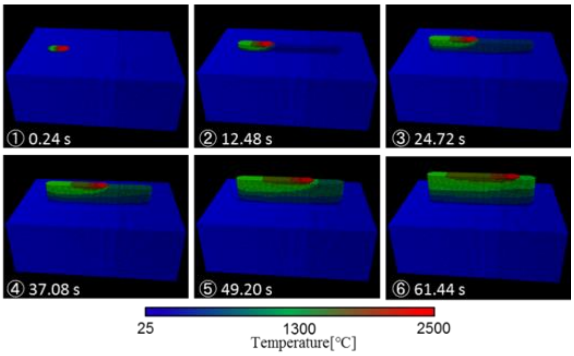

Fig. 3 Temperature distribution simulation result for DED using laser power modified with gradient descent.

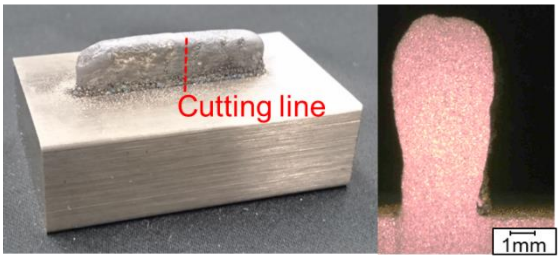

Fig. 4 Deposited object produced on a single track under constant laser power of 2000W.

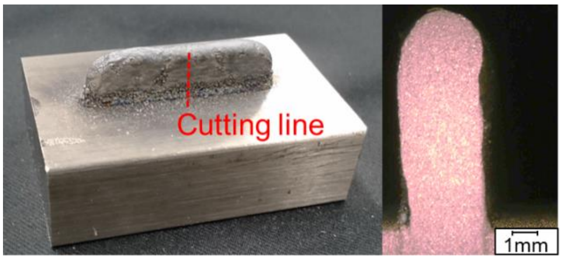

Fig. 5 Deposited object produced on a single track under the calculated laser command.

control. The calculated laser power command is installed to the DED machine and investigated by depositing a wall-shape part with Inconel625 and evaluating shape accuracy.

Applying a finite-difference method with a voxel model, heat distribution in DED can be approximately predicted. The proposed method calculates the optimal laser power command to avoid overheating in DED by introducing gradient descent to the meltpool temperature in the simulation. The meltpool temperature gets higher in higher layers under constant laser power in the simulation (Fig. 2), on the other hand, overheating is certainly avoided with the proposed laser power command as shown in Fig. 3. By introducing the calculated laser command to wall-shape deposition, the proposed method is evaluated from the viewpoint of shape accuracy. Although the width of wall gets larger in higher layers due to overheating under constant laser power (Fig. 4), the deformation due to overheating is suppressed under the calculated laser command with the proposed method as shown in Fig. 5.

Not only single track deposition but also corner track and circular track are evaluated in this study, and the experimental results clearly shows that the proposed method certainly improves shape accuracy of deposited parts in all these tracks.

References

[1] C. Zhong, A. Gasser, T. Schopphoven, R. Poprawe, Experintal Study of Porosity Reduction in High Deposition-rate Laser Material Deposition, *Opt. Laser Technol.*, 70:87-92, 2015.

[2] S. Cao, D. Gu, Laser Metal Deposition Additive Manufacturing of Tic/Inconel 625 Nanocomposites: Relation of Densification, Microstructures and Performance, *J. Mater. Res.*, 30(23):3616-3628, 2015.

[3] M.W. Wu, P. H. Lai, The Positive Effect of Hot Isostatic Pressing on Improving the Anisotropies of Bending and Impact Properties in Selective Laser Melted Ti-6Al-4V Alloy, *Mat. Sci. Eng. A*, 658(21):429-438, 2016.

[4] T.I. Zohdi, Additive Particle Deposition and Selective Laser Processing – A Computational Manufacturing Framework, *Compt. Mech.*, 54:171-191, 2014.