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Effect of mechanical properties of matrises on the tribological behaviour of particulate reinforced aluminium alloy composites

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In recent years increasing interest is being focused on the tribological performance of metal matrix composites (MMCs). The complex wear tests show that tribological behavior of MMCs depends on the testing conditions (i.e. type of contact applied load and speed of relative motion) as well as on material parameters, such as properties of the reinforcing phase (nature, size, geometry and hardness), properties of the matrix (strength and ductility) and also characteristics of the bonding between reinforcing phase and matrix.

The present work was undertaken to investigate the tribological behavior and wear resistance of three unreinforced Al-alloys (AMr1, AJI2, AJI25) with different mechanical properties (Table1) and three Al-alloy MMCs containing 5% (Volum fraction) SiC particles under dry sliding conditions against X40 steel counterface. The test was carried out using the test wear machine YMT-1 at applied axial loads in the range 70-180 N and sliding speeds in the range 0.38－1.88 m/s (300-1500 R.P.M.). Specimens of MMCs were produced by stir casting route by adding to Al-melt the SiC-particles with average size 28 mm. Microstructure of MMCs, evolution of friction surface layers, wear scars and debris were characterized by means of optical microscope, SEM with EDS analyzer and X-ray diffraction (XRD) analysis. The cast MMCs show fine dendrites formed in the Al-matrices by freezing and macroscopically homogenous distribution of SiC particles in them. Fig.1 shows the typical worn surface morphology and microstructure cross section of the composites tested under dry sliding condition at applied constant load of 108 N on the sliding distance of 1000 m. A depth of plastic subsurface deformation of MMCs changes from 150mm to 70 mm with increasing strength of Al-matrices. It can be seen also the presence of the thin mixed layer (<10mm) on worn surface. SEM micrographs of debris which were removed from the worn surface of MMCs under wear test are shown in Figs.2. Results of wear test are shown in Table 2 and Figs.3 and 4. As can be seen tribological behavior of the MMCs is better than that of the unreinforced alloys. Both the wear and seizure resistances are increased with increasing strength of Al-matrices. The friction interaction of the MMCs/steel was interpreted on the basis of the "third body" or mechanically mixed layers, in which constituents varied depending on the sliding loads. According SEM and XRD analyses at a low load mixed surface layers mainly consisted of the original base materials, i.e. Al (Mg, Si, Cu), SiCp and Fe from both the contacting sur-

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faces. With an increase in sliding loads surface layers and debris were incorporated with Fe-Al intermetallic phases and aluminium and iron oxides as result of mechanical alloying and oxidation caused by the large amount of plastic deformation in association with frictional heating. These mixed layers are believed to be protection layers, which probably shifted the transition from mild to severe wear regimes to higher critical loads.

Table 1 Characteristics of the matrix alloys

Alloy	Metallic composition / % (mass fraction)										Mechanical properties		
	Si	Cu	Mn	Mg	Zn	Ti	Ni	Fe	Cr	Sn	σ_b, MPa	$\sigma_{0.2}$ MPa	δ, %
AMr1	<0.05	0.01	-	0.5-1.8	-	-	-	0.01	-	-	80-120	50	28
AJI2	10-13	<0.6	<0.1	-	0.08	<0.1	<0.1	<1.0	-	-	150	90	4
AJI25	11-13	1.5-3.0	0.3-0.6	0.85-1.35	<0.5	0.05-0.2	0.3-1.3	<0.8	<0.2	<0.1	290	160	1.5

Table 2 Composition of the specimens for tribological examination and condition of "seizure"

№	Composition	HB, MPa	Parameters of seizure		
			Load P, N	R.P.M.	Duration to seizure, min
1	AMr1	300	70	300	0.2
2	AJI2	624	70	600	12
3	AJI25	990	108	1000	6
4	AMr1-5%SiC	660	70	600	5
5	AJI2-5%SiC	712	144	1000	10
6	AJI25-5%SiC	1030	180	1500	5

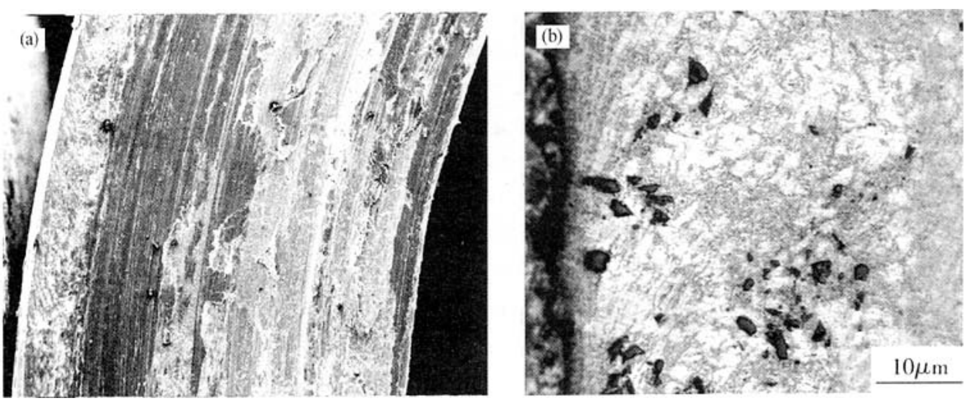

Fig.1 SEM of worn surface (a) and optical micrographs of cross section of MMC after wear test (b)

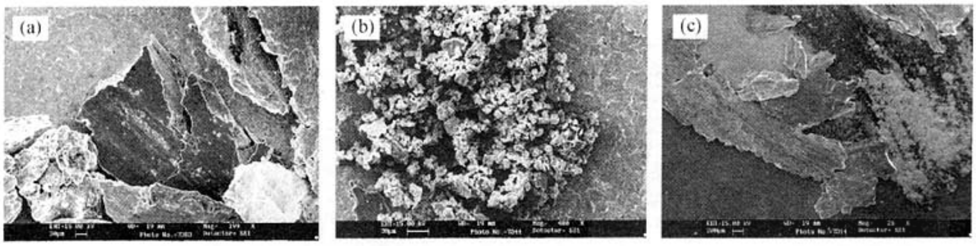

Fig. 2 SEM micrographs of wear fragments collected at the end of the test at varied applied loads: plate-like flaken (a), fine equiaxed particles (b) and a mixture of particles and flakes (c)

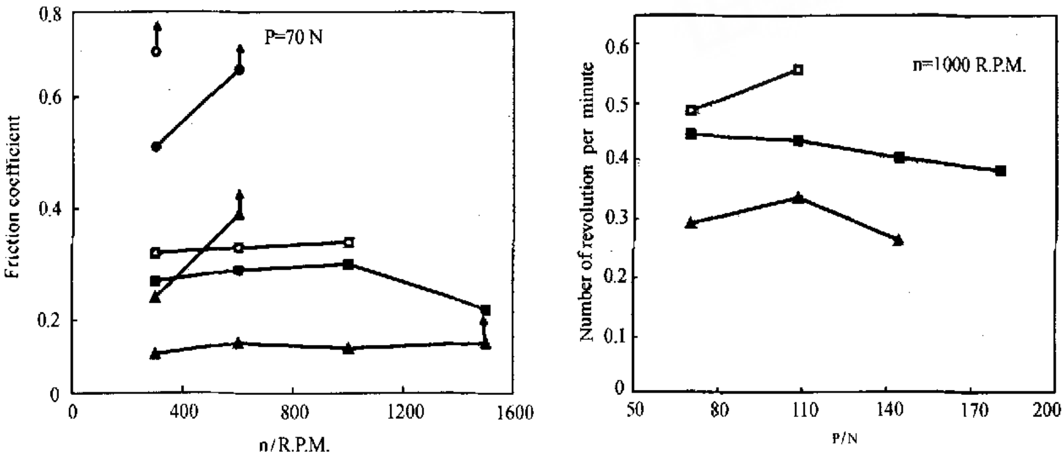

Fig. 3 Coefficient of friction of MMCs versus the sliding speed (a) and the applied load (b)

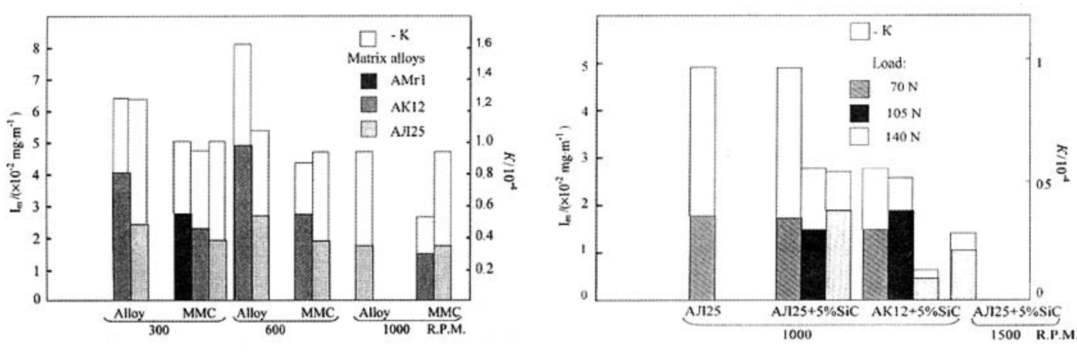

Fig. 4 Sliding wear rates I_m and wear coefficients K of MMCs versus the sliding speed (a) and the applied load (b)

Wear coefficient K by the Archard wear equation: $K = \frac{I_m H}{\gamma P}$

where I_m is the mass wear rate, P is the applied load, H is the material hardness and γ is specific gravity.