Characterisation of pores in additively manufactured Ti by serial FIB sectioning

Jo Sharp[1], Jack Donoghue[2], Samuel McDonald[3], James Carr[4], Samuel Tammas-Williams[5], Iain Todd[1], Phil Withers[2]

[1]University of Sheffield, UK [2]University of Manchester, UK [3]Lund University, Sweden [4]Blue Scientific Ltd, UK [5]Liverpool John Moores University, UK

Repair of Ti aero engine parts by additive manufacturing from powder is an extensively explored field. Fractography shows that pores are a common initiation site for fatigue failure, producing fatigue behaviour not up to the standard of forged material. Pores are introduced through various routes and their contents depends on their creation method. A common strategy to remove pores after part building is hot isostatic pressing (HIP). Small molecules such as hydrogen and water (from material absorbed on powder particles) will re-dissolve in the metal and those pores will disappear; pores of Ar (from hollow powder particles or from melt pool turbulence) will shrink during HIP. Ti alloys, however, require a heat treatment to fulfil other mechanical, and during this, the Ar pores regrow. We aimed to find out whether Ar pores regrow spherical, or in a faceted shape in response to the crystal structure around them.

We found a pair of pores in a sample of electron beam additive manufactured Ti-64 using a combination of X-ray computed tomography and FIB fiducial grid creation. A 100μm cube containing the pores was lifted out and serial sectioned, using slices of 300 nm thickness and taking electron back scattered diffraction (EBSD) maps at each slice. Reconstruction was first attempted using the Euler angle data, but the dataset was too large and the orientation spread within a grain too great. Instead, the inverse pole figure maps were aligned and segmented using FEI's Avizo to produce a dataset of grain "colours".

The two pores were in the same prior β grain and with almost identical, heavily faceted shapes (see figure). One was at a boundary of several α grains. The orientation of each grain was then extracted directly from the EBSD data files, transformed, then added to the 3D model, using a unit cell proportioned hexagon to visualise the crystal orientation for each α-Ti grain. Pore facets were found to correspond to low index planes in the prior β grain; some facets were also low index planes in the surrounding α grains, but not always the grain they faced into. This suggests the pores were participants in the β -> α transformation and affected the resulting microstructure; the α grains were off the classical Burgers orientation relationship to the β, especially around the boundary pore. The effect of the pore's faceted shape on the stress intensity factor was modelled roughly and found to increase it by 1.6 times.

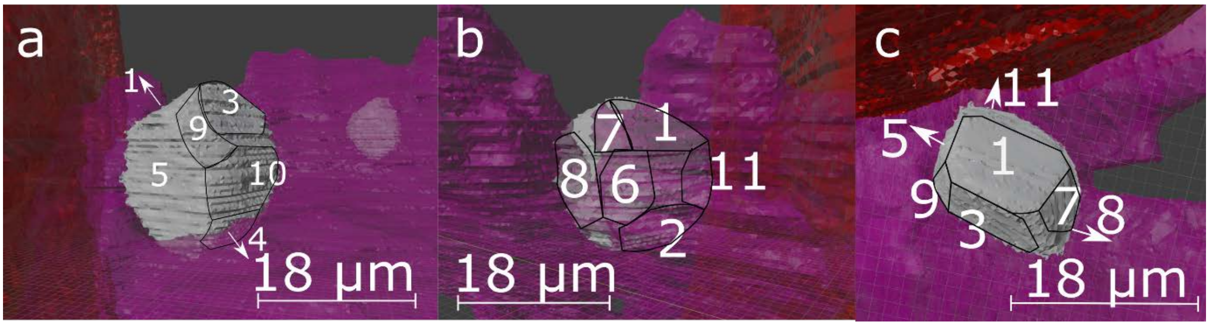

Figure 1 Pore on boundary of multiple α grains, showing facets. Those not in the magenta or red grains are in the largest α grain, set invisible here to enable visualisation.