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Layer Geometry depending on number of tracks during Selective Laser Melting

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Abstract

During Selective Laser Melting, powder layers are successively applied to be locally melted by the laser beam to produce parts layer by layer. Using this technique, complex structures are possible to manufacture. Within the layers tracks are produced by locally melting the powder and attaching the melt to the structure. It is usually expected that the tracks show a certain but constant height before applying the next powder layer. In this work, several tracks within one layer were produced at varied hatch distances. It was observed that the built-up layer height and layer shape significantly depend on the hatch distance due to surface tension effects in combination with extensive re-melting of material of the already processed structure. This effect can lead to changed conditions like varying powder heights in the consecutively applied powder layer or even to a varying precision of the produced part.

Keywords: Powder bed; track geometry; hatch distance; surface tension

1. Introduction

Selective Laser Melting (SLM) is widely used nowadays in many industrial applications in regular production processes. Complex parts can be built at high precision. However, some basic mechanisms of the process are not yet understood and can help for a more efficient processing. When processing the tracks, usually the same processing parameters are used, which is expected to lead to similar results.

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Krauss et al. (2013) found that the track geometry and denudation zones vary also at different line energy and can lead to significant surface roughness. Yadroitsev et al. (2013) could show that the denudation effect leads to a decreased track height with successive scans, which is strongly affected by hatch spacing. Matthews et al. (2016) calculated the denudation zone considering the vapor pressure and found that the denudation width to be of the width of two particle widths (60 µm). Since the experimentally observed denudation zones were much larger, Ly et al. (2017) concluded that the expanded melt pool showing dynamic behavior due to the varying recoil pressure can incorporate adjacent particles into the melt pool leading to the denudation effect.

However, e.g. Yadroitsev et al. (2011) described that the laser energy absorption can significantly vary since the laser beam strikes not only the less reflective powder bed but also the substrate or the previously built track. This leads to a different amount of absorbed energy and therefore to different track shapes. They observed that the second track is lower than the first one and the powder consolidation area is smaller. When processing further tracks next to each other, the surface morphology showed significant variations. They recommend a maximum hatch distance of the average width of the track in order to achieve a smooth surface.

Since the effect of varying track heights can affect the geometry of the final part, the effect must be further explored and explained to consider or counteract for high-precision processing. Therefore, this work aims to describe the track height variations depending on the hatch distance between the tracks.

2. Methods

Powder (stainless steel 316L with diameters from 45 µm to 90 µm) were pre-placed on a 316L substrate (Figure 1a) at a height of 100 µm (Figure 1b).

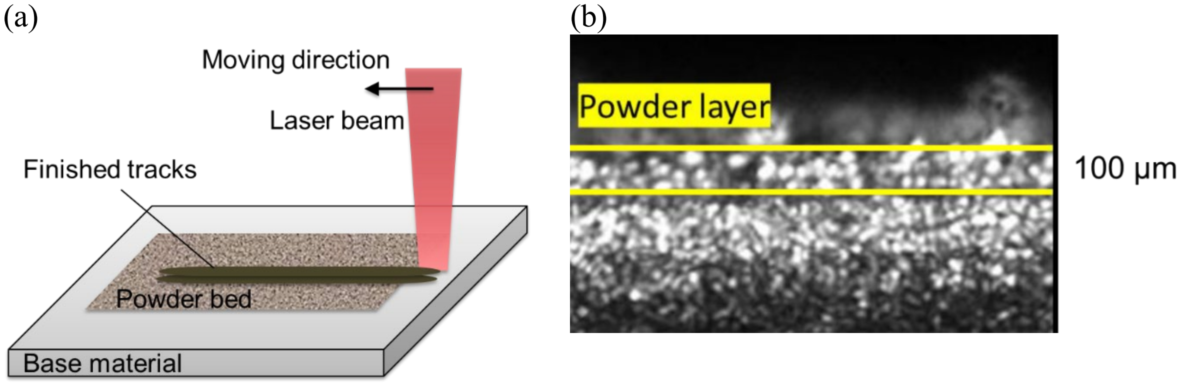

Fig. 1. (a) Sketch of the process setup and (b) powder layer pre-positioning

A laser beam (300 W IPG fiber laser) of 75 µm focal spot diameter was used to melt the material at a laser power of 250 W and a processing speed of 2 m/min and varied hatch distances. After processing of 7 tracks next to each other, cross-section polishes were made to identify the molten area and measure the height and width of the produced layers.

3. Results and discussion

Cross-section polishes of the processed layers were made (Figure 2), while significant differences of the shape of the layers are visible at different hatch distances.

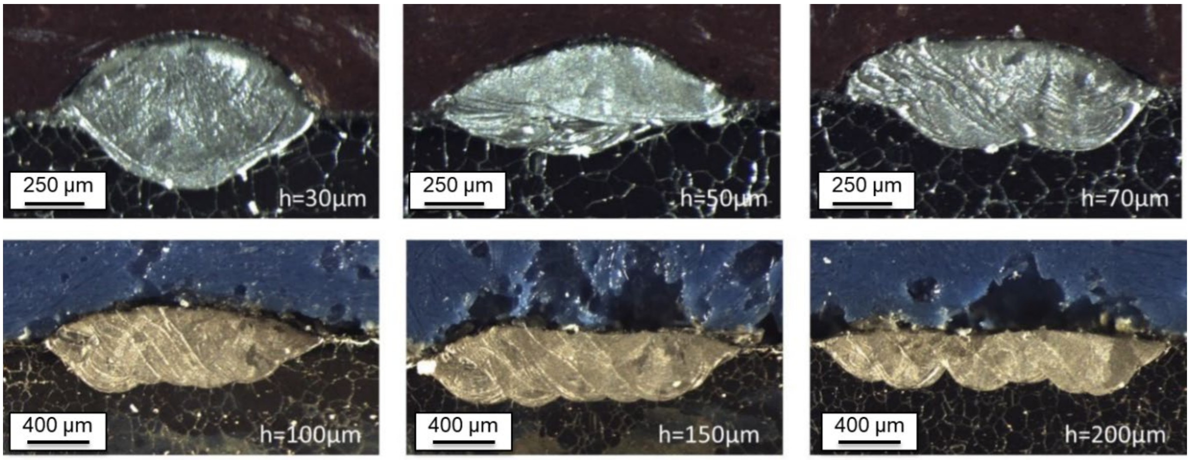

Fig. 2. Layer geometries after building 7 subsequent tracks at different hatch distances

The surface geometries of the layers in Figure 2 were extracted and used for comparison in Figure 3.

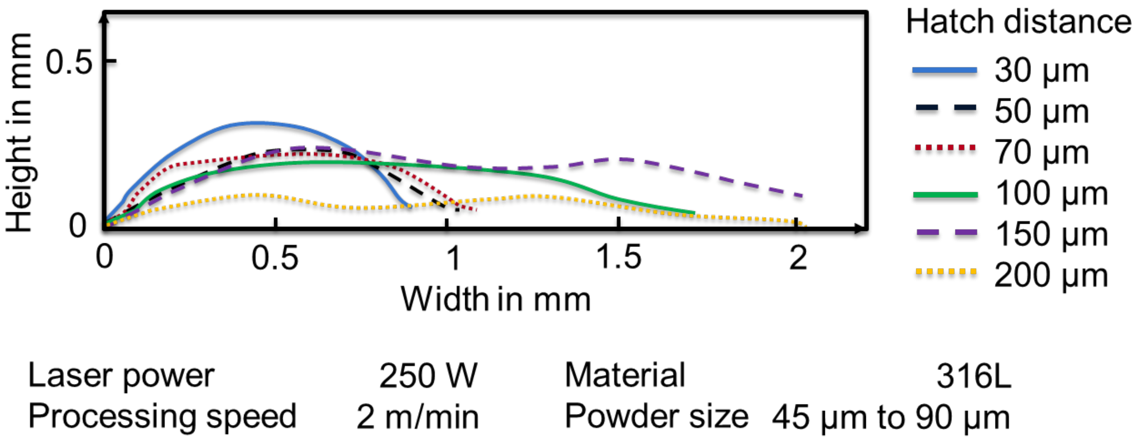

Fig. 3. Comparison of layer heights at different hatch distances after building 7 tracks next to each other

It is visible that the height and shape of the layers significantly vary. At low hatch distances the layers are higher compared to larger hatch distances. A possible reason can be the surface tension effect that leads to a round surface shape when the hatch distance is small. In addition, at small hatch distances, the laser beam strikes more likely processed material or the base material as described in e.g. Yadroitsev et al. (2011). This means that mostly material is re-melted and can form the high structure. At higher hatch distances, the layers become flatter but show irregularities. The height fluctuations may be caused by the different amounts of available powder material for each track as described by Volpp et al. (2019).

These observations show that it is crucial for processing to know the actual layer heights, since the layer height defines the powder amount that will be applied for the following layer and will thereby influence the part geometry.

4. Summary

Single-layer experiments of Selective Laser Melting were conducted producing several tracks next to each other at different hatch distances. It was observed that the layer geometry strongly depends on the hatch distance. It is important to note that although processing the single tracks of the layers with the same parameters, the layer height significantly varied. Surface tension and absorption effects may cause these differences. These observations can help to improve the part quality and processing efficiency.

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References

Krauss H, Zaeh MF. Investigations on manufacturability and process reliability of selective laser melting. Physics Procedia, 41, 815-822; 2013.

Ly S, Rubenchik AM, Khairallah SA, Guss G, Matthews MJ. Metal vapor micro-jet controls material redistribution in laser powder bed fusion additive manufacturing. Scientific reports, 7(1), 4085; 2017.

Matthews MJ, Guss G, Khairallah, SA, Rubenchik AM, Depond PJ, King WE. Denudation of metal powder layers in laser powder bed fusion processes. Acta Materialia, 114, 33-42; 2016.

Volpp J, Brueckner F, Kaplan AFH. Track geometry variations in Selective Laser Melting processes. Journal of Laser Applications (accepted); 2019

Yadroitsev I, Smurov I. Surface morphology in selective laser melting of metal powders. Physics Procedia, 12. Jg., 264-270; 2011.

Yadroitsev I, Bertrand P, Antonenkova G, Grigoriev S, Smurov I. Use of track/layer morphology to develop functional parts by selective laser melting. Journal of Laser Applications, 25(5), 052003; 2013.