Laser polishing - enhancing surface quality of additively manufactured cobalt chrome and titanium components

EPSRC Centre for Innovative Manufacturing in LASER-BASED PRODUCTION PROCESSES

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Introduction

Additive manufacturing (AM) techniques are growing in popularity due to the freedom of design and added functionality of the manufactured parts. Unfortunately the as-built parts need further post-processing to have sufficient surface finish for majority of the application. Laser polishing presents an interesting approach to be used for post-process of AM part.

Experimental procedures

Laser used for polishing was SPI fibre laser redPOWER R4:

- Near IR,
- Max Power output 400W,
- CW mode,
- 400 µm spot diameter.

Samples were placed in a gas cell filled with inert gas – Argon.

Samples were analysed using Alicona InfiniteFocus surface profilometer (ISO 11562/25178/1278).

Beam was scanned across the sample surface using a galvanometer scan head.

Cylindrical samples were mounted on a rotary stage.

Few different scanning patterns were tested:

- Raster scan with alternating direction - 0°, 0°, 0°, 0°,
- Perpendicular scanning directions - 0°, 90°, 0°, 90°,
- Scanning with increasing angles - 0°, 45°, 90°, 135°,
- Scanning imitating halftone printing - 18°, 72°, 0°, 45°.

http://www.spilasers.com/

Motivation

- Simplify the process of improving poor surface quality of as-built AM parts by means of laser polishing
- Currently used abrasive and chemical methods have their drawbacks:
  - Mechanical polishing can be difficult to achieve on complex surfaces.
  - Electro-chemical polishing is a non selective-process.
- Laser polishing offers:
  - Short process duration,
  - High repeatability,
  - Selective polishing – different parts of a surface can have different surface finish,
  - No abrasives, liquids.

Laser based polishing

The laser polishing process is based on melting and subsequent solidification of a micro-layer of material, using a scanning laser beam as the heat source for a smooth topography.

Depending on the character of laser radiation there are two different regimes of laser polishing:

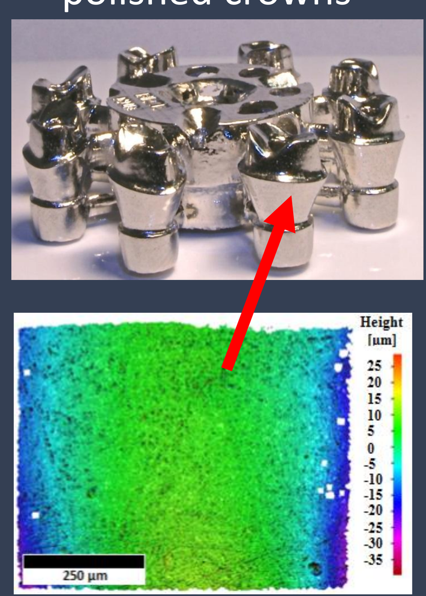
- Macro polishing – CW laser radiation
  A continuous melt pool is created with remelting depth usually between 20 and 200µm.
- Micro polishing – pulsed laser radiation
  Melt duration is significantly shorter with remelting depth usually below 5 µm and larger scale features become unaffected.

CoCr

Application – Dental implants

- A more selective process would allow for the simplification of the post-processing of dental implants.
- Currently dental implants are electrochemically polished and require further processing to reintroduce roughness to the top part of the implant, where the crown is glued.

Electrochemically polished crowns

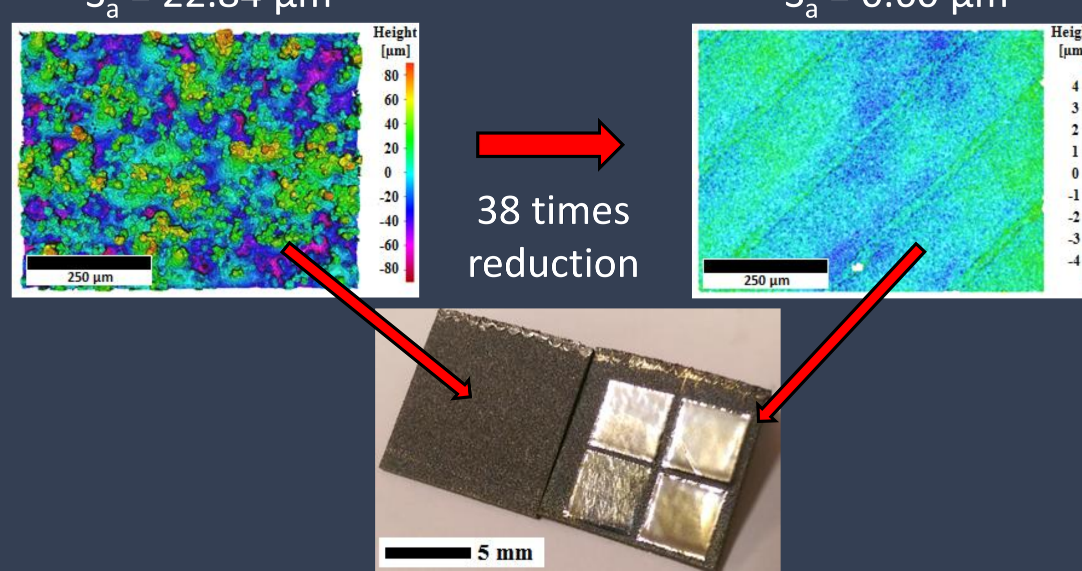


http://www.renishaw.com/

Crown retaining part
Roughness reintroduced to allow successful bonding of the crown

Surface in contact with the gum
Need to be smooth enough to prevent bacteria growth

S_a = 22.84 µm   38 times reduction S_a = 0.60 µm

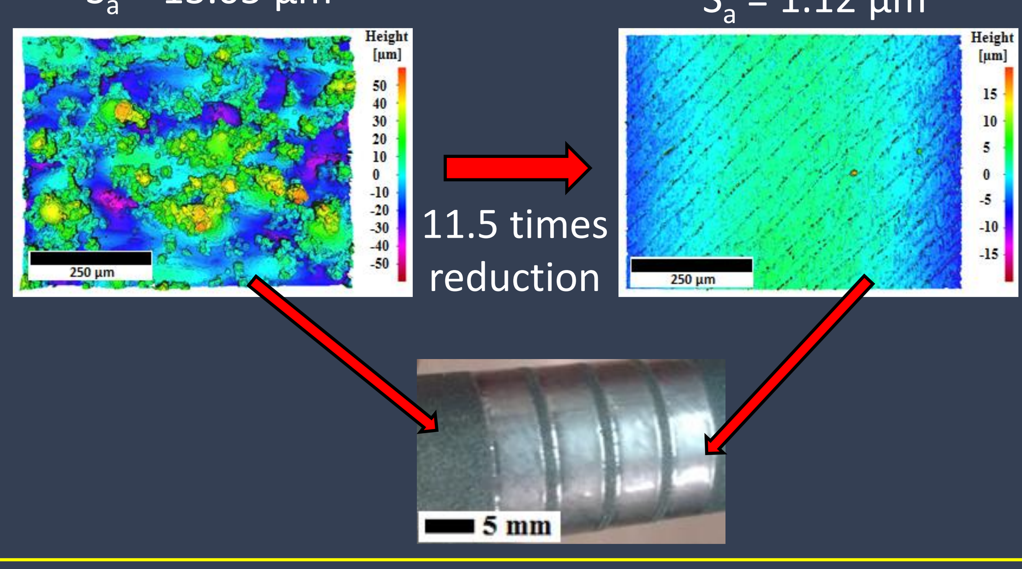


Flat surface

- Achieved processing speed up to 0.33 mm²/s.
- Up to 38 times reduction surface roughness reduction (S_a).
- Halftone printing scanning pattern was used (18°, 72°, 0°, 45°).

Cylindrical surface

S_a = 13.05 µm   11.5 times reduction S_a = 1.12 µm



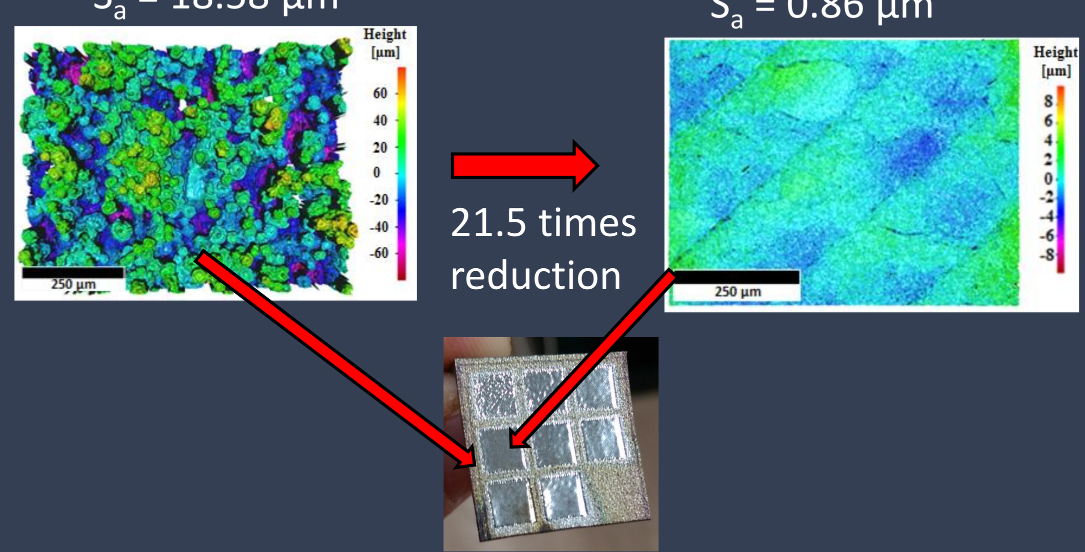
- Achieved processing speed up to 0.33 mm²/s.
- Up to 11.5 times reduction surface roughness reduction (S_a).
- Halftone printing scanning pattern was used (18°, 72°, 0°, 45°).

Ti6Al4V

Application – Cranial implants

- A quicker and more flexible process of post-processing would be beneficial for in the production of titanium cranial implants
- Current process is composed of many complex and time consuming stages to prepare final product.

S_a = 18.58 µm   21.5 times reduction S_a = 0.86 µm



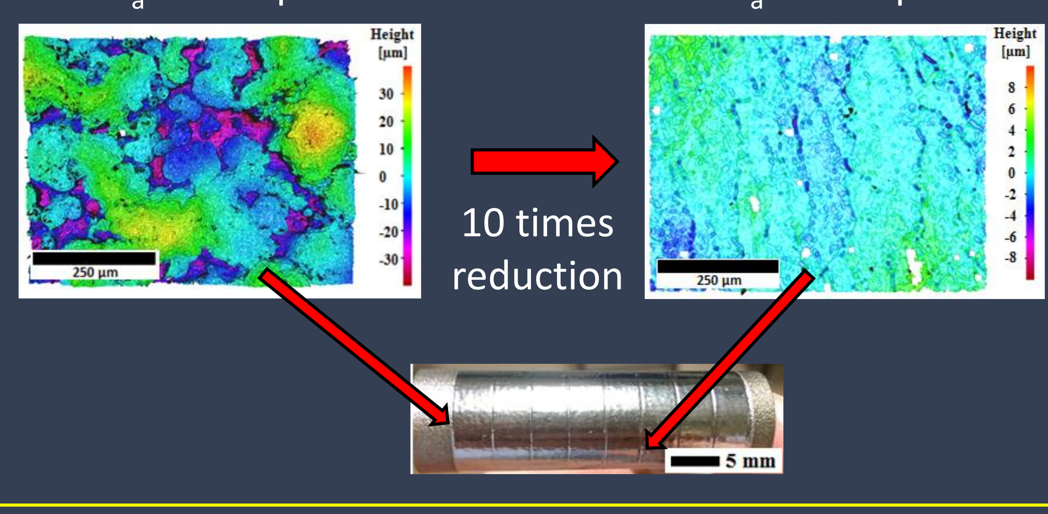
Flat surface

- Achieved processing speed up to 0.5 mm²/s.
- Up to 21.5 times reduction surface roughness reduction (S_a).
- Halftone printing scanning pattern was used (18°, 72°, 0°, 45°).

Cylindrical surface

- Achieved processing speed up to 0.5 mm²/s.
- Up to 10 times reduction surface roughness reduction (S_a).
- Halftone printing scanning pattern was used (18°, 72°, 0°, 45°).

S_a = 8.41 µm   10 times reduction S_a = 0.87 µm



Conclusions

- Laser polishing (CW) of additively manufactured Ti6Al4V parts can provide up to an 21.5 times reduction of surface roughness (S_a) for flat samples and up to 10 reduction of cylindrical samples.
- For additively manufactured CoCr parts, laser polishing (CW) can provide up to 38 times reduction for flat surfaces and up to 11.5 times reduction for cylindrical surface.
- Scanning pattern imitating halftone printing angles worked best due to various angles being used (18°, 72°, 0°, 45°).
- The main difference between achieved factors of improvements between flat and cylindrical surfaces is mainly due to the different initial surface roughness. And the beam being out of focus when scanning across the cylindrical part.
- Achieved surface roughness for polishing of CoCr is lower when compared to electrochemical polishing – S_a 0.60 µm vs 2.14 µm.

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