Synthesis and tribological properties of AA5052 base *insitu* composites

Gaurav Gautam[1], Narendra Kumar[2], Anita Mohan[1,*], Sunil Mohan[2], R.K. Gautam[3]

[1)] Faculty of Physics, IIT (BHU) Varanasi-221005 India.
[2)] Faculty of Metallurgical Engineering, IIT(BHU) Varanasi-221005 India.
[3)] Faculty of Mechanical Engineering, IIT(BHU) Varanasi-221005 India.

[*]Corresponding e-mail: amohan.app@iitbhu.ac.in

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ABSTRACT – In this present study, three insitu composites have been produced with different reinforcement of Al_3Zr, ZrB_2 and Al_3Zr+ZrB_2 in AA5052 alloy matrix by direct melt reaction (DMR) technique. These composites were characterized by XRD for phases present, for morphology under SEM. Mechanical properties have been evaluated in detail and tribological properties have been studied under dry sliding wear conditions for all composites for different variables such as sliding distance and applied loads. XRD and SEM results show the successful formation of reinforcements. The mechanical and wear test results shows that Al_3Zr+ZrB_2 reinforced AA5052 composite has the superior mechanical properties and wear resistance among all composites. This composite could be a suitable substitute for existing materials for applications related to automobile, aero-space and marine applications.

1. INTRODUCTION

Aluminium matrix composites (AMCs) exhibit superior specific strength, specific modulus, damping capacity and wear resistance as compared to monolithic materials [1]. Al-Mg alloy has moderate-to-high-strength, work-hardenable, good welding characteristics and high resistance to corrosion in marine environment [2]. Al_3Zr and ZrB_2 are considered as potential reinforcements to this alloy because Al_3Zr has low density, high melting point and high elastic modulus with excellent resistance to oxidation and corrosion [3] while ZrB_2exhibitsunique combination of mechanical and physical properties, high melting points, good thermal and electrical conductivities [4].

Based on above mention properties of base alloy and reinforcement, in this present study, three composites have been fabricated with different reinforcement Al_3Zr, ZrB_2 and Al_3Zr+$ZrB_2$by DMR technique. These composites are characterized for morphology, mechanical and tribological properties under dry sliding conditions.

2. METHODOLOGY

In the present study, the starting material was AA5052 alloy and inorganic salts K_2ZrF_6, KBF_4. Initially, inorganic salts were pre-heated in an electric oven at 250°C for 3 hours to eliminate the moisture content, simultaneously, AA5052 alloy was brought to melt condition and heated to 885°C temperature in the graphite crucible kept in vertical muffle furnace. The dehydrated powders were added in required amount while stirring the melt until insitu reaction was complete and melt was bottom poured into a mild steel mould. The composition of as cast composites with designation is shown in Table 1.

The phases present in the composites were identified by Rigaku Miniflex II X-ray diffractrometer. FESEM Quanta 200FEG scanning-electron microscope (SEM) was used to study morphology of particles and their distribution in the composites. Tensile tests were carried out at room temperature at a strain rate of 1.07 $\times 10^{-3}$ s^{-1} using a 100 KN screw-driven Instron™ Universal Testing Machine (Model 4206). The bulk hardness of the composites was made by Aktiebolaget Alpha Brinell hardness testing machine. Dry sliding wear test were carried out at room temperature on a pin-on-disk wear and friction tester (DUCOM, Bangalore, India, model: TR20-LE) for various distance and load.

Table 1 Composition and designation of composites.

S.N.	Designation	Compositions
1	C0	AA5052 alloy
2	C1	10 vol.%Al_3Zr/AA5052
3	C2	3 vol.%ZrB_2/AA5052
4	C3	10 vol.%Al_3Zr+3 vol.%ZrB_2 /AA5052

3. RESULTS AND DISCUSSION

Figure 1 shows the XRD pattern of the as cast AA5052 base alloy and composites synthesized from AA5052 alloy and inorganic salts using direct melt reaction method. XRD analysis of peaks indicates the presence of Al, Al_3Zr and ZrB_2 phase which confirm the successful formation of second phase reinforcement in AA5052 alloy matrix. The possible reactions between the alloy and salts to form the Al_3Zr, ZrB_2 and Al_3Zr+ZrB_2 reinforcement particles take place in the following sequence:

$$3K_2ZrF_6+13Al \rightarrow 3Al_3Zr+4AlF_{3(g)}+6KF_{(g)}$$
$$3K_2ZrF_6+6KBF_4+10Al \rightarrow 3ZrB_2+9KAlF_{4(g)}+K_3AlF_{6(g)}$$
$$3K_2ZrF_6+2KBF_4+12Al \rightarrow ZrB_2+2Al_3Zr+2KAlF_{4(g)}+4AlF_{3(g)}+6KF_{(g)}$$

Figures 2a-d show the SEM micrographs of composites. Al_3Zr particles are uniformly distributed in the alloy matrix in two shapes namely, polyhedron and rectangular in micron size as shown in Fig. 2a. ZrB_2particles are uniformly distributed in hexagon and rectangular shapes in nano to micron size as evident from Fig. 2b and Fig. 2c at higher magnification. Figure 2d indicates the presence of Al_3Zr and cluster of ZrB_2 particles.

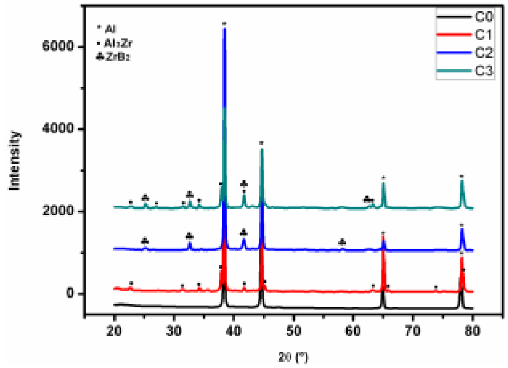

Figure 1 XRD pattern of composites with base alloy.

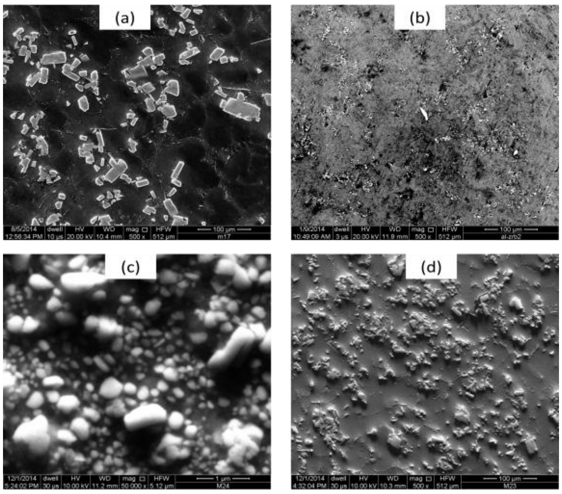

Figure 2 SEM micrographs of composites (a) C1, (b) C2, (C) Morphology of ZrB_2 particles, (d) C3.

Table 2 shows the tensile properties and hardness of composites and base alloy. It is observed that with incorporation of Al_3Zr and ZrB_2 particles in base alloy, tensile properties are improved when reinforced with different particles and it is highest in case of Al_3Zr $+ZrB_2$ reinforced composite. It is interesting to note that %elongation of all composites is superior to base alloy.

Table 2 Tensile properties and hardness of composites and base alloy

S. N.	Alloy/ Composites	UTS (MPa)	0.2% YS (MPa)	Elongation (%)	Bulk hardness (BHN)
1	C0	89.0	59.0	6.0	26
2	C1	106.2	64.4	12.88	35
3	C2	129	71	16.5	38
4	C3	150.3	116.5	13.01	47.5

Figures 3a-b show the variation of wear rate and average coefficient of friction for base alloy and composites with different reinforcement at 1 m/s sliding velocity and different normal load. It is observed that wear rate continuously increases with an increase in normal load (Fig. 3a) while average coefficient of friction shows an opposite trend (Fig. 3b).Figure 4a shows the variation of cumulative weight loss and average coefficient of friction with sliding distance for base alloy and composites with different reinforcements at 40 N normal load and 1 m/s sliding velocity. The Bulk wear continuously increase with sliding distance but with incorporation of reinforcement bulk wear decreases, however, a fluctuating tendency is observed in case of coefficient of friction with sliding distance as observed in Fig. 4b. Figures 5a-b show the variation of wear rate and coefficient of friction for all compositions at 1 m/s sliding velocity. Minimum wear rate is observed in the $(Al_3Zr+ZrB_2)$/AA5052 composite (Fig. 5a), whereas coefficient of friction is higher (Fig. 5b) as compare to other composites and base alloy.

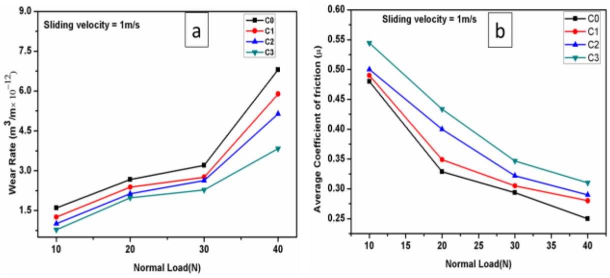

Figure 3 (a) variation of wear rate with normal load, (b) variation of average coefficient of friction with normal load.

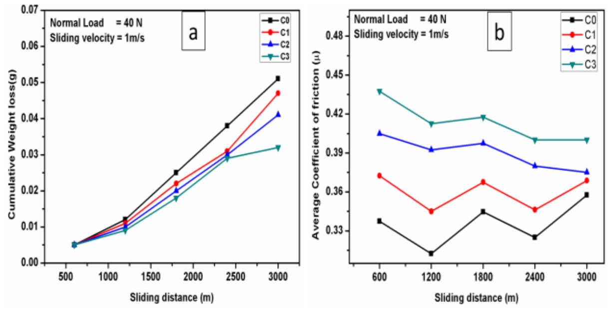

Figure 4 (a) variation of cumulative wear with distance and (b) variation of average coefficient of friction with distance.

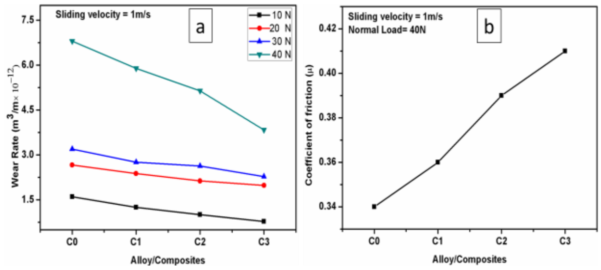

Figure 5 (a) variation of wear rate with composition, (b) variation of coefficient of friction with composition.

4. CONCLUSION

From the present study, the following conclusions may be drawn:

1) The AA5052 base composites reinforced with Al_3Zr, ZrB_2 and $Al_3Zr+ZrB_2$ can be successfully fabricated by DMR route.
2) The Al_3Zr particles are in polyhedron and rectangular shapes, while ZrB_2 particles are in hexagonal and rectangular shapes
3) Maximum improvement in UTS and YS is observed in the $Al_3Zr+ZrB_2$ reinforced composite.

4) Percentage elongation in all composites is higher than base alloy.
5) Cumulative weight loss and wear rate increases with increase in the sliding distance and normal load.
6) Minimum wear rate is observed in the $(Al_3Zr+ZrB_2)/AA5052$ composite, while coefficient of friction is higher.

5. REFERENCES

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