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CHARACTERISATION OF THE COLLAPSE BEHAVIOUR IN 3D PRINTED IN718 ALLOY UNDER A RANGE OF STRESS STATES AND STRAIN RATES

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1. Introduction

Nowadays, the additive manufacturing (AM) with favourable time- and cost-effective benefits and great net-shape production capability has claimed its position at the forefront of manufacturing technologies. With respect to the technical features, AM enables producing objects at various sizes and shapes, e.g. metallic foam called as the preform. The paper examines the ligament deformation and collapse modes, their effect on the behaviour of a highly porous random open cell lattice (HPROCL) in IN718 alloy produced by selective laser melting (SLM), identifying key stages of collapse, stability, and how the dynamic properties of the material influence the hardening behaviour of the HPROCL across the range of strain rates.

2. Materials and Methods

A Renishaw AM 250 SLM system with a Gaussian beam continuous wave (CW) laser (200 W power for set (A) and 175 W power for set (B), 70 µm spot size, and 1070 nm wavelength) was used to manufacture the HPROCL in IN718 test pieces [1]. All test pieces were printed alongside the HPROCL. The SLM parameters to fabricate the cubic test pieces of set (A) (default build parameters) used an energy density of 2.2 to 5.5 J/mm^2 for volume scanning and 0.6 to 3.1 J/mm^2 for the surface. In turn, the energy density applied to the fabrication of set (B) samples (modified design parameters) was from 1.9 to 4.9 J/mm^2) while for volume scanning of the surface from 4.5 to 6.4 (J/mm^2). All test pieces were stress-relieved on the build plate. The diameter of the ligaments in the lattice was typically from 0.4 to 1.2 mm, to give a volumetric porosity of 96% for a 25.4 x 25.4 x 25.4 cubic test piece, Fig. 1. Density measurements of samples was performed using Archimedes and computer X-Ray tomography (CT scan).

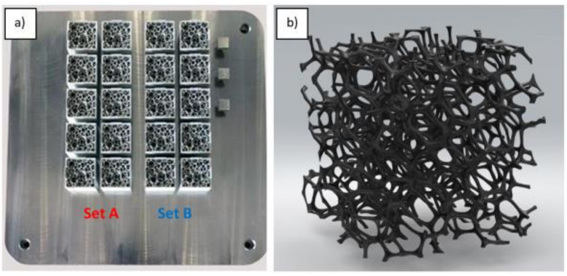

Fig. 1. SLM build record (a), HPROCL sample (b).

Testing of the lattice was performed in compression under quasi-static loading and high speed impact.

Static compression tests were carried out under displacement control with the rate of 0.025 mm/s. The load cell of the MTS testing machine was calibrated in the range of ±25 kN. The axial and transverse strain components were determined using two Aramis 12 M DIC systems positioned at the opposite corners of the cubic test specimen. Recording frequency for the image capturing was kept constant to be 2 Hz.

Dynamic compression tests were performed using the direct impact Hopkinson pressure bar (DIHPB) technique with the impact configuration enabling a large strain deformation of the specimen (up to densification in the case of cellular solids) [1], Fig. 2. During the test of IN718 foam specimen placed at the front of the 6.0 m long output bar was directly impacted by the striker bar of length and mass equal to 0.6 m and 4.76 kg, respectively (both made of C45). In order to record transmitted signals and determine force/stress on the specimen surface loaded, two strain gages were used. They were located 0.5 m from the front end of output bar. The positions of strain gages and the length of output bar were precisely chosen in order to avoid the wave superposition.

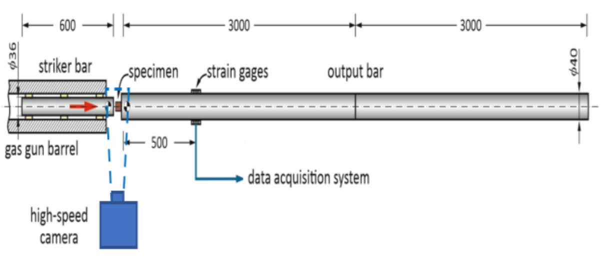

Fig. 2. DIHPB set-up.

Phantom V1612 high-speed camera was applied to measure the compression rate and to identify failure modes. Moreover, it enabled to confirm that the striker bar kinetic energy was sufficient to provide a near-constant compression velocity of the specimen up to a nominal strain of at least 0.5. High-speed video images were recorded with a resolution of 512×208 pixels and a frame rate of 110.000 fps. To ensure a high measurement accuracy based on the video images, a crush test markers and specialized TEMA Classic software were used. An impact velocity and deformation history of specimens were determined by a subtraction of the displacements between the projectile and output bar. Thus, the corresponding nominal strain can be calculated similarly to that of the quasi-static tests.

3. Results and Discussion

The results of first type test carried out under quasi-static loading are presented in Fig. 3.

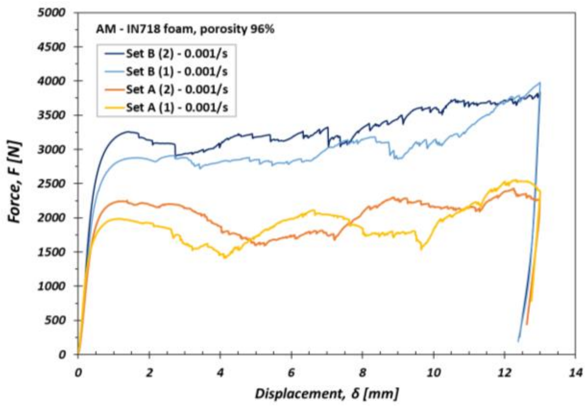

Fig. 3. Force-displacement curves for the specimens of set (A) and (B) under quasi-static loading.

The impact velocity during dynamic tests was varied slightly within the range from 7 to 12.8 m/s, which corresponded to the strain rate of 1100-1550 s^{-1}, approximately, Fig. 4.

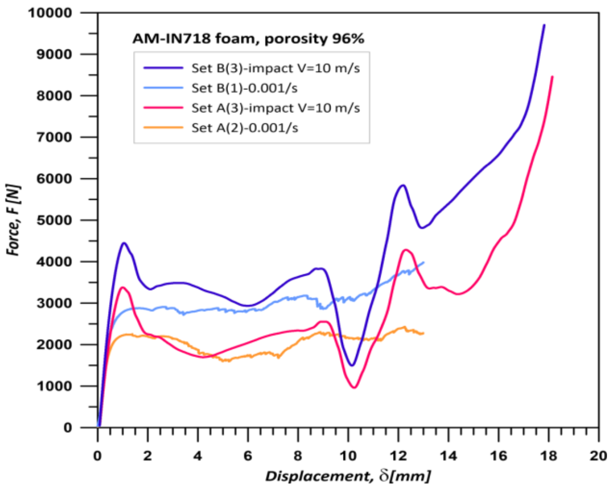

Fig. 4. Compressive behavior of set (A) and (B) under quasi-static and dynamic loading.

IN718 is well known for its outstanding mechanical properties due to precipitation strengthening, however, the Laves phase, that may appear in some cases (e.g. caused by shorter exposure time of laser power), are generally confirmed to be responsible for mechanical properties deterioration [3]. Based on SEM-EDS analysis carried out on the tested specimens, one can to conclude that much less Laves phases occur in set (B) than in (A). Moreover, set (B) is characterized by a higher amount of the δ-phase which leads to an increase either static or dynamic compressive behaviour of the HPROCL in IN718 alloy produced by SLM with modified build parameters (set B).

Acknowledgments

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