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Influence of defect size on the fatigue resistance of AlSi10Mg alloy elaborated by selective laser melting (SLM)

Julius N. Domfang Ngnekou[a,b]*, Yves Nadot[a], Gilbert Henaff[a], Julien Nicolai[a], Lionel Ridosz[b]

[a]Institut Pprime UPR CNRS 3346, Department of Physique and Mechanics of Materials, ENSMA-Université de Poitiers, 1 avenue Clément Ader, Téléport 2, 86960 Chasseneuil-Futuroscope, France.
[b]Zodiac Aerospace, 61 rue Pierre Curie, 78370 Plaisir, France

Abstract

In the aircraft industry, Additive Manufacturing (AM) process is receiving more and more attention to produce parts with complex geometry and also leads to important weight reduction. Due to complex microstructure and the presence of defect both inherited from this specific process, it is necessary to assess the fatigue resistance of the material constitutive of manufactured parts prior to certification. This work is precisely tackling this issue with a special attention paid to the role of microstructural parameters and defects on fatigue life. With this aim, samples were built by a powder-bed process called SLM. Specimens were built with two configurations (0° and 90°) in order to evaluate the impact of the induced anisotropy of microstructure on fatigue properties. X-Ray 3D tomography was used to characterize defect population by their size. Microstructure is furthermore characterized by considering four characteristic scales **[1, 7, 12],** melt-pools, crystallographic grains, dendritic structure and the precipitates. The fatigue properties are determined by establishing S-N curves for as-built and heat-treated samples for R= -1. The defect size responsible for the fatigue damage initiation is determined in each sample so as to establish a relation between the fatigue limit and the defect size by means of Kitagawa type diagrams.
It is shown that the defect size is the first order parameter in terms of the fatigue resistance. Through the Kitagawa diagrams for as-built and heat treated samples, we quantify the improvement of the fatigue resistance due to the peak hardening treatment.

* Corresponding author.
E-mail address: julius.domfang@ensma.fr

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1. Introduction

Additive manufacture is considered to be a process that breaks with the existing ones, insofar as it offers, in particular, the possibility of producing parts with complex geometry and topographically optimized. In the aeronautical context, the realization of the parts requires the understanding of the fatigue behavior due to integrity of the material. So, the knowledge of the microstructure of the material so as the metallurgical defects inherited to the manufacturing process is therefore necessary in order to quantify the impact of each material parameter on the fatigue behavior of such parts. Thus it will be possible to tend towards the optimization of the process regarding the fatigue behavior. In this work, we are talking about a hypo eutectic aluminum alloy developed by the ALM process. Some studies have been carried out on the microstructural characterization and defects, as well as the anisotropy effects due to the direction of growth of the specimens in relation to the statics mechanical properties such as UTS, YS and Ef% **[1, 6].** Concerning the fatigue, Brandl et al **[2]** showed that anisotropy due direction of production is observable for the platform temperature of 30°C. According to the previous author by coupling a platform temperature of 300°C and a T6 heat treatment, no difference is visible anymore due to the direction of sample growth. Maskery et al **[8]** evaluated the impact of T6 treatment on fatigue performance for as built manufacturing surfaces; they work showed a significant increase in the fatigue limit due to T6 treatment. According to Aboulkhair et al **[1]**, the specimens machined from the T6 heat treated bars have a greater fatigue resistance. Few studies quantify the impact of defects on the fatigue limit. This study proposes to evaluate through the Kitagawa type diagrams the impact of defects size on the fatigue limit with and without T6.

Nomenclature

R	Load ratio
UTS	Ultimate Tensile Stress
YS	Yeld Stress
Ef%	Elongation to faillure
A	Basquin coefficient
σ_{D-1}^{ta}	The fatigue limit for alternating tension at R=-1 ratio
N_f	The number of cycle at failure
σ_n	The stress amplitude at the step n
σ_{n-1}	The stress amplitude at the step n-1
DAS	Dendritic Arm Spacing
SDAS	Secondary Dendritic Arm Spacing

2. Experimental approach

2.1. Material and samples

Two distinct productions of AlSi10MgSi by SLM, noticed P1 and P2, were considered in the present study.
Firstly, a PHENIX PM100 developed by 3D SYSTEMS was used for the P1 production using TLS powder. This machine is equipped with a 200W fiber laser YAG. The layering is done by means of a roller. All P1 specimens have been removed from XY bars built on an aluminum platform at 200°C. In order to relax the stress due to the process, a post processing heat treatment have been performed during one hour at 160°C. The P1 specimens were tested on a rotative bending machine. The results of the P1 production tests were analyzed and used as a reference for the study.