THE INFLUENCE OF CARBON ADDITION ON UPSETTING CHARACTERISTICS OF POROUS COMPONENTS PREPARED BY FE-BASED SINTERING TECHNOLOGY

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Abstract

The compression strength is well characterized by the ability to transfer compressive stresses through porous materials. It can be determined by examining the material on the endurance machine in a single-axis compression test. The test was made on a strength machine Zwick / Roell Z100. Cylindrical specimens, made from Fe powder (ASC 100.29 and DISTALOY SE) and Fe powder with carbon addiction, about dimensions H =14 [mm], d = 16 mm, have been subjected to compression. The initial force was 100 N, while the displacement was 1 [mm / min]. Direct compressive strength (R_m) was obtained by examining the maximum value of compressive force of data range for deformation stress function. The diversity in the microstructure and porous structures properties can lead to fluctuations in the results during the endurance tests. The divergence of the Young's modulus of the aluminum porous material can vary from 5 to 30 %, and a compressive strength from 5 to 15 %. The Young's modulus was calculated on the basis of the range of 0.25 - 0.75 stresses in the linear range by dividing the stress by the deformation.

Keywords: Metallic foam, sintering Fe foam, up-settings characteristics

1. INTRODUCTION

Metallic porous materials are a new class of engineering materials that are dynamically researched due to their innovative properties [1-6]. The increase in interest in the porosity of materials was influenced by the understanding that the porous structure occurs in living organisms, such as in wood morphology or human bones, where there is an unusual combination of properties: high rigidity with minimal weight. The development of metallic foams (as high porosity materials, ranging from 40 % to 98 % by volume) began more than 20 years ago [7]. These unique materials combine properties such as energy absorption, fluid permeability, wavelength, low thermal conductivity, and good insulating properties. They can be used as: kinetic energy absorbers, fluid filters and impurities, porous welding electrodes, high temperature sealers, heat exchangers [8 - 10]. As the field of application of metallic foams dynamically grows, there are many methods of obtaining them. Early attempts to obtain a porous structure were based on knowledge of the foaming of polymers, where blown gas served as a foaming agent. Another method focused on the formation of a cellular structure by means of granules that have been introduced into the liquid metal or into the casting mould [2]. Foams and porous materials are commonly produced from ceramics, polymers, and metals such as iron, titanium, copper and aluminium [10 - 21]. Components made of the above materials have been successfully used in the space, automotive and defence industries. Steel is the most commonly used material of construction, however, porous materials made from it has not found wide application [13 - 17]. The reason for this may be problems with the availability of steel foams on the market or insufficient number of proposed uses of such material. Many authors describe that both the way the test material is being prepared and the research method is used, as a key of issues [22 - 27]. The behaviour of the porous materials of uniaxial compression was repeatedly investigated [23]. Their results are strongly dependent on the type of material and its structure. Another reason for differences in the results is the way the samples are prepared. There are a number of publications on conducting upsetting tests for porous materials. Analysed materials show that the samples are generally cylindrical or prismatic. The ratio: height to thickness does not exceed 1.5 and the minimum size of tested material should be seven times the average pore size. Diversity in the microstructure and properties of porous structures can lead to fluctuations in the results of the strength tests. Divergence for the Young's modulus of aluminium porous materials can be from 5 to 30 %, and a compressive strength from 5 to 1 % [1-4].

2. EQUIPMENT AND MATERIAL

The initial stage for the production of porous sinter is to weigh and mix the powders together in appropriate proportions. There are four types of mixtures, labelled ASC, ASC + C, SE, SE + C. **Table 1** shows types and proportions of powders that are components of each blend.

Table 1 Types and proportions of mixing powders

	Sample designation			
Composition	ASC	ASC + C	SE	SE + C
ASC 100.29 g	140	140	-	-
DISTALOY SE[g	-	-	140	140
Cu g	8	8	8	8
Fe_2O_3 g	16.8	16.8	16.8	16.8
C g	-	1.314	-	1.314

The sintering of the prepared samples was done in a laboratory tube furnace at 1130 °C, in a reducing gas shield. Dissociated ammonia was used as a reducing atmosphere. Ammonia dissociates to nitrogen and hydrogen at 850 °C in the presence of an iron catalyst. Such residual gases were directed to the sintering chamber into which a sample was placed. Hydrogen was a reducing oxide agent, iron oxide was reduced, thus providing protective atmosphere for the sintering process. Excess ammonia as well as the process derived products: the nitrogen and water vapour were subject to combustion.

The mechanical properties of porous materials required preparation of samples in the appropriate form. Prior to the measurement of maximum crushing force, sintered shaft had to be properly symmetrical, approximately 14 mm high and 16 mm high. In **Figure 1** a sample after EDM is shown. Unfortunately, shapes differ slightly. The compression test is a fundamental study to determine mechanical properties of porous materials. The compression test is a fundamental test determining mechanical properties of porous materials. It was made on a Zwick / Roell Z100 strength machine. Cylindrical ASC, ASC + C, SE, SE + C samples, sized: H = 14 mm, d = 16 mm was subjected to compression. The initial force was 100 N, while the displacement was 1 mm / min.

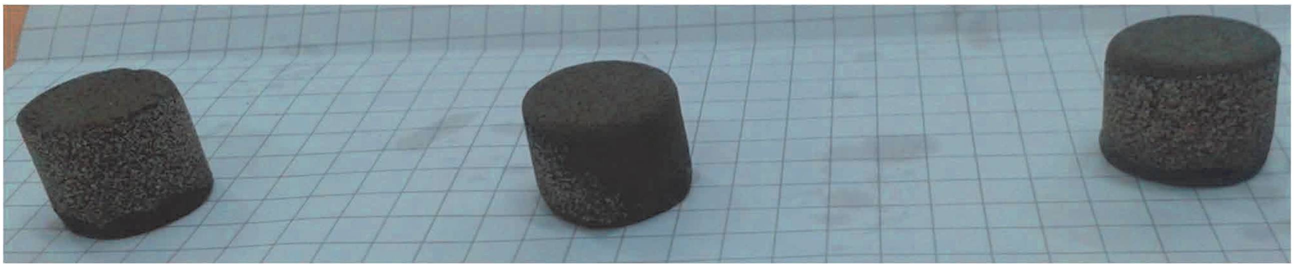

Figure 1 Samples after erosion treatment

3. RESULTS AND DISCUSSION

Drawings (**Figure 2**) represent graphs of the stress strain of deformation in the study. Based on each graph, the yield strength was determined. Immediate compressive strength R_m was obtained by investigating the value of the maximum compressive stress in the data range for the stress-strain function. The calculated values were presented in **Table 2**. Young's modulus was calculated from the range of 0.25 - 0.75 linear stress, dividing the strain by the deformation.

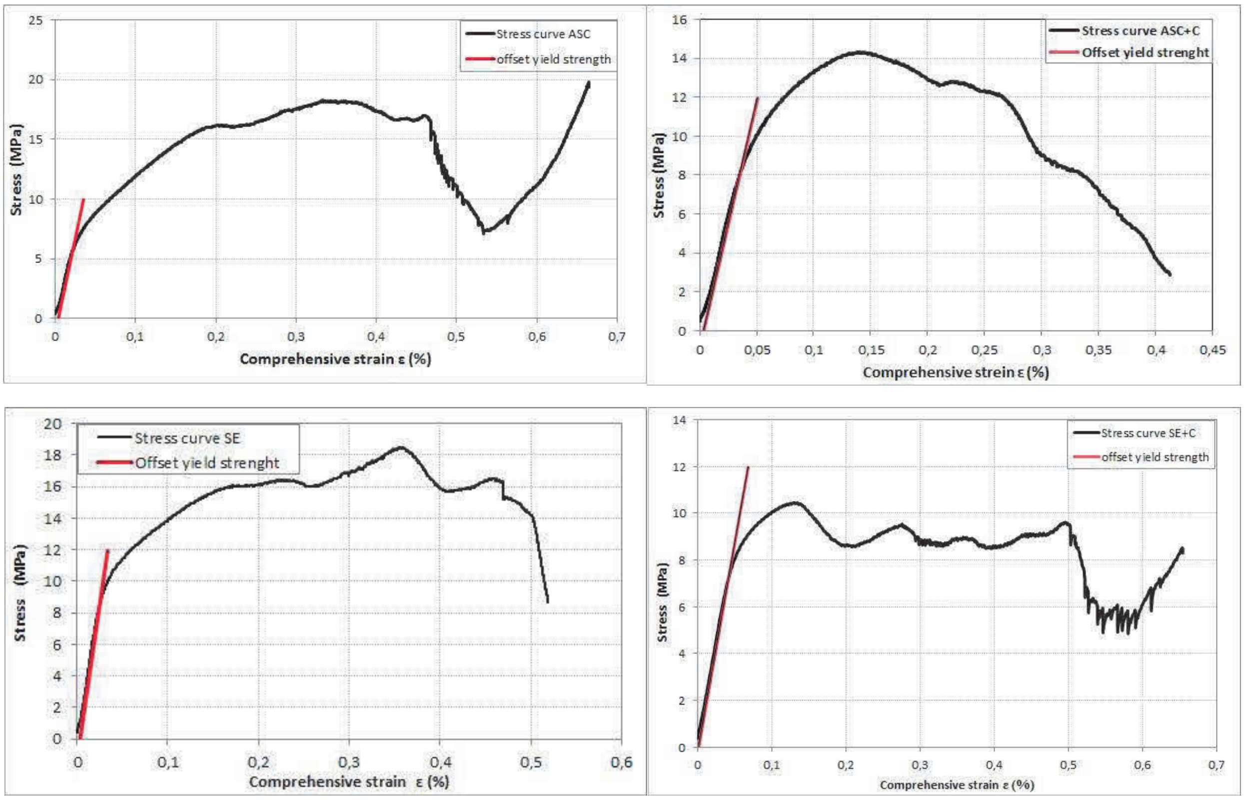

Figure 2 Graphs of the deformed samples as a result of stress strain

Scientists [15] investigated the mechanical properties of the porous materials of low-alloy iron-based powders. The main purpose of their research was to determine whether the properties of porous materials depend on the size and pore size of the structure. One of the studies they conducted was to determine the compressive strength of the materials tested [24]. They showed that compressive strength decreases with increasing porosity in the structure. By analysing the obtained results from the compression test, one can conclude that the yield stress decreases as the carbon content in the material decreases. The diffusion bridges in the carburized material break do not deform and clamp together, under the force applied. As a result, the overall compressive strength is lower. The average compressive force F_{avg} and the maximum displacement value S_{max} were read from the power-displacement graphs prepared for the materials tested. The cross-sectional area was calculated from the formula $A_o = (3.14 \cdot d2) / 4$, where d was the sample diameter equal to 16 mm. Work of deformation:

$$W=FavgSmax \tag{1}$$

Medium crushing stress:

$$\sigma_{avg} = \frac{F_{avg}}{A_0} \tag{2}$$

Graphs from **Figure 2** show stress strain of deformed samples. The extreme point of line drawn determines value of the maximum displacement. The results of the calculations are shown in **Table 2**.

Table 2 The results obtained from compression tests

Sample	$R_{0,2}$, MPa	R_m, MPa	E, GPa
ASC	6	18.235	0.274
ASC + C	8	14.308	0.237
SE	8,7	18.479	0.355
SE + C	7.5	10.451	0.183

Analysing the results obtained from compression tests, it can be concluded that the compressive strength Rm, and Young's Modulus decreases with increasing carbon content in the material. Compression strength Rm was decreased by 3.927 MPa for ASC + C. 8.027 MPa for SE + C composition. Young's Modulus value was decreased by 0.01 MPa for ASC + C and 0.172 MPa for SE + C. Increasing carbon content in the structure leads to a deterioration of the strength properties of the tested for energy absorption. The external compression work was decreased by 5.45 MPa for ASC + C and 4.97 MPa for the SE + C composition. The medium crushing stress was decreased by 2 MPa in the case of ASC + C and 4.015 MPa For SE + C. On the basis of the data obtained from the compressive strength test, it is possible to determine the characteristics describing the energy absorption - the work of external load and the medium crushing stress of tested materials.

4. CONCLUSION

Some test results did not allow us to determine whether the carbon addition strongly influenced the mechanical properties of the porous materials. It is important to note that porous material behaves differently than continuous material, and there may be problems with the definition according to certain characteristics. The yield strength $R_{0,2}$ increased by 2 MPa for ASC + C, and decreased by 1.2 MPa in the case of SE + C. For the purpose of iron based metallic foams usefulness in-depth evaluation, they should be tested further for different properties: filtering ability, vibration absorption and acoustic wave scattering.

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