Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 7 (2017) 84–91

Structural Integrity Procedia

www.elsevier.com/locate/procedia

3rd International Symposium on Fatigue Design and Material Defects, FDMD 2017, 19-22 September 2017, Lecco, Italy

Experimental Evaluation of Fatigue Behaviors and Tensile Properties of Selective Laser Melted K536 Alloy at Elevated Temperatures

R.D. Xu[a], Z.H. Jiao[a], H.C. Yu[a] *

[a]*Aviation Key Laboratory of Science and Technology on Materials Testing and Evaluation, Science and Technology on Advanced High Temperature Structrual Materials Laboratory, Beijing Key Laborotory of Aeronautical Materials Testing and Evaluation, Beijing Institute of Aeronautical Materials, Beijing 100095, China*

Abstract

Additive-manufacturing techniques show more and more utilization potentialities in today's aviation industry. In order to ensure safe operation of additive-manufactured parts, it is important to have their mechanical properties well-characterized and assessed. In this study, elevated temperature fatigue behaviours and tensile properties of a selective laser melting (SLM) fabricated K536 alloy are investigated for horizontal and vertical building orientation, respectively. A series of tensile tests at 20 ºC ~700 ºC temperature range and stress-controlled fatigue tests at 400^{o} C and 600^{o} C are conducted. Effects of building orientation and temperature on tensile and fatigue behaviours are analysed. Scanning Electron Microscopy (SEM) is used to examine the fracture surfaces of fatigue specimens to qualify the failure mechanism and crack initiation sites. K536 parts manufactured via SLM are shown to exhibit anisotropic tensile properties at different testing temperatures. Anisotropy of fatigue properties is not obvious at 400^{o} C and 600^{o} C. Cracks are likely to initiate at the surface sliding or subsurface crystallographic plane of fatigue specimens in middle life regime and at subsurface or central zone crystallographic plane in longer life regime. In shorter life regime, cracks are easy to initiate at un-melted zones of fatigue specimens.

* Corresponding author. Tel.: +86-10-62496718; fax: +86-10-62496733.
E-mail address: yhcyu@126.com

2452-3216
10.1016/j.prostr.2017.11.064

Keywords: Additive manufacturing; Selective Laser Melting; K536; fatigue behavior; tensile

1. Introduction

Additive manufacturing (AM) allows for the layer-by-layer fabrication of components via sequential material deposition, based on discrete-collecting principle [1][2]. Components and structures with a complex shape could be manufactured quickly and accurately using AM technology, helping reduce the manufacturing procedure and shorten the processing period. This layer-wise production technique has evolved rapidly in recent year and it is of immediate interest in many applications, in particularly aviation field. As one method for the AM of metals, selective laser melting (SLM) selectively melt successive layers of powder by the interaction of a high energy density laser beam. All of these layers are fabricated atop horizontal substrates (or build plates) in parallel [3].

Much research has focused on the microstructures of the AM metals, which may differ from the ones of bulk material. It is clear that the inner-defects and building orientations evidently influence the mechanical properties of AM metals, especially tensile and fatigue strength. Contrasting the mechanical properties tests of specimens, which axis is parallel with the substrates (in X-orientation), with the ones of the specimens vertical to the substrates (in Z-orientation), it is apparent that the tensile and fatigue properties are influence by the building orientations [4]. In general, the tensile strength and fatigue resistance of X-orientation specimens are better than Z-orientation specimens. Besides, there are microstructures with anisotropy in AM metals, due to high temperature gradients leading to rapidly solidified, which could result in defects such as pores and inclusions. The shape, size, location and quantity of defects have influence on fatigue properties with various degrees, leading to the increase in the scatter of fatigue properties [5].

K536 is a kind of solid solution strengthening superalloys, which is similar to Hastelloy X, based on Ni-Cr-Fe [6][7]. K536 is widely used in the production of components in the combustor of aero-engines, due to its well corrosion resistance, anti-oxygenic property and high strength at elevated temperatures. There is a great need for the investigation of mechanical properties of AM K536 alloy, which is still blank now.

This study investigated the tensile and fatigue behaviours of SLM K536 specimens which were fabricated in two different building orientations. Then, it was followed by the observation and analysis of fatigue fracture surfaces. By doing this, it was possible to contrast the difference in the distribution of defects in two building orientations and to evaluate its effect on the initiations and propagations of cracks. The fatigue behavior of SLM K536 could be characterized at the last.

Nomenclature

N_f	fatigue life cycle
R	stress ratio
E	modulus of elasticity
$\sigma_{0.2}$	yield stress
σ_b	ultimate tensile stress
σ_{max}	maximum stress
σ_m	mean stress
T	temperature
K_t	coefficient of stress concentration
EL	Elongation to Failure
r	Correlation coefficient

2. Experimental procedure