Al-BASED FOAMS OBTAINED BY POWDER METALLURGY METHOD AND TiH_2 AS BLOWING AGENT. PART II: MECHANICAL PROPERTIES

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Abstract. In this article, we present a study related to the compressive properties of a high porosity aluminium-based material (metallic foams) obtained by powder metallurgy methods. TiH_2 is used as foaming agent. The pores are closed and the pore size is from 2 to 8 mm. Technological aspects of the foam obtaining are discussed in Part I of the same article. Foams with various porosities in the range 79–91% are tested. Compressive stress–strain curves are obtained, as well as basic mechanical parameters, namely: elastic modulus, yield strength (offset 0.2%), stress value at plastic plateau, energy absorption capacity up to 30% and 60% deformation. The values are compared and discussed in detail. The aim is to characterize this closed-cell foam with respect to its structure and compressive properties. The results contribute to

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the multi-functional applications of the aluminium alloy foams in the industry.

Keywords: Al-based foams, powder metallurgy method, mechanical characteristics, stress–strain curves, porosity.

1. INTRODUCTION

There is a relatively large diversity of metallic porous materials obtained by various technologies [1–7]. Meantime, the demand and market for such materials constantly increase. The interest is focused on their functional characteristics and especially on the resistance to mechanical and thermal loads [8]. It is clear that the structure strongly affects the mechanical behaviour of the high porosity materials [9]. The elaboration and characterisation of high porosity metallic materials will stimulate applications and increase their economic and ecological effects.

One of the most important classes of metallic foams is closed cell foams. Such materials are obtained by means of powder metallurgy method using various blowing agents. This route consists of several stages, starting with the preparation of powders, afterwards mixing an appropriate powder composition together with a blowing agent. The blowing agent is a chemical substance which can release gas phase at elevated temperature. In the case of Al foam production, TiH_2 is most often applied as a blowing agent, but ZrH_2 is also largely used [8]. Applying Mg-based agents is also possible because they have some specific advantages [10]. The prepared powder mixture has to be compacted and after that extruded in order to obtain as dense as possible solid body which is used as a foam-able precursor. Heating the precursor, aluminum and others alloying elements are melted and decomposition of the blowing agent starts. The released gas causes foaming of the melt, which after solidification forms Al-alloy foam [11]. By the similar technique, sandwich-like panels could be produced and applied in building, automotive vehicles, electronic devices and others.

In the Part I of this article, we presented and discussed some specific details about preliminary powders preparation, the processes that take place during compacting, extrusion and sintering, and which are not completely explained in previous published works [12]. Here, important mechanical characteristics of the same high porosity AlSi7Mg3 foams are presented. Finally, the obtained relationships between the mechanical properties and the structure of the obtained materials are summarized.

2. MECHANICAL CHARACTERISTICS OF HIGH POROSITY AlSi7Mg3 FOAMS

The main compressive mechanical properties of the obtained aluminum-alloy foams were determined using HA 250 ZWICK ROELL servo-hydraulic testing machine. The test samples have parallelepiped shape with height 35 mm, width 15 mm and length 15 mm. The deformation is realized in the direction of the height of the sample with a speed of deformation of 10^{-4} sec^{-1}. The machine automatically calculates the elasticity modulus, the yield strength, the energy absorbed by the sample during its deformation from 0% to 30%, and the energy absorbed from 0% to 60%. The last two values are important for highly porous materials, as they determine their application as dampers in various systems. The main characteristics of the test samples are given in Tables 1 and 2. In the left columns of the Tables the designations of the test samples are given, as well as the values of the measured characteristics in the corresponding rows of the other columns. The densities of samples P4, P5 and P6 are practically the same, and therefore the average values corresponding to these samples are given in the last rows of the Tables. Before taking the stress–strain curves for the samples, their densities ρ were obtained as ratios of mass to volume, and their porosity ε was calculated using the formula:

$$\varepsilon = 1 - \frac{\rho}{\rho_0}, \tag{1}$$

where ρ_0 is the density of nominally non-porous aluminum alloy, in our case being $\rho_0 = 2.6$ g/cm^3, Table 1. The obtained stress–strain curves for six test samples with different porosities are shown in Fig. 1.

The stress–strain curves show three distinct regions typical for highly porous metallic materials, namely: linear elastic (on the left hand-side of the curve), plateau-like (middle) and densification region (on the right). In the plateau region, the stress oscillates around a mean value and remains relatively constantly as the strain increases. The recorded plateau stresses for samples with different densities are given in Table 2, as well as the absorbed energies at strains up to 30% and up to 60%.

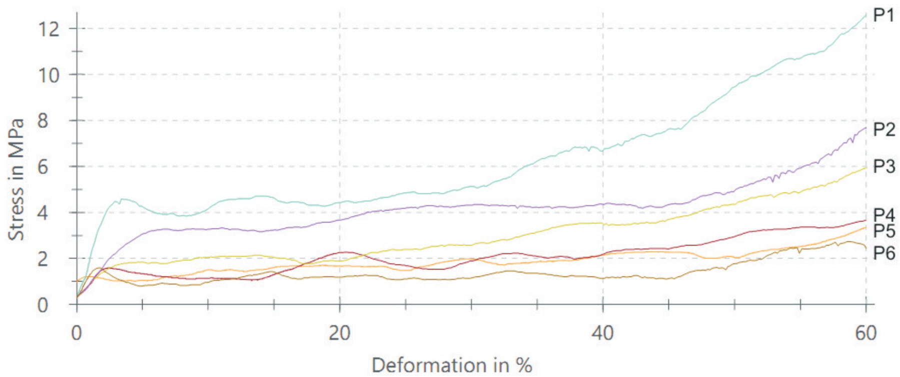

Fig. 1. Stress–stain curves of foams with different porosities:
P1–79%, P2–82.2%, P3–85.8%, P4–91.0%, P5–88.3%, P6–87.9%

Table 1. Density, porosity and main mechanical characteristics of the foams obtained

Sample designation	Density g/cm^3	Porosity %	Elasticity modulus, GPa	Yield strength (0.2%) MPa
P1	0.547	79.0	0.250	3.4
P2	0.463	82.2	0.069	2.5
P3	0.369	85.8	0.050	1.6
P4	0.234	91.0	0.089	1.5
P5	0.304	88.3	0.043	1.2
P6	0.316	87.9	0.094	1.5
Average P4–6	0.284	89.1	0.075	1.4

Table 2. Additional mechanical characteristics of the foams obtained

Sample designation	Plateau stresses MPa	Absorbed energy (30%) Nmm	Absorbed energy (60%) Nmm
P1	4.8	8 267	24 112
P2	4.0	7 407	18 390
P3	2.9	3 089	9 284
P4	2.0	3 460	9 584
P5	2.1	880	2 207
P6	1.4	2 079	5 182
Average P4–6	1.9	2 140	5 658

3. SUMMARY OF THE RESULTS AND CONCLUSION

In this article, we present a study related to the compressive properties of a high porosity aluminium-based material (metallic foams) obtained by powder metallurgy methods. TiH_2 is used as foaming agent. The pores are closed and pore size is from 2 to 8 mm. Technological aspects of the foam obtaining are discussed in Part I of the same article. Foams with various porosities in the range 79–91% are tested. Compressive stress–strain curves are obtained, as well as basic mechanical parameters, namely: elastic modulus, yield strength (offset 0.2%), stress value at plastic plateau, energy absorption capacity up to 30% and 60%. The following conclusions are drawn:

- The size of pores and the extent of porosity can be controlled by the quantity of TiH_2 and the time for foaming.
- The resulting foams have compressive stress–strain curves typical of highly porous metallic materials with a well-defined plateau and densification region after 50% strain.
- The elasticity modulus, yield strength, the plateau value of stress, and the energy absorbed at the same deformation of the resulting foams decrease smoothly as the porosity increases.

All established relations and clarification of the accompanying physico-chemical processes are of essential importance for possible future developments with a practical orientation.

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