VHCF response of Gaussian SLM AlSi10Mg specimens: Effect of stress relieve heat treatment

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Keywords: Selective Laser Melting (SLM); Very High Cycle Fatigue (VHCF); AlSi10Mg alloy; Heat treatment: Gaussian specimen.

ABSTRACT

In the last decades, the use of Additive Manufacturing (AM) techniques for the production of metallic components used in structural applications has rapidly increased. Among the AM techniques, Selective Laser Melting (SLM) is one of the most used, especially for Aluminum alloys as the AlSi10Mg alloy. SLM permits to manufacture parts characterized by very good quasi-static mechanical properties [1], that can even outperform those measured on parts manufactured with traditional subtractive technologies. Nonetheless, defects originating during the AM process (e.g., porosities induced by vaporization of light elements, incomplete melting of powder and residual oxide layers) may significantly affect the fatigue response of SLM parts. Therefore, High Cycle Fatigue (HCF) and Very High Cycle Fatigue (VHCF) can be critical and should be properly investigated to guarantee a safe and conservative design of SLM parts subject to fatigue.

According to the literature, the optimization of the process parameters and the proper design of the AM process (e.g., specimen orientation with respect to the building direction, heating of the building platform) can help to reduce the defect population and to enhance the fatigue response [2]. Moreover, the removal of the surface layer in AM parts has proved to improve the fatigue response [2] since superficial defects are generally more critical than internal ones [3]. Heat treatments could also affect the fatigue response, even if they do not permit to reduce the defect population. The effect of traditional heat treatments, which are usually applied to cast components, has been already investigated in the literature (for example the T6 heat treatment for the AlSi10Mg alloy in [2]). However, different heat treatments, specific for SLM parts, are being proposed by producers of SLM equipments and their effect on the HCF and the VHCF response is still under investigation.

The present paper compares the VHCF response of SLM AlSi10Mg specimens in two working conditions: as built and subjected to a standard heat treatment for stress relieve [4,5]. The heat treatment consisted of heating for two hours at 320°C and cooling in air down to room temperature. A significant increment of the material ductility was obtained after heat treatment: the elongation to failure (ε_f) was about four times the ε_f value of the non-treated material. Ultrasonic tests at 10^9 cycles were performed on SLM-built specimens (only a fine polishing is performed, according to [6]) before and after the heat treatment. To properly estimate the defect size distribution and to reliably assess the VHCF response [3], Gaussian specimens with large loaded volumes [7] were used for the ultrasonic tests. Fig. 1 shows the Gaussian specimen geometry used for the experimental tests.

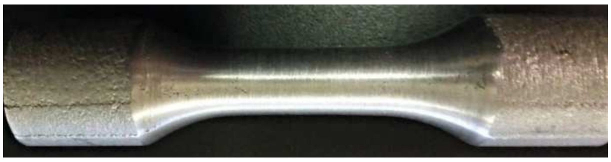

Fig. 1. Gaussian specimen used for the ultrasonic VHCF tests.

Fracture surfaces were investigated with the optical and the Scanning Electron Microscope (SEM) to assess the distribution of defect size. The fatigue strength at different number of cycles was statistically compared to assess the effect of the heat treatment on the VHCF response. The obtained microstructure and microhardness of heat treated and as built specimens were investigated and compared. Finally, a correlation among mechanical properties, microstructure and fatigue behaviour was proposed.

REFERENCES

[1] Kempen, K., Thijs, L., Van Humbeeck, J., Kruth, J.-P.: Processing AlSi10Mg by selective laser melting: parameter optimisation and material characterisation, Mater. Sci. Tech. Ser. 31:8, 917-923 (2015).

[2] Brandl, E., Heckenberger, U., Holzinger, V., Buchbinder, D.: Additive manufactured AlSi10Mg samples using Selective Laser Melting (SLM): Microstructure, high cycle fatigue, and fracture behaviour. Mater. Design 34, 159–169 (2012).

[3] Murakami, Y. Metal Fatigue: Effects Of Small Defects And Nonmetallic Inclusions. 1st ed. Elsevier Ltd, Oxford, UK (2002).

[4] Renishaw plc, Laser Meting: Aluminum AlSi10Mg_25mm_AM250-400W Parameter Validation, 2014.

[5] J. Fiocchi, A. Tuissi, P. Bassani, C.A. Biffi, Low temperature annealing dedicated to AlSi10Mg selective laser melting products, Journal of Alloys and Compounds 695C, 3402-3409 (2017).

[6] Tridello, A.: VHCF response of Gaussian specimens made of high-strength steels: comparison between unrefined and refined AISI H13. Fatigue Fract. Engng. Mater. Struct. 40(10), 1676–1689 (2017).

[7] Paolino, D.S., Tridello, A., Chiandussi, G., Rossetto, M.: On specimen design for size effect evaluation in ultrasonic gigacycle fatigue testing. Fatigue Fract. Engng. Mater. Struct. 37, 570–579 (2014).

ACKNOWLEDGMENTS

The Authors acknowledge the Piedmont Region Industrial Research Project STAMP (Sviluppo Tecnologico dell'Additive Manufacturing in Piemonte, MIUR – POR FESR 2014/2020 – Azione 3 Piattaforma Tecnologica "Fabbrica Intelligente") and Accordo Quadro CNR/Regione Lombardia n. 3866 del 17/07/2015 FHfFC for financial support, BeamIT for technical assistance.