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Procedia Structural Integrity 1 (2016) 126–133

Structural Integrity
Procedia

www.elsevier.com/locate/procedia

XV Portuguese Conference on Fracture, PCF 2016, 10-12 February 2016, Paço de Arcos, Portugal

Assessment of the fatigue life on functional hybrid laser sintering steel components

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Abstract

Click here and insert your abstract text. The construction of hybrid parts: comprised of two different materials or obtained by two distinct technological processes is one of the main advantages of laser sintering metal. Various important aspects strongly affect the mechanical properties of sintering metal components: porosity, surface roughness, scan speed, layer thickness, and residual stresses. A major drawback is the occurrence of pores originating from initial powder contaminations, evaporation or local voids after powder-layer deposition, once these pores can act as stress concentrators leading to failure, especially under fatigue loading. The purpose of present work was to study the effect scan speed on the porosity and mechanical properties. Also the performance of two different material parts was studied. 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.
The results showed that a very high scan speed (400 or 600 mm/s) causes the appearance of high porosity percentages and consequent drastic reduction of tensile strength and stiffness. Tensile properties of sintered specimens and two different material parts was similar. However, the fatigue strength of two different material parts tends to decrease, for long lives, when compared with single sintered specimens.

Peer-review under responsibility of the Scientific Committee of PCF 2016.

Keywords: Laser sintering metal, Fatigue, Functional materials, Mechanical properties;

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2452-3216
Peer review under responsibility of the Scientific Committee of PCF 2016.
10.1016/j.prostr.2016.02.018

1. Introduction

Direct Metal Laser Sintering (DMLS) is a rapid manufacturing technology where a high power laser is used to fuse metallic powder particles, doing a scan of the transversal cross sections of the final component generated from a CAD model. After each scan a new powder layer is deposited and is subsequently laser sintered, until the entire component is manufactured. DMLS 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 DMLS 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. This technique is increasingly used in automotive, aerospace, medical and of injection molds industries, to obtain components with complex shapes.

The scientific and technical aspects of sintered microstructure on the mechanical properties have not been well studied and understood. DMLS sintered materials are usually anisotropic and heterogeneous (Khaing et al. (2001) and Simchi et al. (2006)), which affects the quality and performance of built parts. Earlier studies mainly focused on the influence of sintering parameters and selection of metal powder on microstructure of the sintered parts. Scarce information has been published on fatigue properties of laser sintered materials (Wang et al. (2006) and Leuders et al. (2013)) and particularly thermal fatigue (Wang et al. (2009)). Thermal fatigue cracking (or heat checking) is one of the most important failure mechanisms in hot working applications. The main reason for heat checking is rapid alternation of surface temperature, which induces high stresses enough to impose an increment of plastic strain (Persson et al. (2004)).

Various important aspects strongly affect the mechanical properties of sintered components, such as: the porosity, surface roughness, scan speed, layer thickness, and residual stresses. Internal stresses resulting from steep temperature gradients and the high cooling rates during the processing need also to be taken into account when evaluating the performance of parts manufactured from any metallic powder using selective laser melting process (Shiomi et al. (2004)). A major drawback is the occurrence of pores originating from initial powder contaminations, evaporation or local voids after powder-layer deposition (Murr et al. (2010), Gorny et al. (2011)), Brandl et al. (2012) and Vilaro et al. (2011)). Eventually, these pores act as stress concentrators leading to failure, especially under fatigue loading (Brandl et al. (2012)). At the moment these pore-like defects cannot be totally avoided, but with hot isostatic pressing (HIP) the reduction of pore size or even the closure of these can be achieved (Santos et al. (2004)).

Laser sintering metal originally destined for rapid prototyping has recently been used in the manufacture of metallic structural components. Also, the construction of hybrid parts: comprised of two different materials or obtained by two distinct technological processes is one of one the main advantages of this technique. The key idea of this project is to evaluate the parameters of the process in order to perform hybrid functional parts with optimized mechanical properties.

2. Materials and testing

Tensile static and fatigue tests were performed in round specimens with the geometry and dimensions shown in Fig. 1. Two types of samples were used: single sintered specimens (all specimen is done by laser sintering technique) and two materials hybrid samples, in which one part in made laser sintered steel and other part is a substrate machined in other steel (as shown schematically in Fig.1). 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. Table 1 shows the chemical composition of the three materials, according with the manufacturers. Table 2 shows the material design composition of the three types of samples used in present study.

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 speeds: 200, 400 and 600 mm/s.