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THE INFLUENCE OF BUILD PARAMETERS ON THE COLLAPSE BEHAVIOUR OF A HIGHLY POROUS RANDOM OPEN-CELL LATTICE 3D PRINTED IN IN718 ALLOY

Tomasz LIBURA[1], Judyta SIENKIEWICZ[2], Zdzisław NOWAK[3], Zbigniew L. KOWALEWSKI[4], Alexis RUSINEK[5], George Z. VOYIADJIS[6], Urvashi GUNPUTH[7], Paul WOOD[8]

[1] 0000-0003-0526-8973 Institute of Fundamental Technological Research, Pawińskiego 5B, 02-106 Warsaw, Poland. E-mail: tlibura@ippt.pan.pl

[2] 0000-0001-5372-1862 Faculty of Mechatronics, Armament and Aerospace, Military University of Technology, ul. Gen. S. Kaliskiego 2,00-908 Warsaw, Poland. E-mail: judyta.sienkiewicz@wat.edu.pl

[3] 0000-0003-4441-5112 Institute of Fundamental Technological Research, Pawińskiego 5B, 02-106 Warsaw, Poland. E-mail: znowak@ippt.pan.pl

[4] 0000-0002-8128-0846 Institute of Fundamental Technological Research, Pawińskiego 5B, 02-106 Warsaw, Poland. E-mail: zkowalew@ippt.pan.pl

[5] 0000-0002-8060-0844 Laboratory of Microstructure Studies and Mechanics of Materials, 7 rue Félix Savart, 57073 Metz, France, E-mail: alexis.rusinek@iniv-lorraine.fr

[6] 0000-0002-7965-6592 Affiliation, Department of Civil & Environmental Engineering, Louisiana State University, Baton Rouge, USA, E-mail: voyiadjis@eng.lsu.edu

[7] 0000-0002-8739-2427 Institute of Innovation in Sustainable Engineering (IISE), University of Derby, UK, E-mail: U.Gunputh@derby.ac.uk

[8] 0000-0002-9030-6868 Institute of Innovation in Sustainable Engineering (IISE), University of Derby, UK, E-mail: p.wood7@derby.ac.uk

1. Introduction

Nowadays, additive manufacturing (AM) is revolutionizing production, enabling the rapid fabrication of objects in various sizes and shapes, including complex designs such as metallic foam, while significantly reducing material waste. This paper examines the effect of 3D printing parameters (Set A and Set B) on the mechanical behavior of a highly porous random open-cell lattice (HPROCL) in IN718 alloy produced by selective laser melting (PBF-LM). The modified build parameters were applied to reduce manufacturing cost and time while minimizing micro porosity in ligaments by increasing exposure time through reduced laser scanning speed or higher energy density. Furthermore, the researchers investigate ligament deformation, key stages of collapse and stability, its role in impact resistance, and how microstructure influences the hardening behavior of the HPROCL across a wide range of strain rates. The SEM-EDS elemental distribution analysis carried out on the tested specimens enabled to conclude that the foam printed with modified parameters (Set B) contained a lower content of the Laves phase and a higher amount of the δ-phase, which led to an increase in both static and dynamic compressive behavior of HPROCL in IN718 alloy.

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 within the range 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 ligaments in the lattice range in size from typically 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 were performed using Archimedes' method and computer X-Ray tomography (CT scan).

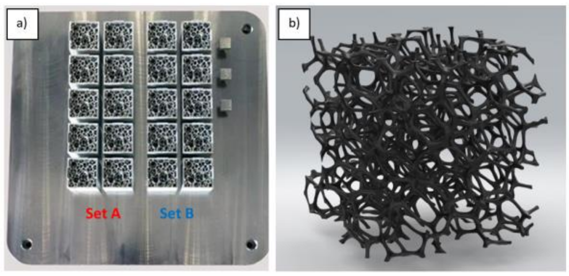

Fig. 1. SLM build record (a), HPROCL sample (b).

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. The load cell of the MTS testing machine was calibrated in the range of ±25 kN. The axial and transversal strain components were determined using two Aramis 12 M DIC systems positioned at opposite corners of the cubic test specimen. Recording frequency for image capturing was constant and equal to 2 Hz.

Dynamic compression tests were performed using the Direct Impact Hopkinson Pressure Bar (DIHPB) technique with the impact configuration which ensures large strain deformation of the specimen (up to densification in the case of cellular solids) [2], Fig. 2. The IN718 foam specimen located during each test 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 4760 g, respectively, (both made of C45). In order to record transmitted signals and determine force/stress on the loading surface of specimen, a pair of strain gauges placed 0,5 m from the front end of output bar was used. Position of strain gauges and length of output bar were chosen in such manner that enabled to avoid the wave superposition.

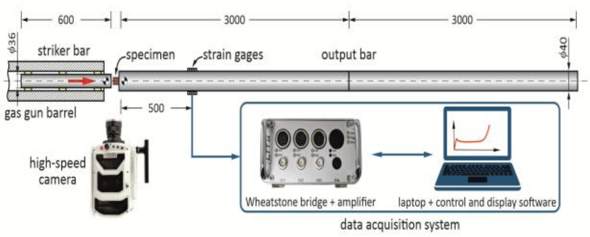

Fig. 2. DIHPB set-up.

Phantom V1612 high-speed camera was used to measure the compression rate and to identify the failure modes, as well as to confirm that the striker bar kinetic energy was sufficient to provide a nearly constant compression velocity of specimen up to the nominal strain equal to 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. A crush test markers and specialized TEMA Classic software were applied to ensure high measurement accuracy based on video images. Impact velocity and deformation length history of specimens were determined by the subtraction of the displacements between the projectile and output bar. Thus, the corresponding nominal strain values can be calculated similarly to those in the quasi-static tests captured.

3. Results and Discussion

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), often leads to deterioration of its mechanical properties, significantly [3]. Schirra et al. reported that the Laves phase observed in the grain boundary network reduces the room temperature impact and fracture toughness properties.

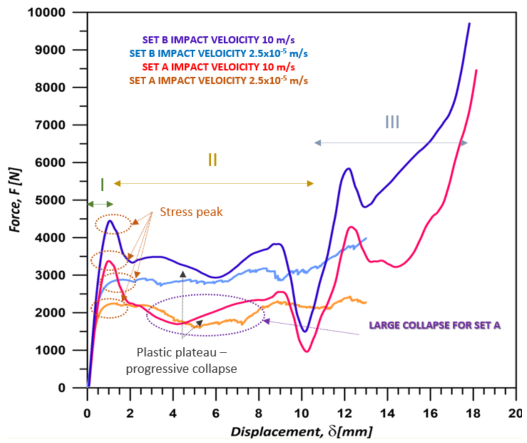

Fig. 3. Force-displacement curves for the specimens of set A and B under quasi-static and dynamic loading.

The SEM-EDS elemental distribution analysis carried out on the tested specimens enabled to conclude that the content of Laves phases in set B was much lower than that observed in set A. Moreover, set B was characterized by the higher amount of δ-phase which led to an increase in both static and dynamic compressive mechanical parameters of IN718 alloy produced by SLM with modified build parameters (set B).

Acknowledgements

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