Mircotexture effects on the properties of aerospace Titanium (Ti) forging.

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There is environmental pressure from the EU to reduce the carbon footprint of aircrafts, which is achievable through a reduction in their weight. Modern aircrafts are manufactured with an increasing amount of carbon fibre reinforced polymers, more commonly known as "c*arbon fibre"*, and Ti to replace some of the aluminium (Al) content. Ti is used because of its light weight, high strength and good corrosion resistant properties in many areas of the aircraft, such as the airframe and the cool areas of the jet engine. Some types of Ti can withstand temperatures up to around 600°C. Ti is more compatible with carbon fibre than Al & carbon fibre in terms of thermal expansions and 'galvanic coupling' which is a type of corrosion caused by the electrostatic nature of the two materials.

Ti alloys are made up of small crystals known as 'grains'. The size, shape and orientation of the grains, which is described as the microstructure, affects the way the alloy behaves. Small, round, randomly orientated grains give the alloy isotropic properties, which means the properties are the same in all directions, which for many applications is very important. The shape of the grains depends on how the component is produced. Metallic components can be cast, where the liquid metal is poured into a mould of the final shape, or they can be forged, where the material is worked after casting. A cast microstructure is made of many large grains and does not have the required properties for application in aerospace structures. The high pressure from the forging breaks up the grains and reshapes them into smaller, spherical shaped grains, which improve the material's properties. On annealing, this process sometimes produces one or two abnormally large grains: where normally grains are around 0.5-2mm, these grains can grow to around 10 times the size to 1-2cm in diameter.

Metal components fail by fatigue, which is where failure occurs from loading under repeated stress cycles, at a value lower than the strength of the material. This is the same mechanism that causes metallic components to fail in our everyday lives, from bicycle spokes to alloy wheels. All metallic components are susceptible to fatigue failure when loaded, but since failure in aerospace components cannot be tolerated, components are tested so that for a set load it can withstand a certain number of cycles (miles flown by the aeroplane). However, it is not fully understood how the presence of abnormal grains can affect this fatigue life, and because they only occur rarely, it is not feasible to run a complete test programme.

In my PhD project, which is sponsored by the EPSCR: https://epsrc.ukri.org/ and AIRBUS: https://www.airbus.com/ and is a part of the LightForm research group: https://lightform.org.uk/. I will investigate the effect of abnormal grains on the deformation and fatigue life of a alloy of Ti, Ti-6Al-4V which has approximately 90% Ti, 6% Al and 4% V by weight. A computational model will be created to provide an understanding of how the abnormal grains behave under fatigue loading. We will use the Düsseldorf Advance Material Simulation Kit (DASMASK, more information can be found: https://damask.mpie.de/), which is a hierarchical structured modelling software for crystal plasticity modelling. DAMASK can represent the physics of different magnifications and reproduce the microstructure, reflecting the history of how the part was produced. To make sure the model is representative, we will carry out state-of-the art deformation experiments on a small number of abnormal grain regions, using electron microscopy and diffraction.

This research will help us to better understand the deformation of abnormal grains and how they might behave in fatigue loading, but it can also be used to guide the optimisation of the microstructure and improvements to the fatigue strength of the material. Higher strength would enable the use of smaller parts, which reduces weight and improves fuel consumption, lowering the carbon footprint.

Further reading at:
https://www.sciencedirect.com/science/article/pii/S1359645420309174?dgcid=rss_sd_all