Mesoscale Mechanical Performance of SLM Manufactured 17-4 PH

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Compliant mechanisms can achieve macroscopic linear or rotary motions without friction and wear, while ensuring extremely high fatigue performances [1]. Such compliant properties originate in the use of fine lamellas with thickness ranging from 100 um to 400 um, traditionally manufactured using Electrical Discharge Machining (EDM). With the design freedom offered by Selective Laser Melting (SLM), the printing of fine structures represents a field of growing interest, for which the impact of the process inherent high surface roughness on the mechanical properties is not yet clear, especially for mesoscale samples. In this study, we report on the fabrication and mechanical performances of such structures printed in 17-4 PH.

Selective Laser Melting (SLM) is an additive manufacturing process in which a laser selectively melts a powder bed, layer after layer, thus reconstructing a Computer Aided Design (CAD) file. Four process parameters are generally admitted as having the greatest impact on the process stability and part quality: the laser power, the laser scanning speed, the scanning strategy and the layer thickness [2]. To assess the mechanical properties of mesoscale SLM structures (400 um in this case, Figure 1), an optimization of the process parameters was carried out with the objective of reaching a high density part. The main steps are as follows: (1) definition of an appropriate process window; (2) measurement of the meltpool dimensions and corresponding hatch overlap; (3) iteration based on density measurement and minimum line width until a satisfactory density with respect to the bulk material is reached.

Once the process parameter window was optimized, a tensile structure with a 400 um wide reduced section was manufactured and tested on a CSEM developed mesoscale tensile machine. The classic tensile test curve is then reconstructed using the data of a high precision load cell and Digital Image Correlation performed on sample images captured during the test (Figure 1).

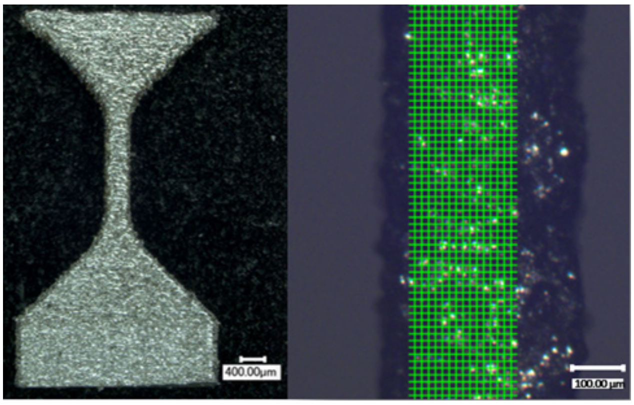

Figure 1: Image of the mesoscale tensile structure (left), grid used for the DIC on images recorded during the test (right).

The mesoscale mechanical property obtained (UTS) is presented after a solution annealing and age hardening (H925) and compared to the mechanical performance of SLM printed macroscale samples (tested according to ASTM E8/E8M). With an UTS of 1307 MPa (± 13 MPa) for the mesoscale sample and 1345 MPa (± 2 MPa) for the macroscale sample, no significant difference is measured between both sample sizes. When compared to conventionally manufactured macroscale tensile sample, the SLM printed structures, regardless of size have a slightly lower UTS (reference sample [3]: UTS=1379 MPa)

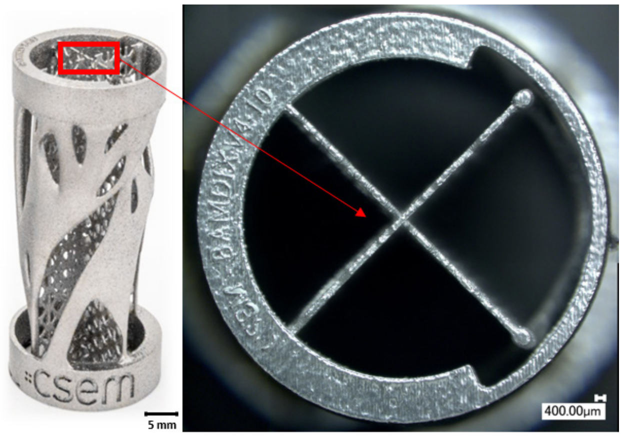

Figure 2: Lamellar pivot designed and manufactured at CSEM (left), 400 um wide interlocked compliant lattice (right).

In conclusion, a SLM process was developed for the manufacturing of thin wall samples (400 um) of 17-4 PH maraging steel. The UTS of 1307 MPa obtained for the mesoscale sample is comparable to that of macroscale parts, a result currently used for the design of compliant structures, such as lamellar pivots (Figure 2).

[1] L. L. Howell, S. P. Magleby, B. M. Olsen, eds. Handbook of Compliant Mechanisms. Wiley; 2013. doi:10.1002/9781118516485.

[2] J. P. Choi, G. H. Shin, M. Brochu, *et al.*, Densification behavior of 316L stainless steel parts fabricated by selective laser melting by variation in laser energy density. Mater Trans. 2016;57(11):1952-1959. doi:10.2320/matertrans.M2016284.

[3] MatWeb YS for MI. AK Steel 17-4 PH® Precipitation Hardening Stainless Steel, Condition A. Matweb. http://www.matweb.com/search/DataSheet.aspx?MatGUID=20362bbf0a7f45b8ae59b19a9425239e. Accessed September 23, 2019.