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An analysis on some mechanical properties of AlMg10-SiCp ultralight metal composites

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Abstract. The paper presents some results on analysis of some mechanical properties of AlMg10-SiCp composite materials, namely hardness and behaviour at static compression. Hardness values clearly separated the range of cellular composite materials from the porous ones, the compression tests data showing that with the increase of porosity the energy absorbed by the composite materials rises, the cellular composites requiring a higher mechanical deformation work that the porous ones. The increase of the silicon carbide percentage causes the increase of mechanical deformation work and of the absorbed energy, which can be explained by the stabilizing role of the respective particles on the composite material cells walls. The investigated samples were obtained using two methods: a method based on melt bubbling with a reactive gas (M1) and a method based on using various salts powders particles, soluble in suitable solvents (M2). We chose AlMg10 alloy for the material base and silicon carbide reinforcement particles introduced in varying amounts in the base mass (5%, 10% and 15% SiC). First method leads us to cellular composites and the second one to porous composites.

1. Introduction

The structure of metal ultralight composites gives them a unique combinations of properties: high mechanical rigidity and strength, excellent strength-to-weight ratio, very good thermal conductivity, high vibration damping capacity, high sound absorption capacity, high mechanical shock energy absorption, etc. All these characteristics make them suitable for various applications, such as making light rigid structures (like sandwich structures), vibration control, shock absorbers, sound absorption panels, filters, heat exchangers, etc.

By its nature, cellular composite material collects properties that are practically not specific to its components. Thus, the cellular matrix provides promising premises in terms of its plastic deformability by absorbing the deformation energies [1, 2]. The ceramic components introduced into the cellular metallic composite have a major influence on the plasticity of the matrix but also on the thermal and mechanical energies that can be absorbed by it. They also influence the tendency to fragile the composite during the plastic deformation process, a phenomenon that could also be considered as an advantage in terms of load transfer, especially when it comes to the protection afforded to components of armoured structures or the protection of car passengers at an impact [3-7].

To analyse the ultralight composite materials, we will take into account some particularities of the mechanical behaviour of the composite materials such as:the existence of several deformation mechanisms with totally different effects on the size and nature of the deformation, due to which,

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under different stress conditions for the same composite, can be obtained elastic, quasi-elastic or plastic behaviours; dependence of mechanical properties on some geometric and physical parameters such as load directions, test speed, time load increase, load duration, temperature, etc.; the dependence of mechanical properties on the conditions for obtaining the composite material, depending on the manufacturing technology and the applied thermal treatment (e.g., it may be a molded, expanded, laminated cellular composite material, etc.);dependence of mechanical properties on the nature and characteristics of matrix reinforcement components: particle layout, density, total volume of reinforced material, nature of interface and input materials introduced to modify internal stresses, etc..

Until now, there has not been developed a unitary theory that can fully describe the mechanical behaviour of metal matrix composites and silicon carbide reinforced cellular structure and establish the mechanisms of dependence of the mechanical characteristics of the parameters already mentioned. In the theories that refer to the calculation of structures in cellular composite materials, there are patterns that partially describe the properties of these materials, usually under specified and limited conditions [8-17].

2. Experimental results and their analysis

In the practical applications of ultralight metallic composite materials, particular attention is paid to their mechanical properties, especially to their hardness and to compression and shock behaviour.

Hardness determinations of the AlMg10-SiC composites ware made on a WOLPERT hardness tester type DigiTestor 930/250N. The hardness tests were performed with a force of 250 N, with a 5 mm diameter indentor head. For each sample were carried out three test sets, then determining the average value (figure 1 and table 1, where P1-i - composite samples obtained by the M1 method, P2-i - composite samples obtained by the M2 method, i = 1, 2 or 3 (5, 10 or 15% SiC)). The hardness of the AlMg10 base alloy is 46 HB under the same test conditions.

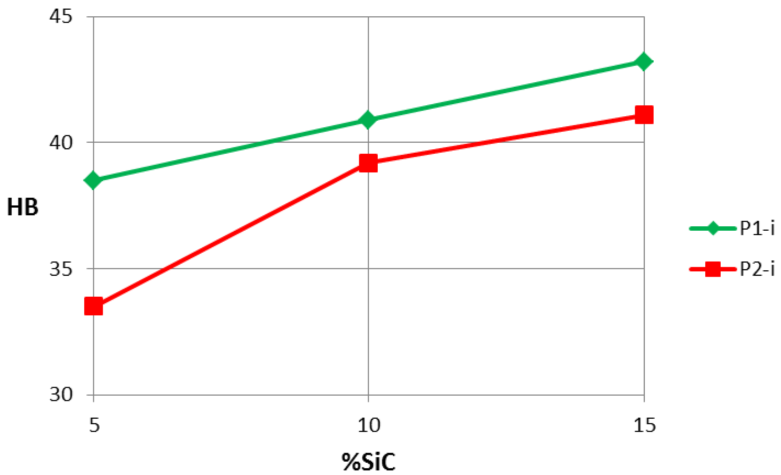

Figure 1. Average hardness variation of various types of ultralight AlMg10-SiC composites, depending on the macrostructure and the percentage of used SiC.

Table 1. Data regarding average hardness variation of various types of ultralight AlMg10-SiC composites, depending on percentage of used SiC.

%SiC	HB	
	P1-i	P2-i
5	38.5	33.5
10	40.9	39.2
15	43.2	41.1

We can observe the existence domains separation of the obtained ultralight composite materials according to the macrostructure: at the upper part are placed the cellular materials (made by the M1 method - method based on melt bubbling with a reactive gas), while at lower values of the hardness are found the porous ones (obtained by M2 method - method based on using various salts powders particles, soluble in suitable solvents).

The analysis of the compression behaviour of the obtained ultralight metallic composite materials was carried out on anInstron 8802 universal test machine. For compression stress tests, we performed parallelepiped samples obtained by machining from the raw composite ingot. In order not to destroy the surface of the specimen cells the samples were cut from the ingot and processed on an electroerosion cutting machine. The test pieces were subjected to one-axial compression with a force of 500 kN, the machine being equipped with a load cell with sensitivity of ± 0,5%. The tests were recorded until cracks appeared on the surface of the specimens and reached up to a 30% dimensional variation (above these values fracture of the material occurs and the composite tests are no longer relevant).

The general profile of the curves follows in principle a parabolic increase (figure 2, where P1-i - composite samples obtained by the M1 method, P2-i - composite samples obtained by the M2 method, i = 1, 2 or 3 (5, 10 or 15% SiC)). The amount of absorbed energy as a result of the integration values from the stress/strain domain, denote that the porous/cellular material absorb much more energy compared to a dense material of the same type.

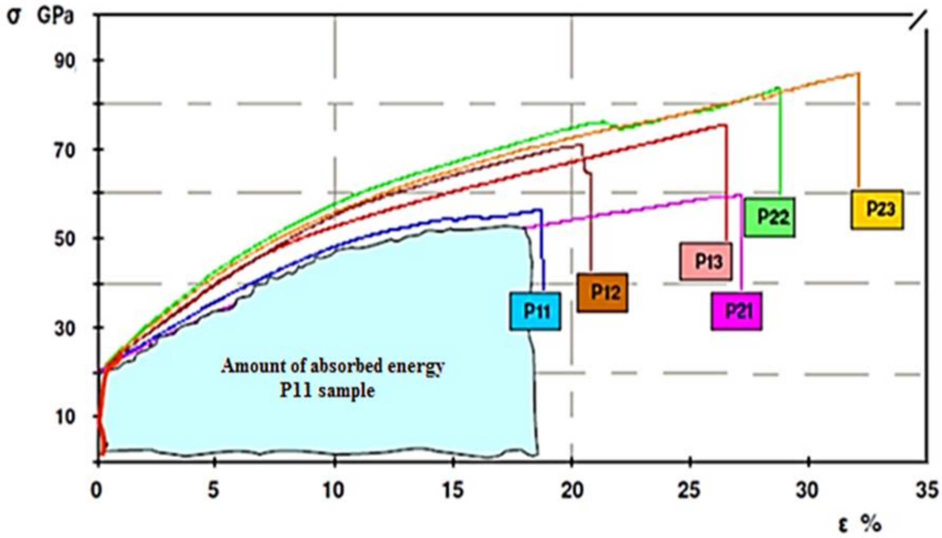

Figure 2. Stress-strain curves obtained on AlMg10-SiC ultralight composite specimens, highlighting the absorbed deformation energy.

The experimental determinations allowed plotting the variation of the mechanical work needed for deformation and of the absorbed energy depending on the percentage of silicon carbide present in each sample of the ultralight composite material (figures 3 and 4, tables 2 and 3, where P1-i - composite samples obtained by the M1 method, P2-i - composite samples obtained by the M2 method, i = 1, 2 or 3 (5, 10 or 15% SiC)). It can be noticed that with the increase of porosity the energy absorbed by the composite material increases (see P2-i porous composite samples), justifying its use in the case of structures subjected to shocks, with direct applications in automotive, aerospace, military industry and so on. On the other hand, cellular composites (P1-i) require a greater mechanical deformation work, the material being more compact than that of P2-i specimens.

As the percentage of SiC increases, mechanical deformation work and absorbed energy increase, which can be explained by the stabilizing role of the respective particles on the cells walls of the ultralight composite material. The density of metallic cell composites, the shape, size and relative density of cells, the distribution of reinforcement/stabilization particles play an important role in determining the amount of absorbed energy in deformation and impact tests of cellular/porous ultralight composites.

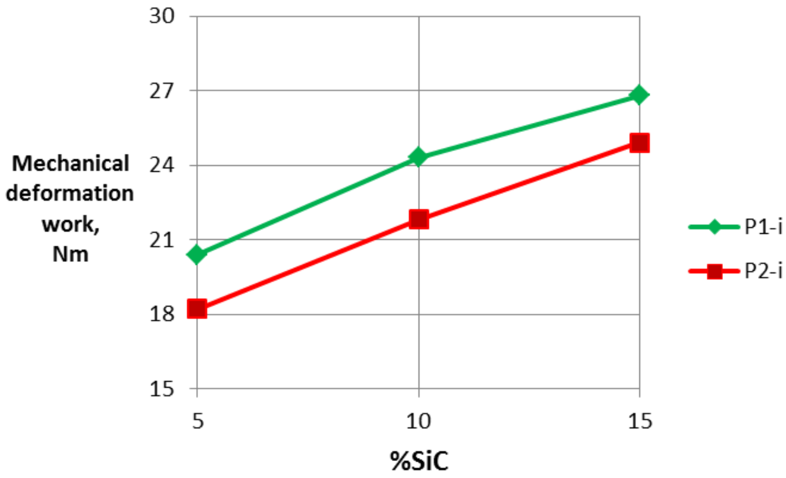

Figure 3. Variation curves of the mechanical deformation work of AlMg10-SiC composites based on the SiC percentage and the obtaining method of the ultralight composite material.

Table 2. Data regarding variation of mechanical deformation work of AlMg10-SiC composites based on the SiC percentage and the obtaining method of the ultralight composite material.

%SiC	Mechanical deformation work, [Nm]	
	P1-i	P2-i
5	20.4	18.2
10	24.3	21.8
15	26.8	24.9

Consequently, the analysis of the microstructure of the deformed samples can give precious information on the deformation mechanism and thus the behaviour of these materials at static or dynamic deformation. Consequently, as a future direction of research, the analysis of the microstructure of the deformed samples can give precious information on the deformation mechanism and thus the behaviour of these materials at static or dynamic deformation.

The deformation energy initially refers to the kinetic energy absorbed in the composite. The phenomenon occurs by advanced deformation of the cell walls, but also by an extra energy loss. The loss of energy occurs as a consequence of the stresses that arise and causes the carbons to break off and / or fragment them. Loss of energy also takes place due to the internal friction that appears on the boundaries of the cells of the composite. This reduces the zonal tensions as a final result, resulting in a particularly significant absorption of total fracturing energy.

From the experiments performed and those presented by the material analyzes, it can be suggested, even indirectly, that the deformation of the intercellular walls of these types of materials together with the obvious reinforcement phenomenon of the matrix (by inclusion of carbides) could lead, after a study of optimization and multiple experiments, to obtain a cellular composite that can successfully absorb, in the case of industrial applications, shocks and deformation energy.

Silicon carbide particles also participate in the deformation of composite material. Thus, they will take over some of the loads acting on cell walls and cell bonding bridges, the resulting tensions leading to the detachment of the porous structure composite particles and the diminishing of the charges acting on the cell walls, eventually leading to the fracture of the walls.

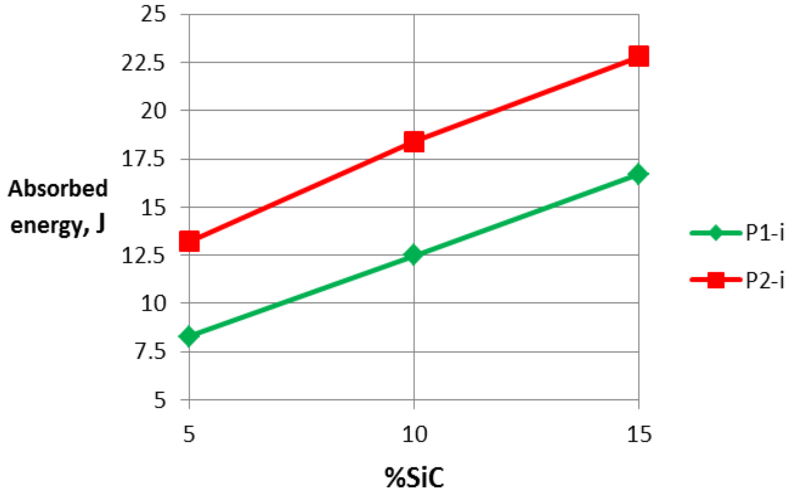

Figure 4. Absorbed energy variation based on the SiC percentage and the obtaining method of the ultralight composite material.

Table 3. Data regarding absorbed energy variation based on the SiC percentage and the obtaining method of the ultralight composite material.

%SiC	Absorbed energy, [J]	
	P1-i	P2-i
5	8.3	13.2
10	12.5	18.4
15	16.7	22.8

3. Conclusions

It was observed the separation of existence domains for obtained ultralight composite materials according to their hardness values: at higher values (38÷43 HB) cellular materials (made by the M1 method), while at lower hardness values (33÷41 HB) are disposed the porous ones (obtained by the M2 method).

The value of the absorbed energy as a result of the integration of the stress/deformation values indicates that AlMg10-SiC ultralight composite materials absorb much more energy compared to dense materials, which justifies their use in shock absorbent structures.

AlMg10-SiC cellular composites require a higher mechanical deformation work, the material being more compact than the one made of porous ultralight composite material.

As a result of the analyses made for this type of materials, we can say with certainty that the ultralightmetallic matrix composite materials and SiC stabilizing particles are part of the category of materials that can be successfully used due to their mechanical properties in the field of machine building, in the aeronautical industry, etc.

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