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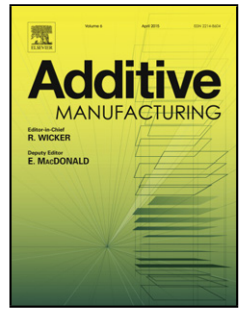

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Assessment of the effect of isolated porosity defects on the fatigue performance of additive manufactured titanium alloy

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Abstract

Studies on additive manufactured (AM) materials have shown that porosity reduces the fatigue strength. However, the quantitative impact is not well understood. This paper presents a mechanistic approach to quantify the influence of size, location and shape of gas pores on the fatigue strength of AM Ti-6Al-4V. Ideal spherical and oblate spherical pore geometries were used in the finite element (FE) analysis. The FE results showed a stress concentration factor of 2.08 for an internal spherical pore, 2.1 for a surface hemispherical pore and 2.5 for an internal oblate spherical pore. Subsurface pores within a distance of the pore diameter from the free surface were found to be most critical. The material's constitutive relation under the cyclic load was modelled by a mixed non-linear hardening rule that was calibrated with published literature on selective laser melted Ti-6Al-4V. The cyclic plasticity effect caused a local mean stress relaxation, which was found to be dependent on the pore geometry, the applied stress amplitude and the stress ratio. Fatigue life was predicted by using the FE calculated local strain amplitude and maximum stress in the strain-life relationship proposed by Smith-Watson-Topper. The methodology was validated by published literature with crack initiation at gas pores of known size, location, and shape. Parametric study showed that for internal pores, fatigue performance is more sensitive to the shape and location of the pore than the size. An S-N curve was proposed by the parametric study to account for the fatigue strength reduction due to internal gas pores.

Keywords: Porosity defects; stress concentration factor; additive manufactured Ti-6Al-4V; finite element modelling; fatigue life prediction.

1. Introduction

Additive manufacturing (AM) offers unprecedented design freedom, material savings and ease of process automation that makes it a key technology in the industry 4.0 revolution. Consequently, AM is being rapidly researched for industrial applications involving components made from nickel, titanium, stainless steel and aluminium alloys [1,2]. Particularly, aerospace applications require a high strength to weight ratio, and the use of AM processed titanium parts can potentially reduce the weight of the component to half of the conventionally machined component [3]. However, studies have shown that the process-induced defects in as-built AM parts have a detrimental influence on the fatigue performance [4–7]. These defects are of two types, (a) lack of fusion (LOF) defects, in the form of