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Mechanical properties of silver matrix composites reinfroced with ceramic particles

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Materials

ABSTRACT

Purpose: Silver, silver alloys, as well as silver matrix based composites have been well known and applied in the electrotechnical and electronics industry for several decades. For many applications in electrotechnology, including electric contacts and brushes, unreinforced sliver alloys do not meet the requirements concerning mainly durability and wear resistance, first of all to tribological and electroerosive wear. These wear processes may be prevented by introducing to silver reinforcement particles and alloys. The target of the research included basic mechanical properties determination of the silver matrix composites reinforced with ceramic particles, manufactured with the use of suspension methods.
Design/methodology/approach: In the presented paper the authors demonstrate possibilities of manufacturing of silver matrix composites on the way of casting technology utilization.
Findings: The results of the research prove that applied suspension technology, based on introducing of agglomerated foundry alloy which is the carrier for reinforcement particles (SiC lub Al_2O_3) allows to produce in an effective and, what is important, in an economically attractive way, sliver alloys based composites.
Research limitations/implications: The researches on the structure of manufactured composites and their mechanical properties that are presented in the paper prove the possibilities of mechanical mixing technology application for producing mechanical and stable connection between silver matrix and ceramic particles of aluminium oxide and silicon carbide.
Originality/value: The manufacturing of this type of composites is based most of all on the utilization of powder metallurgy techniques. However the obtained results of the research prove that there is a possibility of silver matrix composites forming in the casting and plastic working processes. Extrusion process carried out in the hydraulic press KOBO has its favourably influence on ceramic reinforcement distribution, providing even distribution particles in matrix.
Keywords: Composite; Mechanical properties; Materials design; Casting

1. Introduction

The application of silver, silver alloys and silver matrix composites in the electrotechnical and electronic industry results from their good electric and thermal conductivity. High electric conductivity, high wear resistance, sparking resistance, strength, cracking resistance and chemical stability as well are the properties due to which these materials find their application in electrotechnics and electronics. They are applied to electric contacts, circuit-breakers, plug coatings, brushes, slide bearings in electrotechnics [1,2]. Reinforcement in the form of dispersive particles improves hardness, reduces wear resulting from corrosion at the increased temperature, increases adhesive wear resistance, lowers or completely eliminates sparking. These applications require apart from good electric properties also good sliding and mechanical properties. Silver alloys and their composites provide these properties, however temperature of their applicability does not exceed 500 °C [3,4]. Many applications in electrotechnics including electric contacts and brushes do not meet requirements that are faced with. This is associated with low resistance to electric arc and erosion as well, and with high plasticity and ability to deform under load [5]. These processes may be prevented through introduction of reinforcement particles or fibres to silver. Due to this fact their resistant properties increase, deformability decreases, however it leads to substantial deterioration in thermal and electric conductivity. Particles of oxides: CdO, SnO_2, ZnO, TiO_2, SiC, Al_2O_3 are applied to silver alloys reinforcement [6,7]. The properties of silver matrix composites are determined not only by the form of reinforcement, its size and volume fraction, determining proper level of mechanical and physical properties [8,9]. The character of components interaction on the intherface is essential as well. The choice of the reinforcement material is therefore decisive for composite quality.

2. Target and scope of the research

The target of the research included basic mechanical properties determination of the silver matrix composites reinforced with ceramic particles, manufactured with the use of suspension methods. Composites which had been shaped in the form of 3 mm diameter wires through extrusion were put through direct investigations of the mechanical properties.

Two different kinds of composites differing in the sort of applied reinforcement were subjected under investigations. Phase composition of produced composite materials is presented in Tab. 1.

Investigated composite materials were manufactured with the use of liquid phase production technology. The process of introducing reinforcement particles to the liquid silver alloy was carried out in the induction furnace equipped with chamber that allowed suspension degassing in underpressure [10].

The schema of the stand for producing silver matrix composites with the use of suspension method is presented in Fig. 1.

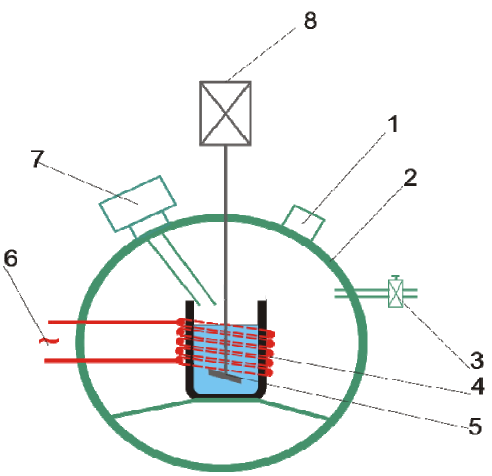

Fig. 1. The schema of the stand for producing of ceramic particles silver alloy composites. 1- eyepiece 2- vacuum chamber, 3- valve, 4- induction coil, 5- graphite mixer, 6- voltage feed, 7- air-lock, 8- electric motor

Table 1.
The composition of utilized in the researches agglomerated composite foundry alloys.

Marking	Matrix alloy	Reinforcement	Particles size, μm	Volume fraction
$AgAl_2O_3$	AgMg4	Al_2O_3	25	10 %
AgSiC	AgSi3	SiC	25	10 %

The structure of produced composites in the condition after casting with characteristic reinforcement particles clusters is presented in Fig. 2 and Fig. 3.

In order to impart the form of wire to the composite material manufactured with casting methods, the plastic working process was conducted which consisted in composite ingot extrusion with the KOBO hydraulic press. The composite ingot 40mm diameter was used for the extrusion. In the process of extrusion the composite wire of 3 mm circular intersection was obtained.

The composite ingot extrusion process from f = 40 mm diameter to the wire form of f = 3mm diameter provided homogenizing of phase composition of the composite.

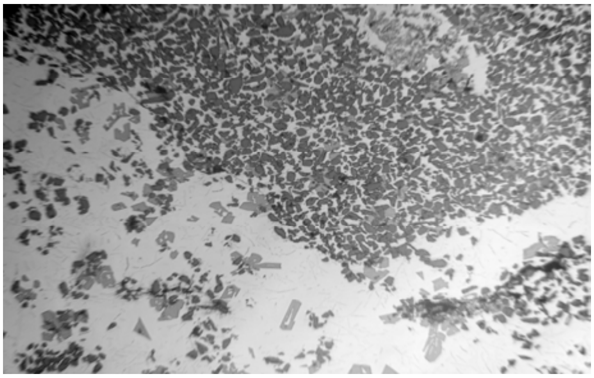

Fig. 2. Structure of $AgAl_2O_3$ composites after casting, mag 150x

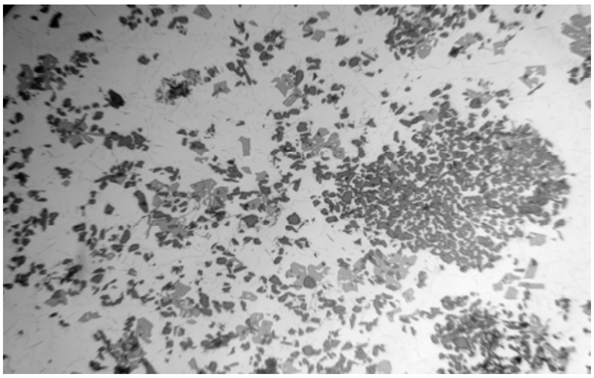

Fig. 3. The structure of AgSiC composites after casting, mag 150x

It influenced particularly favourably the reinforcement particles distribution in Ag matrix. The composite structure after the extrusion process with characteristic streaked distribution of reinforcement particles having developed due to conducted extrusion is presented in Fig. 4 and Fig. 5.

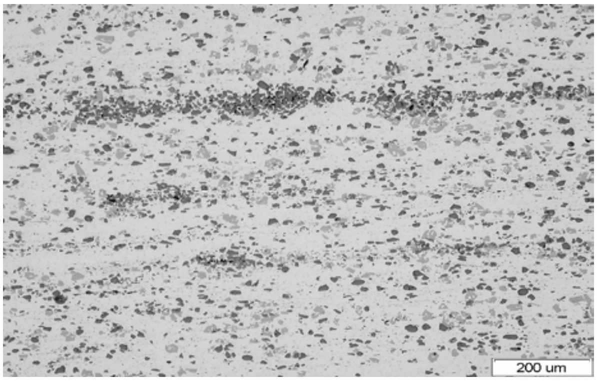

Fig. 4. Structure of $AgAl_2O_3$ composite after extrusion process – longitudinal cross-section

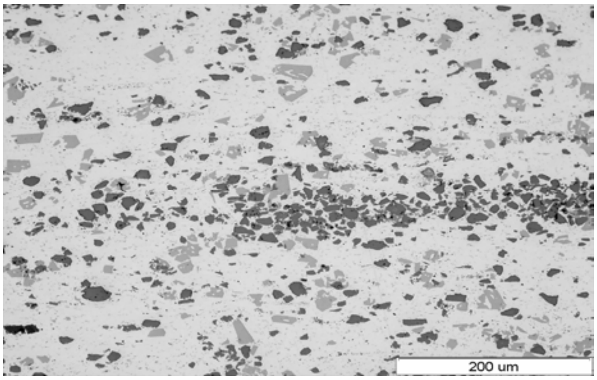

Fig.5. Structure of AgSiC composite after extrusion process – longitudinal cross-section

3. The investigations of mechanical properties

Produced through extrusion composite wires served to make investigations of mechanical properties. The investigations were carried out for composites after extrusion and also for the material subjected to annealing carried out in 670 °C temperature in the 5h period of time.

Mechanical properties were determined in static stretching test for samples taken from wires that were obtained after extrusion. The investigation were conducted with the use of Instron mechanical testing machine, type 4469. The test was carried out with the stretching velocity equal 10mm/min for samples with geuge length equal 50 mm. Demonstrative diagrams of composites tensile test are shown in Fig. 6 and Fig. 7.

In both investigated composite materials the course of the stretching curve was similar. For materials directly after extrusion slight differences in deformability were recorded which did not exceed 10 %. The average recorded deformation for composites reinforced with SiC particles amounted to 3% whereas for composites reinforced with Al_2O_3 it amounted to 2,5%.

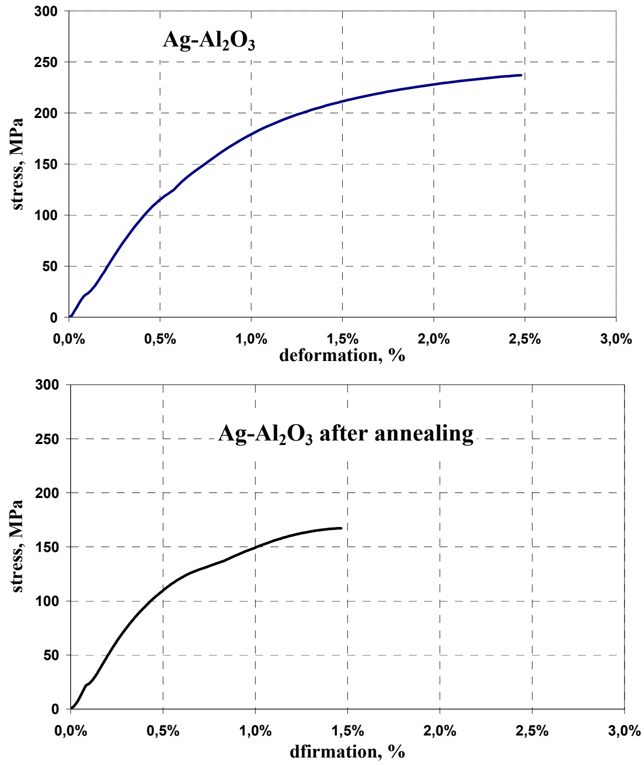

Fig. 6. The streching curve for $AgAl_2O_3$ composite

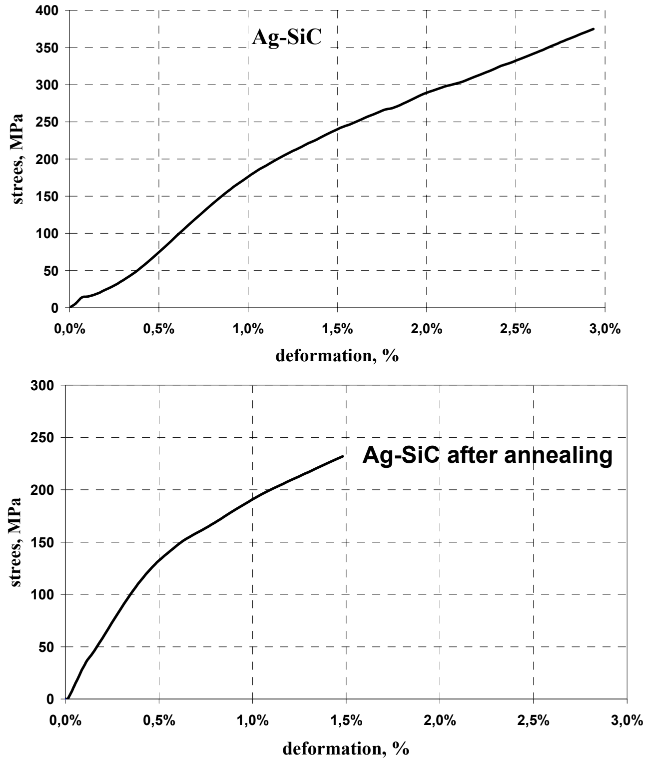

Fig. 7. The streching curve for AgSiC composite

These differences did not appear in the case of materials after heat treatment, for both investigated composites deformation after annealing amounted to 1,5%.

Similar differences were recorded for rupture stresses. For composites that were not subjected to annealing reinforced with silicon carbide they were higher (370 MPa) than for composites reinforced with alumina (245 MPa). For these materials after annealing rupture stresses decreased by 30%, thus amounted to 225 MPa for composites reinforced with silicon carbide particles and 175 MPa for composites reinforced with particles of alumina. For both kinds of materials character of fracture resulting from rupture was similar (Fig. 8 and Fig. 9)

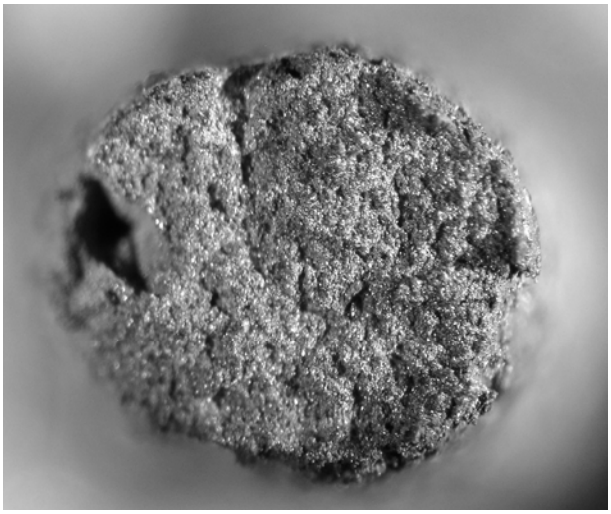

Fig. 8. The composite $AgAl_2O_3$ wire 3mm diameter after rupture in stretching test

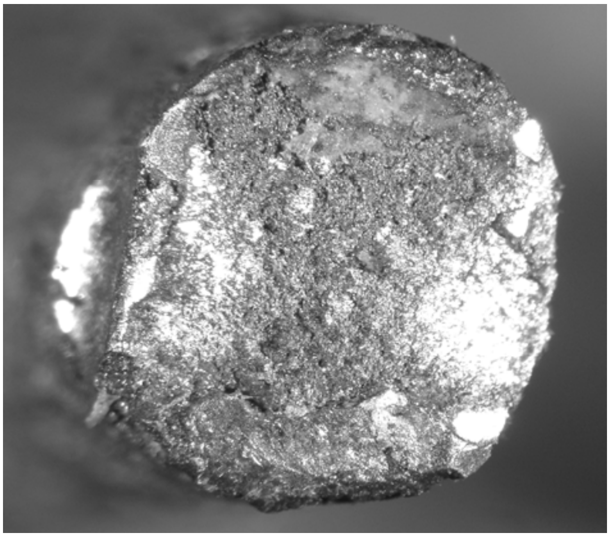

Fig. 9. The composite AgSiC wire 3mm diameter after rupture

4. Summary

The obtained results of the research prove that there is a possibility of silver matrix composites forming in the casting and plastic working processes. Extrusion process carried out in the hydraulic press KOBO has its favourably influence on ceramic reinforcement distribution, providing even distribution particles in matrix.

Properties of AgSiC and $AgAl_2O_3$ composites differ significantly. It is determined by matrix composition as well as particles material. AgSiC composites are characterized by higher stretching resistance (R_m = 370 MPa).

Furthermore AgSiC composites have higher plasticity (ε = 3%) then $AgAl_2O_3$ (ε = 2,5%).

Heat treatment that composites were subjected to after extrusion process had an adverse influence on the mechanical properties level. Composites deformability decreased in both analyzed cases per 50%. Similarly rupture stresses value decreased per 30%. It proves disadvantageous influence of heat treatment on silver matrix composites reinforced with ceramic particles.

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