Feature-based characterisation of evolving surface topographies in finishing operations for additive manufacturing

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Introduction

Finishing operations are applied to additively manufactured surfaces for a variety of reasons; support removal, part accuracy compliance, surface texture improvements [1]. Commonly ISO 25178-2 [2, 3] texture parameters are used to describe a change in topography. However, parameters do not address changes in a individual surface topographical formations (features). Surface texture measurement instruments are able to capture great detail on the surface so that, in theory, geometrical and dimensional information of surface features can be processed using algorithms for feature identification, extraction and quantitative characterisation. In this work, feature-based characterisation is used to investigate evolution of topography as a consequence of finishing operations on AM processes.

Methodology

The approach to investigate evolution of topography consists of the following steps:

- **Samples** - Titanium alloy (Ti-6Al-4V) and nickel super-alloy (Inconel 718) samples were fabricated by EB-PBF (Arcam A2X) and L-PBF (Renishaw AM250). The blocks were built at multiple orientations.
- **Relocation landmarks** - Three slots were fabricated via micro-milling on each sample. Each slot is shaped as a (1.0 × 0.5) mm rectangle with rounded corners and 300 µm depth. The slots are arranged as shown in Figure 1.
- **Measurement strategy** - A focus variation microscope [4] (Alicona IF G5) was used to measure the surfaces. A (5 × 5) mm stitched measurement area was acquired to include both the relocation landmarks and a sufficient evaluation area (figure 1). Measurements performed before and after the finishing operations with the same set-ups. Relocation was performed in Digital Surf MountainsMap [5] using the landmarks as fiducials.
- **Finishing operations** - Finishing parameters shown in Table 1 were used.
- **Feature based evaluation of surface topography** - After alignment, custom algorithms were applied to identify and isolate relevant features on the AM as-built and finished surface. Feature attributes, such as number of instances, footprint area and volume were computed as indicators of topography evolution.

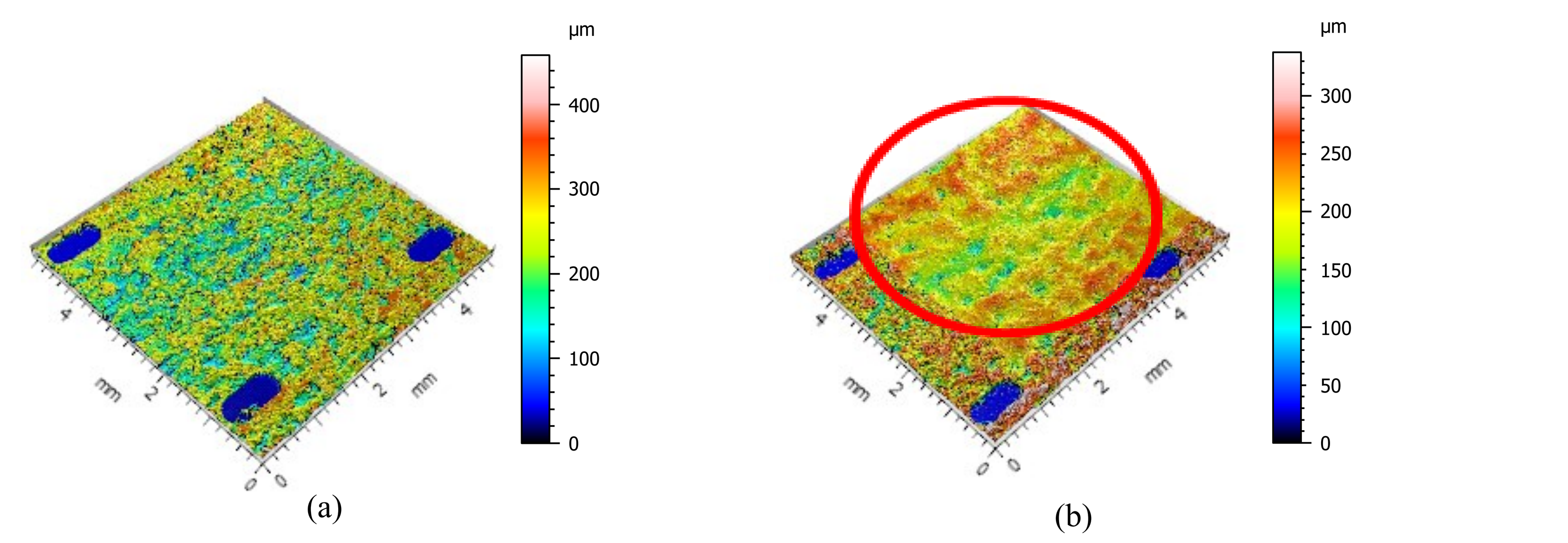

Figure 1: Measured surface before (a) and after (b) shot peening showing the slots acting as relocation landmarks and the shot peened region (b – red circle).

Finishing operation	Key parameters and values
Shot peening	ASH110 cast steel shot approx. 280 µm Ø, Almen intensity 0.2 mm to 0.25 mm A, 200% coverage, 0° impact angle
Linishing (grinding)	P80 grit flap wheel , 100 mm/s spindle speed, 0° attack angle, 12 N contact force, 3 passes
Laser Polishing	500 W 1090 nm laser, 350 µm spot size, 225W laser power, 30 µm hatch, 500 mm/s scan speed, 0° angle from nominal, argon shielding

Table 1: Finishing parameters

Results

The extracted regions of various EB-PBF titanium alloy surfaces at different build orientations can be seen in Figure 2.

Pre- and post- finished surfaces possess features as a result of the build process (top surfaces - weld tracks; side surfaces - adhered particles) or the finishing operation (linished - directional tool marks; laser polishing - laser weld tracks; shot peening - surface craters).

Spatter features were algorithmically identified (Figure 3) for an as built (Figure 3-a) and shot-peened (Figure 3-b), 30° angled titanium EBM surface. The feature-based analysis allows to track both the instances that underwent modification as a consequence of the finishing operation, and those that survived the process basically unchanged. Evolution of the surface can be shown by overlaying the original identified features on the post-finished surface (Figure 3-c).

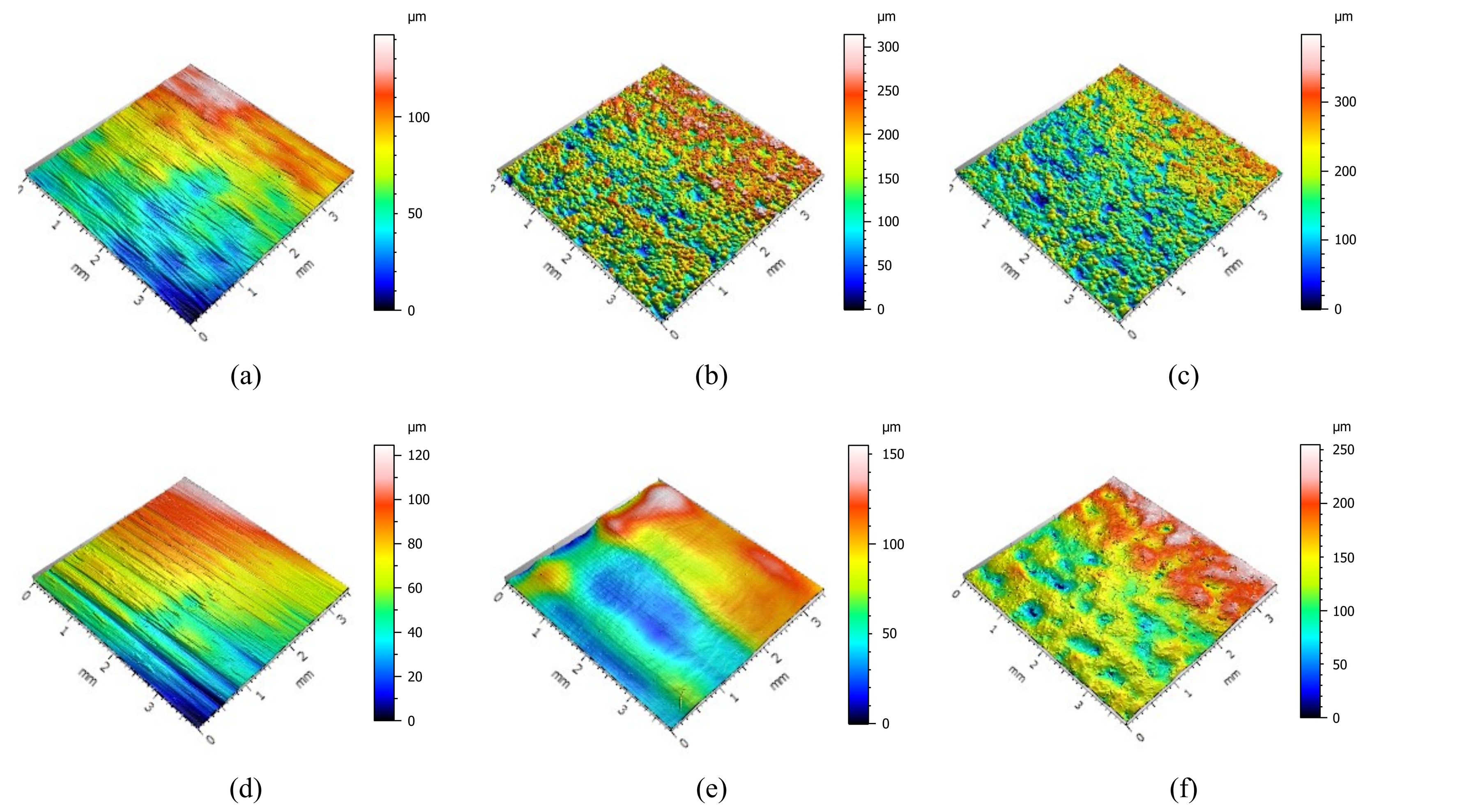

Figure 2: Aligned and extracted (3.79 × 3.5) mm regions of the titanium EBM surfaces before and after finishing. As-built top surface (a) and corresponding linished surface (d), as-built side surface (b) and corresponding laser polished surface (e), and as-built side surface (c) and corresponding shot peened surface (f).

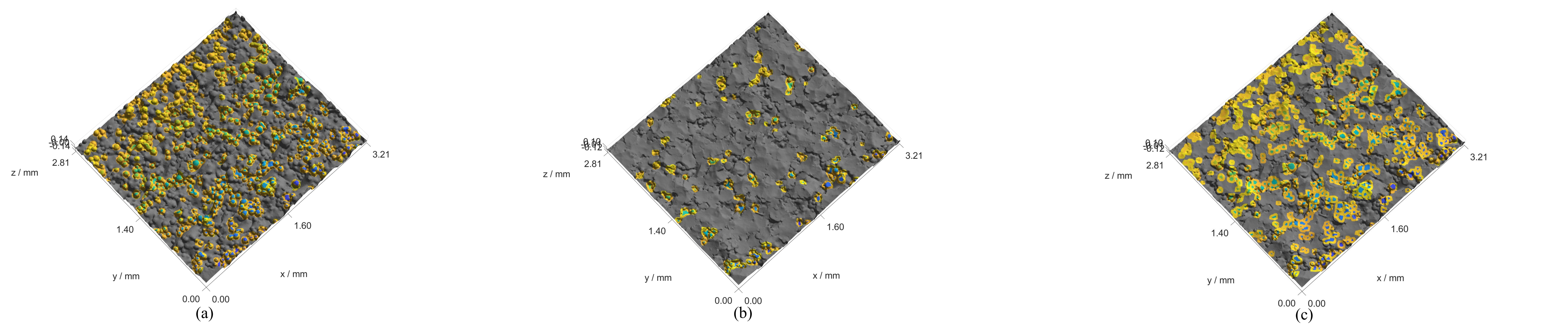

Figure 3:Identified spatter formations in the as-built surface (a) and surviving unaltered the finishing operation (b), overlaid identified spatter formations from the as-built surface on the finished surface (c).

Future work

An original method has been presented for the investigation of evolving topographies as a consequence of finishing operations. The method has been applied to AM parts. The method is based on combining topography registration based on fiducials, with feature-based characterisation for the identification of relevant topography formations, and to track how they change as a consequence of the finishing operation. Further work will apply this methodology to other finishing operations, AM processes and orientations to offer further understanding of the evolution of the features on the AM surface.

References

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Acknowledgements

The authors would like to acknowledge the support provided by the (Grants EP/ L01534X/1 and EP/M008983/1), the Manufacturing Technology Centre (Flex finish project), and Ben McGrory of Sandwell UK Ltd.