ABSTRACT

Aluminum Metal Matrix Composites (AMC's) are increasingly used in the field of automobile, aerospace, nuclear and electronic industries due to their attractive properties such as elastic modulus, hardness, tensile strength and wear resistance. However, their high cost and weight of Al alloys or composites made them as expensive sources in restricting their use. In this context, reinforcing the AMC's with suitable particulate materials such as silica carbide (SiC), boron carbide (B_4C), graphite, fibres and fly ash prove to be advantageous over unreinforced Al alloy due to their less cost and high formability. Reinforcing aluminium alloy with Boron carbide and graphite particles imparts high specific strength and elastic modulus coupled with good wear resistance and thermal stability. Hence an attempt has been made in the present investigation to fabricate hybrid aluminium composites (Al/ B_4C/Graphite), characterize their mechanical, physical, tribological and ECAP behaviour.Al7.1Si0.3Mg alloy was selected as matrix material and reinforced with B_4C in varying amounts (3, 6, 9 and 12 wt. %) along with constant 3 wt.%Gr to produce hybrid composites by stir casting techniques. Unreinforced Al alloy specimens were also casted for comparison with the hybrid composites. Micro structural investigations of hybrid Al composites containing B_4C and Gr through optical microscopy showed uniform distribution of spherical B_4C particles and angular Gr particles in a dendritic Al alloy matrix. Density of hybrid composites decreased with increasing B_4C/graphite particles reinforcement. Density of Al/12B_4C/3Gr hybrid composite was the lowest among all the hybrid composites.

Hardness of the hybrid composites increased with increasing % B_4C reinforcement and the highest BHN was observed at 12 % B_4C.Higher strength of boron carbide (9.30 Moh) might have contributed to increased

strength of hybrid composites. Al/12 B_4C/3Gr hybrid composite exhibited the highest Brinell hardness value of 115 which was 76.92% improvement over Al alloy. Ultimate tensile strength of Al/9B_4C/3Gr hybrid composite was the highest among all hybrid composites (187MPa) showing 16.9% increase over unreinforced Al alloy.However increasing the B_4C reinforcement beyond 9 wt % did not show a considerable increase in tensile strength. On the other hand, elongation to fracture of the unreinforced aluminium alloy was the highest at 4.0%. Al/9B_4C/3Gr hybrid composite showed a reduction in ductility when B_4C content increased from 0 to 12 wt%.Fracture of hybrid composites showed a mixed morphology involving brittle and ductile fracture.

Wear rate and COF of the composites increased with increasing load and the highest wear was observed at 30 N load for all the sliding speeds at a constant sliding distance of 2500m. Maximum wear rate was observed in unreinforced Al alloy and the lowest wear rate was noted in Al/9B_4C/3Gr composites which were attributed to the significant improvement in resistance due to B_4C and Gr particles reinforcement. SEM investigations carried out to follow the progress of wear under various applied load showed that adhesive wear is a severe wear regime characterized by very high wear rates, COF, plastic deformation at 30 N, and in extreme cases it leads to seizure. Wear resistance increased with increasing B_4C reinforcement upto 9% in the hybrid composites and with B_4C above 9wt% decreased the wear resistance. Among the hybrid composites, Al/9B_4C/3Gr composite exhibited the highest wear resistance and the lowest COF at all applied loads. Wear loss of Al alloy was the highest at a load 30N and decreased with sliding speed which might be due to the decrease in particle retention time for abrasive. Increasing the sliding speed led to abrasive wear causing pull out of abrasive material on the surface and forming loose abrasive debris. Higher wear rate was observed at a sliding speed of 1m/sec which decreased thereafter with increasing sliding speed. Presence of B_4C reinforcement resulted in the lesser amount of debris and delamination even at higher sliding speeds. Al/3B_4C/3Gr recorded the highest wear rate while Al/9B_4C/3Gr composite exhibited the lowest wear rate at all the levels of sliding speed and load. SEM investigations showed formation of delamination crater which was extensive upto the sliding speed of 2 m/s for all applied loads in the unreinforced Al alloy. Higher sliding speed (3m/s) and oxide wear debris filled out the valleys on the pin surface which subsequently get compacted into a protective layer.

Taguchi DOE was used to study the influence of parameters and their interactions on the wear rate of hybrid composites. S/N ratio increased linearly with increasing sliding speed as well as % B_4C reinforcement. However, applied load showed a negative relationship with S/N ratio. Higher S/N ratio was noted at a normal load of 10N and 9 % B_4C reinforcement at a sliding speed of 3 m/s. Hence the wear variable combination of 10N load (L), 3m/s Sliding speed (S) and 9wt%B_4C/3%Gr reinforcement was found to be the optimum test parameters giving the lowest wear rate. ANOVA analysis indicated that, load was the most influential parameter having the highest statistical influence (54.5%) on dry sliding wear rate of Al-B_4C composites, followed by sliding speed (29.28%) and B_4C reinforcement (4.95%). Interactions between load and sliding speed exhibited very less statistical influence on wear rate (0.467%). The value of regression coefficient (R^2) calculated for this model was 0.899 which is reasonably close to unity, and hence acceptable. Confirmation wear tests conducted with various wear parameters indicated a very little error (2 to 5 %) between the experimental and predicted values from the regression model. SEM investigations also confirmed the validity of the model.

Dry sliding wear tests conducted on both hybrid composites as well as unreinforced Al alloy revelaed a increased wear with increasing temprature which varied with the composition of composites. At low temp (25^0 C) very limited wear was noticed for all the composites. Higher wear was observed with Al alloy. In contrast, fine, smooth and lesser number of wear scars was observed in the reinforced hybrid composites of Al/9 % B_4C / 3wt% Gr which indicated the higher wear resitance of these materials. At 50^0C, delamiantion of the surface occured which subsequently melted and formed large number of adhesions. On increasing the temperature to 100^0C, severe wear in both Al alloy and hybrid composites was observed. In the severe wear regions, deeper and wider groves are evident. Poor interfacial bonding and excess particles upon aberation with higher temprature results in defoliation of layers in the hybrid composites and forming wider-deeper grooves and debris at constant applied load of 20 N and sliding distance of 2500m.ECAP significantly increased the tensile strength and ductility by altering the microstructure. The Al alloy prone to ECAP showed large sized grains in its microstructure. Reinforcement of B_4C linearly increased the tensile strength and ductility of Al composites up to 9 % after ECAP but showed a decreasing trend at 12 % reinforcement. The mechanical properties of both Al alloy and its hybrid composites increased with increasing number of ECAP passes. SEM observations on fracture surfaces for both un-pressed Al alloy and two pass ECAP processed hybrid aluminum composites showed planar and fine-grained surface with ductile fracture of Al alloy. However in hybrid composites, shear fracture with debris pull-out was observed indicating the plastic deformation prior to fracture.