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Wear resistance of PM composite materials reinforced with the Ti(C,N) ceramic particles

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Materials

ABSTRACT

Purpose: of the project was evaluation of the effect of heat treatment and of the reinforcing Ti(C,N) particles in the EN AW-AlCu4Mg1(A) aluminium alloy on the mechanical properties, wear resistance.
Design/methodology/approach: some of the composite materials were hyperquenched for 0.5 h at the temperature of 495ºC with the subsequent cooling in water, and were quench aged next for 6 h at 200°C. Hardness tests were made on HAUSER hardness tester with the Vickers method at 10 N. Abrasion resistance wear tests were carried out with the constant number of cycles of 5000 (120 m) at various loads: 4, 5, 6, 7, and 8 N. Test pieces were rinsed in the ultrasonic washer to clean them and next were weighed on the analytical balance with the accuracy of 0.0001 g to check the mass loss.
Findings: Besides visible improvement of mechanical properties and wear resistance there were also observed the influence of heat treatment.
Practical implications: Tested composite materials can be applied among others in automotive industry but it requires additional researches.
Originality/value: It was demonstrated that the mechanical properties, as well as the wear resistance of the investigated composite materials with the EN AW-Al Cu4Mg1(A) alloy matrix may be formed by the dispersion hardening with the Ti(C,N) particles in various portions and by the precipitation hardening of the matrix.
Keywords: Composites; Mechanical properties; Abrasive wear

1. Introduction

Composites with an aluminium alloy matrix are a group of materials which due to their properties are more and more frequently used in modern engineering constructions.

The metal matrix composite can be reinforced with particles, dispersoids or fibres. However, the biggest interest in composite materials is observed for those reinforced with hard ceramic particles due to the possibility of controlling their tribological-, heat- or mechanical properties by selection of the volume fractions, size, and distribution of the reinforcing particles in the matrix.

Composites reinforced with ceramic particles (Ti(C,N), Al_2O_3, SiC) are gradually being implemented into production in electronic, automotive or aircraft industries, first and foremost due to high resistance to friction wear [1,2].

Employment of the hard particles as reinforcement increases their hardness, Young's modulus and abrasion wear resistance; however, at also results in deterioration of their plastic properties. Heat treatment is carried out consisting in hyperquenching and ageing to improve their mechanical properties. Composite materials precipitation hardening occurs due to hyperquenching and ageing as a result of precipitation of the hard dispersive particles of the intermetallic phases. The intermetallic phases occurring in the aluminium alloys matrix most often are: Al_2Cu, Al_2CuMg, Al_2Mg, Al_3Mg, Cu_9Al_4 , and Al_2Cu_3 [3-14].

The goal of the work is to investigate selected mechanical properties and wear resistance of the composite materials with the EN AW-Al Cu4Mg1(A) aluminum alloy based matrix reinforced with the ceramic particles of the Ti(C,N) phase with various weight ratios.

2. Material and method

2.1. Material for investigations

The investigations were made of the composite materials obtained with the powder metallurgy methods and by hot extrusion of the EN AW-AlCu4Mg1(A) aluminium alloy (0.20% Si, 0.30% Fe, 3.8-4.9% Cu, 0.30-0.9% Mn, 1.2-1.8% Mg, 0.10% Cr, 0.25% Zn, 0.15% Ti and Al rest [15]) reinforced with the Ti(C,N) phases particles with the mass portions of 5, 10, and 15%. The initial size of the matrix material powder particles is smaller than 75 µm, of the reinforcement Ti(C,N) powder is smaller than 25 µm.

The weighed matrix and reinforcement powders were wet mixed together (methanol slurry) in the laboratory vibrating ball mill for 2 h to obtain the uniform distribution of the reinforcement particles in the matrix, and also to avoid development of the reinforcement particles clusters.

Aluminium containers were filled with the obtained mixtures. The powders mixtures in the containers were thickened initially (compacted) in the O.D. 26 mm die in the laboratory press with the computer load logging.

The following compacting process parameters were used:

- unidirexional, uniaxial compacting,
- room temperature,
- 350 kN load.

The selected compacting load was sufficient to obtain prepregs which would not crumble and at the same time would not be deformed too much, which would also have the adverse effect on their quality, as the excessive air pressure in the closed pores causes breaking the prepreg up when it is taken out from the die.

Aluminium containers filled with the compacted composite powders featured the charge for extrusion. These prepregs were heated to the temperature of 480-500˚C and were extruded at 500 kN load. The die walls were lubricated with the zinc stearate to attain slide during charge extrusion. The O.D. 8 mm bars were obtained as the final product, enclosed in a thin aluminium sheath.

To evaluate the heat treatment effect on properties and corrosion resistance some of the composite materials were hyperquenched for 0.5 h at the temperature of 495ºC with the subsequent cooling in water, and were quench aged next for 6h at 200°C.

2.2. Experimental procedures

Hardness tests of the fabricated composite materials were made on HAUSER hardness tester with the Vickers method at 10 N load, according to the Polish Standard PN-EN ISO 6507-1. Seven indentations were made on the transverse section diameter for specimens taken from bars obtained by extrusion, both for the EN AW- Al Cu4Mg1(A) aluminium alloy and for the fabricated composite materials reinforced with the Ti(C,N) phase particles, to determine their average hardness.

Abrasion resistance wear tests were carried out using the device designed at the Faculty of Mechanical Engineering of the Silesian University of Technology. Test pieces were 30 mm long. Preparation of the test pieces for tests consisted in grinding with the 1200 grit abrasive papers, to obtain four flat and even surfaces. Tests were carried out on surfaces prepared in this way using the steel balls with 8.7 mm diameter as the counter-specimens.

Tests were carried out with the constant number of cycles of 5000 (120 m) at various loads: 4, 5, 6, 7, and 8 N. Test pieces were rinsed in the ultrasonic washer to clean them and next were weighed on the analytical balance with the accuracy of 0.0001 g to check the mass loss.

Additionally wear rate were determined based on the wear track width measurements. Leica MEF4A microscope with the image analysis system were employed to this tasks. For every single track 20 measurements were performed along the track length to determine the mean width.

3. Results and discussion

Hardness tests of the fabricated composite materials revealed its diversification depending on the weight ratios of the reinforcing particles in the aluminium matrix.

Mean hardness values of the aluminium alloy and of the fabricated composite materials reinforced with the Ti(C,N) ceramic particles with the weight ratios of 5, 10 and 15% are shown in Table 1.

Table 1.
Hardness of the matrix from the EN AW-Al Cu4Mg1(A) aluminium alloy and composite materials (A-before the heat treatment, B-after the heat treatment)

Material	Hardness HV1	
	A	B
EN AW-Al Cu4Mg1(A)	89.3	97.7
EN AW-Al Cu4Mg1(A)/5%Ti(C,N)	98.6	104.7
EN AW-Al Cu4Mg1(A)/10%Ti(C,N)	100.4	109.8
EN AW-Al Cu4Mg1(A)/15%Ti(C,N)	143.2	164.4

Investigated composite materials are characterized by an higher hardness compared to the non-reinforced material. Hardness of composite materials increases with increasing content of the reinforcing material in the metal matrix.

Heat treatment carried out caused hardness increase and, like in case of the composite materials before their heat treatment, the hardness grows along with the volume portion increase of these particles in the matrix.

Wear of the investigated materials versus load change at the constant distance is of a linear character. Many factors affect the mass loss after the wear tests of the composite materials: hardness of the obtained composite materials, shape and dimensions of the reinforcement particles, and also values of load between the test piece and the counter-specimen. Mass loss of the composite material decreases along with the increase of the portion of the Ti(C,N) particles in the matrix (Figure 1a).

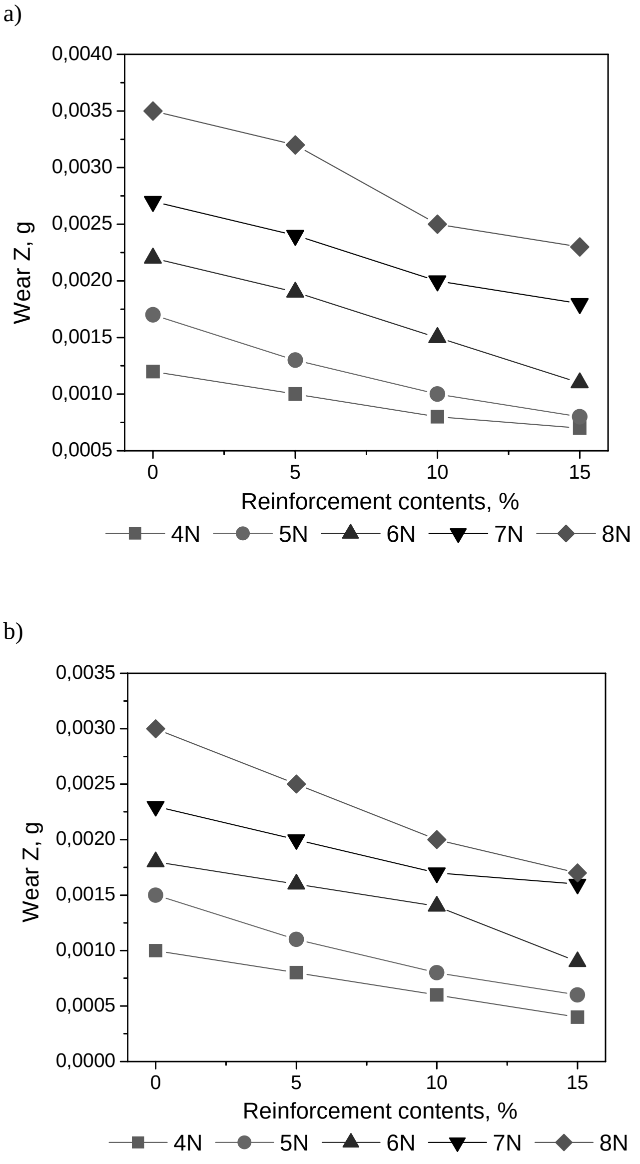

Fig. 1. Wear of the aluminium alloy and composite materials in the following states: a) before the heat treatment, b) in the precipitation hardened state, at various load values, N

The cause of the lower wear of the investigated composite materials containing more reinforcing phases is a phenomenon of "protruding" of the reinforcing particles over the friction surface. The bigger is the surface portion of these reinforcing particles in the matrix, the bigger part of the load they carry between the chafing surfaces. Thanks to this phenomenon the soft aluminium matrix wears more slowly, and therefore the entire composite material is characteristic of a smaller mass loss. The size of the Ti(C,N) (≤ 25 μm) reinforcing particles also adds to the wear resistance improvement.

Heat treatment carried out resulted in the wear resistance improvement of the matrix material and of the fabricated composite materials (Figure 1b) because of decreasing the presence and sizes of the intermetallic precipitations occurring in the structure of the investigated materials.

Figures 2 a, b shows microphotographs of wear tracks produced during the wear tests of investigated composite materials. One can see the nature and course of the trybological destruction. The wear rate is proportional to the applied load and inversely proportional to the reinforcing particles contents (Figure 3).

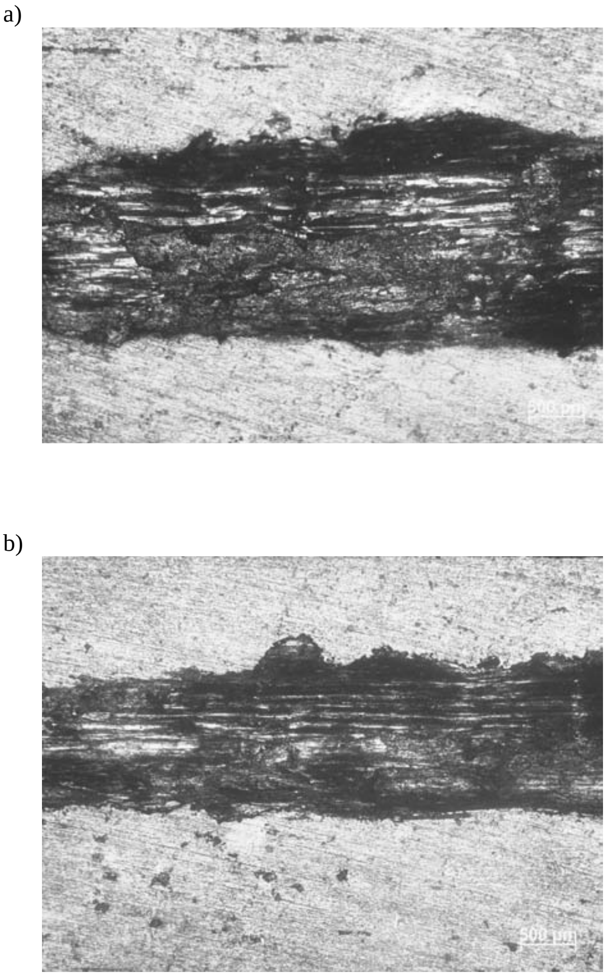

Fig. 2. Structure of wear track of the aluminium alloy and composite materials in the following states: a) before the heat treatment, b) in the precipitation hardened state

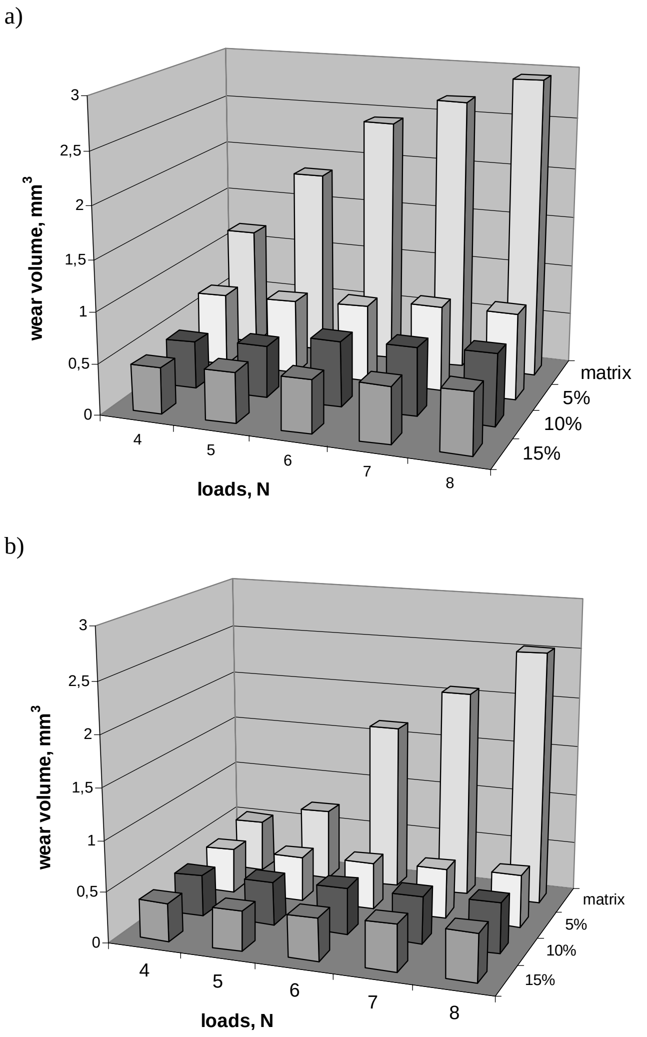

Fig. 3. Wear volume of the aluminium alloy and composite materials in the following states: a) before the heat treatment, b) in the precipitation hardened state, at various load values, mm^3

4. Conclusions

Introducing the hard Ti(C,N) particles into the soft matrix from the aluminium alloy causes hardness increase. Hardness of composite materials grows along with the increasing portion of the reinforcing material in the metal matrix. Precipitation hardening causes additional hardness increase of the investigated materials.

Moreover, addition of the Ti(C,N) reinforcing particles in the soft matrix from the aluminium alloy causes also increase of the abrasion wear resistance. The wear rate is proportional to the applied load and inversely proportional to the reinforcing particles contents. The precipitation hardening process caused wear resistance growth.

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