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ScienceDirect

Procedia Engineering 160 (2016) 143 – 150

Procedia Engineering

www.elsevier.com/locate/procedia

XVIII International Colloquium on Mechanical Fatigue of Metals (ICMFM XVIII)

Fatigue performance of hybrid steel samples with laser sintered implants

L.M.S. Santos[a], J.A.M. Ferreira[a], J.D. Costa[a], C. Capela[a,b]*

[a] *CEMUC, University of Coimbra, Department of Mechanical Engineering, Rua Luís Reis Santos, 3030-788, Coimbra, Portugal.*
[b] *Instituto Politécnico de Leiria, ESTG, Department of Mechanical Engineering, Morro do Lena – Alto Vieiro, 2400-901 Leiria, Portugal.*

Abstract

Laser sintering metal has recently been used in the manufacture of metallic structural hybrid components comprising two different materials obtained by two distinct technological processes. This process allows to obtain productivity gains reducing sintering time and hence the cost. In current study it was used a machined substrate in which it is built by sintering the remaining part. The purpose of present work was to study the effect of the substrate material and interface microstructure on the fatigue performance under constant and variable block loadings. The sintering laser parts were manufactured in maraging steel AISI 18Ni300, while the substrates of hybrid specimens were produced alternatively in two materials: the steel for hot work tools AISI H13 and the stainless steel AISI 420. Fatigue strength will be quantified in terms of S - N curves. The results show that tensile properties of sintered specimens and of the hybrid parts was similar. Fatigue strength for short lives, of the sintered specimens and hybrid parts was quite similar. However, the fatigue strength of hybrid parts tends to decrease, for long lives, when compared with single sintered specimens. The fatigue tests under block loadings leads to indicate that the application of Miner's law is adequate to predate fatigue life in hybrid components with sintered implants, despite having been observed a tendency to be conservative for long life.

Peer-review under responsibility of the University of Oviedo

Keywords: Laser sintering metal, Fatigue, Block loadings, Functional materials;

1. Introduction

Selective laser melting (SLM) is a laser based rapid manufacturing technology that builds metal parts layer by-layer using metal powders and a computer controlled laser. According, Abe et al. [1] and Santos et al. [2] a high power laser

* Corresponding author. Tel.: 351 244 820 300.
E-mail address: ccapela@ipleiria.pt

Peer-review under responsibility of the University of Oviedo
doi:10.1016/j.proeng.2016.08.874

is used to fuse metallic powder particles, doing a scan of the transversal cross sections of the final component generated from a CAD model. Laser energy and scan speed must be adequately combine in order to continuous melting. The delivered energy produced continuous molten tracks by means of the complete melting of the powder, leading to coherent sintered tracks after solidification. This technique is increasingly used in automotive, aerospace, medical and of injection molds industries, to obtain components with complex shapes. Abundant literature has been previous reported on the scope of SLM using different metal powders, for instance, Simchi et al. [3] and, Kruth et al. [4] use iron-base alloys, Mumtaz et al. [5] nickel-base alloys, Gu et al. [6] copper-base alloys, Osakada et al. [7] titanium-base alloys.

SML products could show characteristic cast structure, with high superficial roughness, presence of porosity, heterogeneous microstructure and thermal residual stresses, resulting in mechanical properties which can be improved by additional post-processing treatments. Since SML can be used to manufacture functional components, it is essential a good characterization of the sintered parts to control final integrity of the parts, and to warranty that the components fulfill final functional requirements. As indicated by Simchi et al. [8] both powder characteristics (e.g., particle shape, size and its distribution, and component ratio) and processing parameters (e.g., laser power, scan speed, scan line spacing, and powder layer thickness) influence the densification level and the attendant microstructures of SLM-processed materials. Mechanical properties of sintered components are mainly affected by parameters, such as: porosity, surface roughness, scan speed, layer thickness, and residual stresses. A major drawback was obtained by Shiomi et al. [9], Murr et al. [10], Gorny et al. [11] and Vilaro et al. [12], consequence of the occurrence of pores originating from initial powder contaminations, evaporation or local voids after powder-layer deposition, which act as stress concentrators leading to failure. Especially effect was found by Brandl et al. [13] under fatigue loading.

The focus of this work is to produce and investigate the fatigue performance of hybrid specimens obtained by sintering laser of maraging steel implants into hot working tools and stainless steels substrates. The fatigue tests under constant amplitude and block loadings were carried out. Failure mechanisms and interfaces microstructures were detailed analysed.

2. Materials and testing

Experimental tests were performed in round specimens with the geometry and dimensions shown in Fig. 1. A high power laser was used to fuse steel powder particles layer by-layer in axial direction Fig. 1a). Two types of samples were prepared: single sintered specimens (all specimen is done by laser sintering technique) and two materials hybrid samples, in which one half part is an implant made laser sintered steel powder deposed on other half part machined substrate in other steel (as shown in Fig.1b). Powder particles to produce sintering laser parts was the maraging steel AISI 18Ni300, while the substrates of hybrid specimens were machined alternatively in two materials: the steel for hot work tools AISI H13 and the stainless steel AISI 420. Geometry and dimensions of the specimens are indicated in Fig. 1c). Table 1 show the chemical composition of the three materials, according with the manufacturers. Table 2 show the material design composition of the three materials compositions used in present study.

Table 1. Chemical composition of the materials.

Steel	C	Ni	Co	V	Mo	Ti	Al	Cr	P	Si	Mn	Fe
18Ni300	0.01	18.2	9.0	-	5.0	0.6	0.05	0.3	0.01	0.1	0.04	Balance
1.2344	0.40	-	-	0.94	1.30	-	-	5.29	0.017	1.05	0.36	Balance
1.2083	0.37	-	-	0.17	-	-	-	14.22	0.021	0.64	0.37	Balance

The samples were synthesized by Lasercusing®, with layers growing towards the application of load on the mechanical tests. The equipment for sintering is of the mark "Concept Laser" and model "M3 Linear". This apparatus comprises a laser type Nd: YAG with a maximum power of 100 W in continuous wave mode and a wavelength of 1064 nm. The samples were manufactured using the sintering scan speed of 200 mm/s. The test series are identified by the sample code followed by the scan speed.

The fatigue tests were carried out in tension at room temperature using a 10 kN capacity Instron EletroPuls E10000 machine, at constant amplitude and block sinusoidal load wave was applied with a frequency within the range 15–20