COMPRESSION OF ALUMINUM SPONGE

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1. General

Porous metals are a wide class of materials, constantly developing and finding new applications for its representatives. One of these interesting and relatively new groups of materials are open cell sponges with metallic skeleton. The authors would like to present here an open-cell aluminum sponge and some of its properties in compression.

The material was not bought from an external supplier but produced in own laboratories. The parameters of the production method were calibrated along with the material's mechanical study, so the material tested was prepared as two series of samples: the prototype group and the regular group. Next, compression tests of the samples were performed, revealing a distinct difference and improvement in the production method from the prototype to the regular series. As for mechanical properties of the sponge, the experimental procedure of the compression test included a hysteresis loop at the initial region. A closer examination of the results for the loop led to formulation of some hypotheses in discussion on linearity of the unloading and re-loading curve.

2. Material and samples

There are many good resources that treat about production routes for porous (and also cellular) metals, e.g. [1], [2]. These publications give, as far as it is possible in the constantly and rapidly growing 'knowledge market', complete classifications of manufacturing methods, including, among others, their taxonomy due to: the porosity type obtained and the initial substrates' state. Numerous examples are referred there.

The background for the production process of the here-by discussed aluminum sponge, the method description and some of the calibration details are to be presented in [3].

As has been mentioned, as the effect of manufacturing attempts, two series of material samples were produced: the prototype samples (denoted here with the index 'P') and the regular samples (the index 'R'). The material had open-cell, orthotropic, stochastic structure. General characteristics of the produced material are shown in Table 1.

Samples of the prototype series had a few structural imperfections, such as: some of the cells were closed or half-closed, some of the cells were filled with aluminum drops and in some cells there remained entrapped small amounts of foreign materials utilised in the manufacturing process. On the other hand, the series named 'R' did not show visible structure mistakes.

Feature	Value or description
Average PPI	According to anistropy: 5,4 $\div$ 6,2
Av. sample size, P	53,0 $\times$ 39,5 $\times$ 39,0 [mm]
Av. sample size, R	62,8 $\times$ 39,5 $\times$ 38,0 [mm]
Av. apparent density, P	0,485 $\pm$ 0,010 $[\frac{\mathrm{g}}{\mathrm{cm}^3}]$
Av. apparent density, P	0,312 $\pm$ 0,006 $[\frac{\mathrm{g}}{\mathrm{cm}^3}]$

Table 1. Basic specifications of the produced aluminum sponge

3. The compression test. Results, discussion and conclusions

Cellular materials with metal skeleton require specific way of conduct regarding compressive experiments. Directions for methodology can be found e.g. in standards [4], [5].

The experiments were conveyed using Zwick 1455 20 kN machine. Experimental conditions were: initial force 5 N, data acquisition frequency 100 Hz, strain speed $0{,}5\%{\cdot}L_0$ [mm/s], where L_0 was the initial length. The hysteresis loop started at stress 0,25 MPa till 0 MPa and then there was re-loading.

Data from the experiments were analysed in terms of determination of loop secant slope. Measures to help characterisation of open cell metals were proposed: instant and average loop secant gradients ($E^{**}_{\mathrm{ch.siecz}}$ and $E^{**}_{\mathrm{sr.ch.siecz}}$) and linear loop gradient ($E^{**}_{\mathrm{sr.lin}}$).

Obtained results are presented in Table 2. Two main conclusions were drawn based on the results. Firstly, the difference between ‘P’ and ‘R’ group was visible so the calibration of the production method improved samples’ quality significantly. Secondly, due to the fact that the instant secant loop gradient was not a constant value for a given sample but had a non-linear plot with a distinct maximum, the hypotheses was formulated that the loop region might not be best approximated by a straight line, but the proposed measure of instant or average secant or linear gradient might be a more exact characteristics.

Sample group	av. $E^{**}_{\mathrm{sr.ch.siecz}}$ [MPa], unload	av. $E^{**}_{\mathrm{sr.ch.siecz}}$ [MPa], re-load	av. $E^{**}_{\mathrm{sr.lin}}$ [MPa], unload	av. $E^{**}_{\mathrm{sr.lin}}$ [MPa], re-load
P	193,03	227,04	195,36	228,12
R	175,05	215,02	181,38	219,44

Table 2. Loop gradients for the open-cell aluminum

4. References

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[3] A. M. Stręk (2016). *Ocena właściwości wytrzymałościowych i funkcjonalnych materiałów komórkowych*, doctoral thesis, AGH, Kraków. Submitted.

[4] ISO 13314:2011 *Mechanical testing of metals — Ductility testing -– Compression test for porous and cellular metals.*

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