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Comparison of the stiffnesses of three types of porous structures

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Abstract

The article deals with the investigation of the stiffness of selected porous structures. Three types of structures (Fisher-Koch S, Schoen IWP and Schoen F-RD) with cellular topology belonging to Triply Periodic Minimal Surfaces (TPMS) were modelled in PTC Creo software and additively manufactured by Direct Metal Laser Sintering (DMLS) technology. All samples were designed with a basic cell size of 10 x 10 x 10 mm at a specific mass of 0.5 g/cm^3 to compare their properties. Based on the results, it was possible to see that the best bending stiffness was shown by the Schoen F-RD type structure.

Keywords: porous structure, stiffness in bending, additive technology, specific mass

1. Introduction

Nowadays, additive technologies enable the production of shape-complex components, but they still face many challenges. Before applying the manufactured parts, it is therefore necessary to know their properties under a given load and correctly simulate their behaviour so that it corresponds to real conditions. (Gibson, 2010; Babić, 2020; Alexopoulou, 2022).

Experimental investigation of the characteristics of porous materials with complex structures forms the basis for determining all aspects affecting the operational properties, service life and reliability of such manufactured products. (Baragetti, 2020; Boursier Niutta, 2022)

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The behaviour of components based on cellular materials, which are part of a big family of porous materials, under the influence of external loads is determined by several factors, which include, for example, the properties of the base material from which the component is made, as well as the volume fraction of the material (or a specific mass) and the topology of the cell determined by its size and geometry. (Mishra, 2023; Petrova, 2020; Vantadori, 2023)

2. Materials and methods

The stiffness properties of three types of porous structures, namely Fisher-Koch S, Schoen IWP and Schoen F-RD, produced via additive technology from aluminium alloy AlSi10Mg were studied in the research. A three-point bending test up to the failure of the specimen was employed in this investigation to study the properties of complex porous structures. The alloy AlSi10Mg is often used in automotive and aviation industries for a lightweight application. (Matušů, 2024; Papuga, 2024)

It is characterized by very good dynamic properties (especially tensile and shear strength), but at the same time it is tough. Exceptional electrical and thermal conductivity, as well as resistance to corrosion, predetermine it for use for heat-exchange components, or for outdoor applications. (Kastratović, 2021; Fernandes, 2024; Sarvestani, 2018, Khosravani, 2021).

A basic cell of the individual structures is shown in Fig. 1.

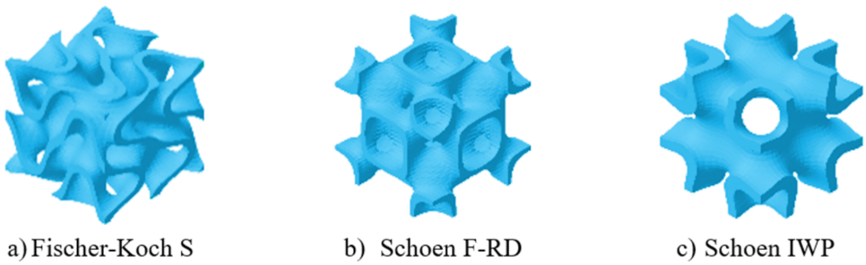

Fig. 1 Basic cells of the samples.

The produced specimens were weighed and their specific mass SM (g/cm^3) was calculated according to the equation: [2] (Monkova, 2023; Boursier Niutta, 2023)

$$SM = \frac{M_S}{V_T} \quad (1)$$

where M_S is the mass of the sample with a porous structure (g) and V_T is the total volume of a sample filled with the structure (cm^3).

The resulting specific gravity SM of all samples was 0.5 g/cm^3, which was set as a criterion for comparison. The specimens were produced by using DMLS (Direct Metal Laser Sintering) technology using a 3D printer EP-M250 with fibre laser power 500 W and Argon gas supply, built layer thickness 40 µm, and platform temperature 45 °C, volume rate 5.1 mm^3/s, and a flow rate of 40 m/s.

The tests were performed according to the ISO 7438:2020 (2020) standard at an ambient temperature of 22 °C and a humidity of 60 % on a ZWICK 1456 testing machine with a force of 250 kN and a load cell head of 20 kN. The samples were placed and cantered on supports 220 mm apart each from the other. A 20 mm rounded push thorn acted perpendicular to the continuous layer of material covering the specimen structure, while the crossbar moved at a feed of 20 mm/min. The test machine with a detail of the sample positioned in the test rig is shown in Figure 2.

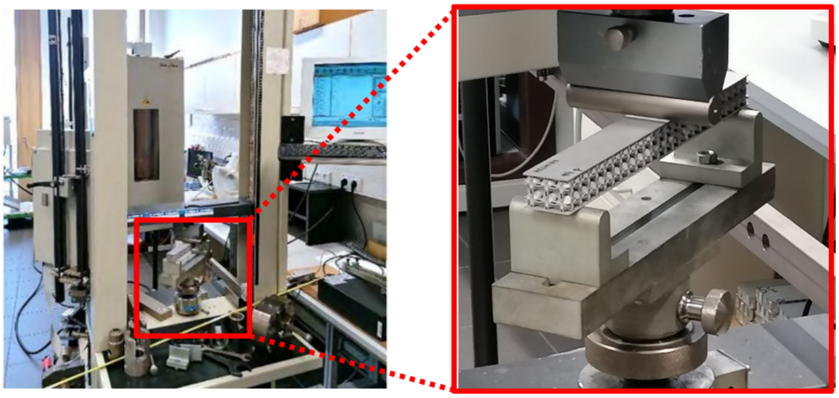

Fig. 2 Experimental testing - a sample set-up.

3. Results and discussions

Figure 3 shows the measured force-deflection dependences for all three types of structures at 0.5 g/cm^3 specific mass. The curves are representative, they are coming from the same series of production.

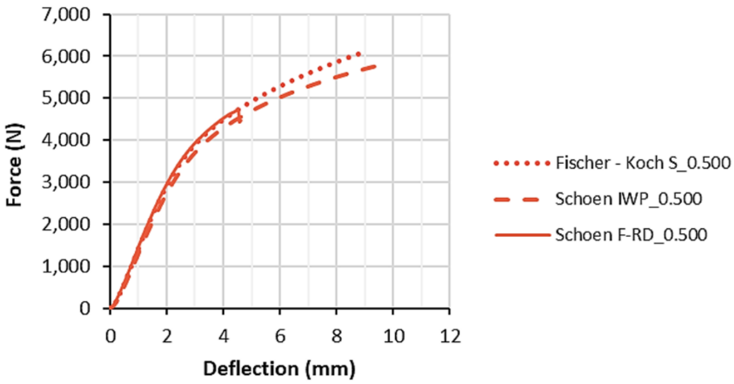

Fig. 3 Measured force-deflection dependences.

To detect outliers, a statistical evaluation was done. The measured data were analytically processed, while the stiffness in the bending of the samples was evaluated to compare the properties of the structures. The histogram in Figure 4 shows the obtained values.

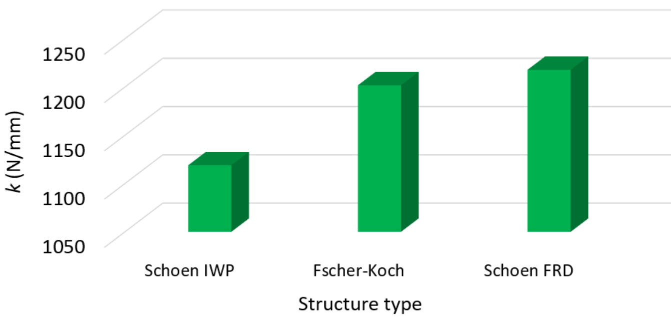

Fig. 4 Stiffness in bending of the individual types of structures.

4. Conclusions

The study examined three types of additively manufactured cellular structures to compare their bending stiffness. Aluminium alloy was selected for research as a light material with use in a wide industrial area. Based on the results achieved, it can be said that within the studied porous structures, in which a specific weight of 0.5 g/cm^3 has been applied, the Schoen FRD type showed the best results in terms of stiffness for application under bending loads. In the near future, the authors would like to investigate the bending behaviour of the structures produced with several specific weights to compare them more comprehensively and to find out, whether a functional dependency of the stiffness on specific mass can be mathematically established.

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