SURFACE LAYERS BY WEAR TESTS OF PARTICULATE METAL MATRIX COMPOSITES

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ABSTRACT

The dry sliding wear behaviour of varying weight fraction of SiC particles reinforced AK12M2MgN aluminum alloy metal matrix composites (MMCs) fabricated by a vortex method was investigated using a pin-on-disk tester CETR UMT. The effect of SiC particle content on the friction coefficient and wear resistance has been evaluated. The formation on friction surface of mechanical mixed layers consisting of debris and fragmented SiC particles was indentified using a optical and a scanning electron microscopes.

Key words: composite materials, coefficient of friction, wear resistance, friction surfaces, mechanically mixed layers.

INTRODUCTION

Metal matrix composite materials (MMCs) which consolidate the plastic metal and refractory high-strength high-modulus fillers are increasingly used instead of the traditional anti-friction materials [1, 2]. Such substitution can increase the carrying capacity of bearings and extend the temperature ranges of operation. Studies of the structure and properties of the new MMCs is the actual problem. The aim of the work was to study the effect of the weight fraction of SiC particles in the aluminum alloy matrix on formation of the surface layers at friction and tribological properties of the MMCs.

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

MMCs was prepared by mechanical mixing (vortex method) of discrete refractory fillers into the matrix melt. The composition of the samples is presented in *Table. 1*. Foundry aluminum alloy AK12M2MgN was used as the matrix, green silicon carbide particles (SiC) were ceramic fillers with an average size of 14 microns. The particles were injected into the melt AK12M2MgN heated to 750 $^{\circ}$C, and stirred for 1 min.

Wear tests was conducted on the multifunctional setting CETR UMT Multi-Specimen Test System for mechanical loading on scheme "pin (contrbody of hardened steel, 63HRC) on the disk (MMCs)" with the recording charts of loads and friction coefficient.

Table 1– The composition of the samples

Number of samples	Composition of the samples
1	AK12M2MgN
2	AK12M2MgN + 3,8 %SiC
3	AK12M2MgN + 7,7 %SiC
4	AK12M2MgN + 15 %SiC

The tests were conducted at five consecutivestages of loading 0.21, 0.33, 0.46, 0.59 and 0.7 MPa. Duration of tests at eachload was 10 min. Sliding velocity was equal to 0.37 m / sec. The wear rate was determined by weighing the sample before and after a full cycle tribotetst and calculated by the formula $I_m = \Delta_m / L$, where Δm - weight loss, L – friction way. Hardness and Young's modulus of the surface of the original samples and surfaces after friction were performed on the set CETR UMT by the method of Vickers Indentation by load 50 gr. In this case the mechanical properties of the MMCs can be determined directly from data on the load and displacement during indentation without the need to visualize the imprint. The data needed to calculate the hardness and Young's modulus are the maximum load, maximum indenter displacement of the indenter and the elastic stiffness during unloading, defined as the slope of the curve at the initial stage of discharge. The friction surface was analyzed by optical microscopy, SEM and EDS.

RESULTS AND DISCUSSION

Figure 1 shows typical changes in the load and the coefficient of friction during the tests. The areas of material adaptability of the friction pair can be identified on the curve of the coefficient of friction. Also areas with varying stability coefficient of friction can be selected/ Thus, the duration of the adaptibility of the matrix alloy AK12M2MgN not was exceed 2 minutes. The coefficient of friction f in the first stage of loading (0.21 MPa) was minimal and amounted to 0.41. Probably, oxide film Al_2O_3, which protects the matrix from removing, remains under such a load on the friction surface of matrix sample. When the load increases from 0.21 to 0.33 MPa the increase of coefficient of friction to f = 0.5, and then its stabilization, or output to normal regimen, with f = 0.46 were observed. Such behavior of the curve of the friction coefficient depending on the load was attributed to the formation of the secondary structures on the friction surface [3]. Occasional bursts of values of the friction coefficient may be related to the phenomenon of seizure-slip when materials of tribopair in actual contact spots at the moment form the adhesive joins, which are then broken in shear. Duration of adaptability of MMC AK12M2MgN + 3,8 % SiC was 5 min. Then the friction process proceeded steadily with constant coefficient of friction f = 0.39 and some deterioration of stability with increasing loads. Adaptability MMC AK12M2MgN + 7,7 % SiC lasted 18minutes.

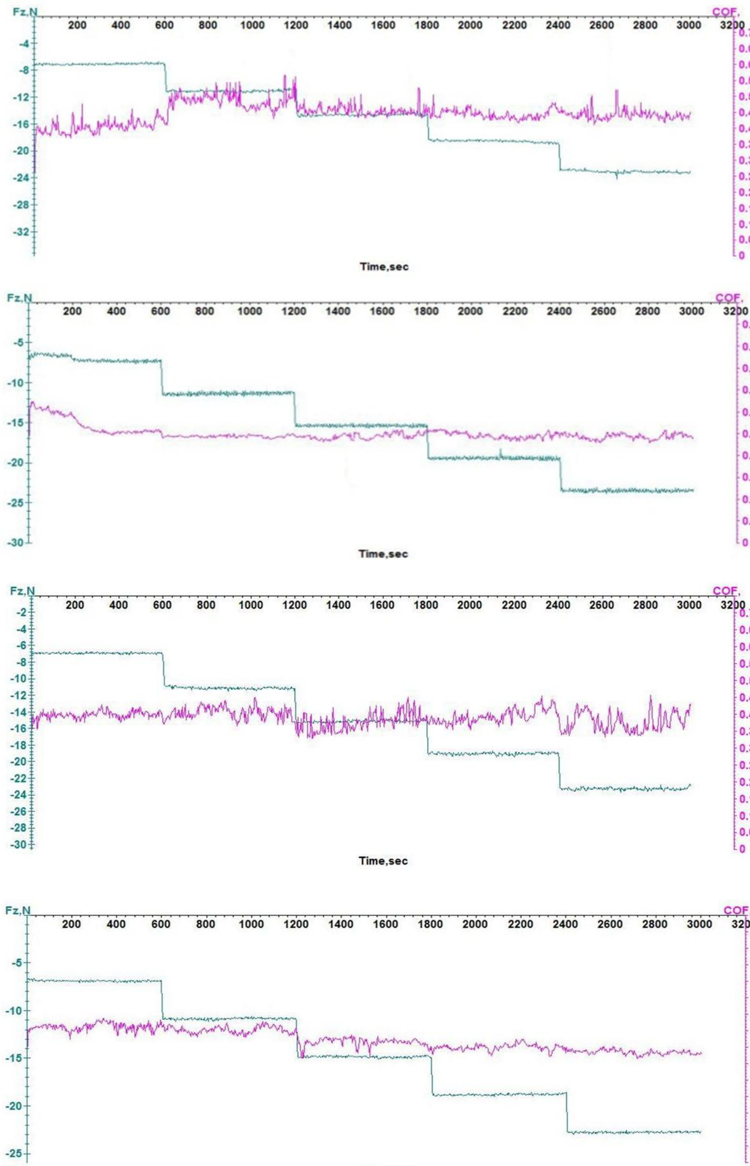

Fig. 1 – The profile of the load and friction coefficient of the matrix alloy AK12M2MgN (a), and samples of MMC AK12M2MgN + 3,8 % SiC (b), AK12M2MgN + 7,7 % SiC (c) AK12M2MgN + 15 % SiC (d).

With increasing load the friction process stability deteriorated. In normal regimen f = 0.38. Samples of MMC AK12M2MgN + 15 % SiC adapted in 21 minutes. Further, the friction process proceeded steadily with the constant reduction in the coefficient of friction to f = 0.35. An increase in the duration of the adaptability of the samples with high content of SiC may be attributed to the increasing number of high abrasive particles in tribocontact.

The cross-section of sample AK12M2MgN + 7,7 % SiC in the area of the friction track is shown in *Figure 2*. It can be seen the forming a surface layer, differed by the dispersion and composition fromthe base material, crushing the reinforcing phase near the surface friction, the plastic shift in the underlying layers. View by SEM of the surface friction reveals the areas morphologically different from the overall picture of the friction surface where there are ridges and grooves in the sliding direction (*Fig. 3*). According to [4], these areas are transition layers, which are a mechanical mixture of the matrix material, rider, their oxides and fragments of reinforcing particles. These transition layers protect the surfaces of the samples of the MMC of direct contact metal / metal, extending triboload range up to the seizure. The area on the friction surface occupied by the transition layers increases with increasing content of SiC particles in the MMC. According to the results energy dispersive spectroscopy, the amount of Fe in the surface layer of samples with big content of SiC particles is maximal after tribotest.

Analysis of the data (Fig. 4) shows that with increasing content of SiC particles in MMC a decrease of wear rate is. The particles of SiC in the MMCs play the role of supports, which accept most of the load and protect the matrix from wear. For a given cycle of triboloads value of wear intensity I_m of the sample AK12M2MgN + 15 % SiC reduced by half compared with the matrix. In the case of larger loads by tribotest the increase of wear resistance MMCs will be more visible [5].

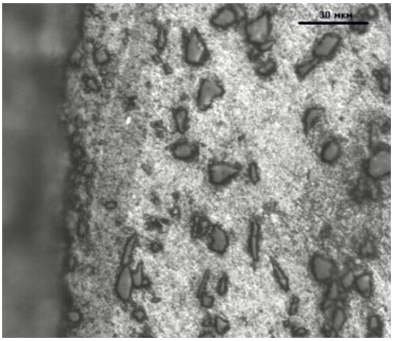

Fig. 2– The cross-sectional sample KM AK12M2MgN + 7,7 % SiC

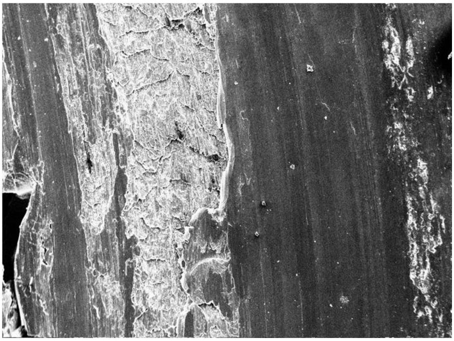

Fig. 3– Transition layers on the friction surface of the sample KM AK12M2MgN +7,7% SiC

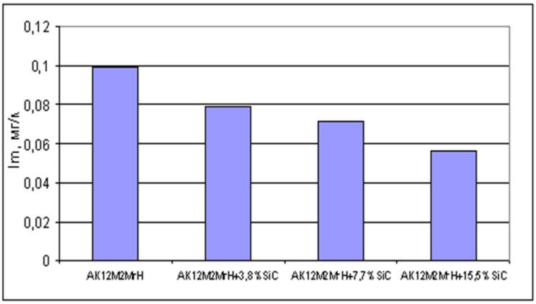

Fig. 4.– The wear rate of the samples

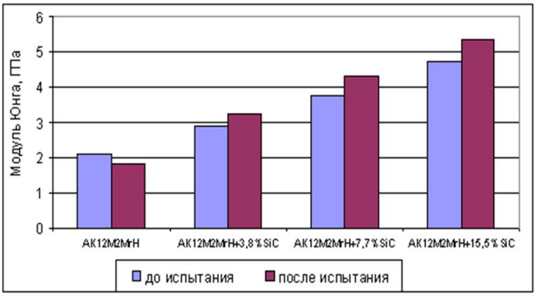

Fig. 5– Young's modulus of the samples measured before and after tribotests on the track of friction

The values of Young's modulus, as in the initial state well as on the wear track increases with increasing of the content of SiC particles in MMCs (*Fig. 5*). Noticeably gronth of modulus has taken place on friction. The greatest hardening was detected in the sample MMC AK12M2MgN + 15 % SiC(0.7 GPa). The exceptions are the results of measurements of Young's modulus of the matrix alloy. The observed softening of the friction surface alloy AK12M2MgN after the complete test cycle may be due to the strong frictional heating and the approach to seizure at the last stage of testing.

CONCLUSIONS

Conducted wear tests showed that the introduction in the matrix alloy AK12M2MgN the particles SiC increases the duration adaptability, increasing the stability of the process of friction, reduced coefficient of friction. The increase of content of SiC particles reduces the wear rate of the MMC. The particles of SiC in the MMCs play the role of supports, which accept most of the load and protect the matrix from wear. The increase of Young's modul indicates a hardening of the surface of the MMCs during sliding.

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