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Three-Body Abrasive Wear Behavior of Al-8011 alloy Reinforced with Graphite and Red Mud Particulates

[1] Anil.K.C,[2] Sachin Gadge, [3] Rishabh Kumar Srivastva [4]K.V.Sreenivas Rao
[1]Assistant Professor, Department of Industrial Engineering and Management,
[2][3]Research Students, [3]Professor, Department of Mechanical Engineering
Siddaganga Institute of Technology, Tumakuru, Karnataka, India

***Abstract*- Aluminum Metal Matrix Composites have been in extensive demand due to their promising properties with respect to space, aerospace and automobile applications. In the present research work aluminum-red mud particulates (Al-RMp) &aluminum-graphite particulates (Al-Grp) reinforced composites were synthesized by traditional stir casting route. The reinforcement was varied from 4wt% to 20wt% in steps of 4wt%. The composites thus prepared were subjected to 3-body abrasive wear test as per the ASTM-G65 standard with three different loads of 10kg, 20kg and 30kg. The test was conducted for three different time periods of 10min, 20min, and 30min. The rotational speed of rubber wheel was set to 200rpm.The feed rate of the silica particles of 400 microns size were 280±10 g/min. The specimens were also tested for hardness. The experimental results indicate that the hardness and the wear resistance of the composite increases with the increase in the addition of reinforcement particulate. Al-RMp composites exhibit higher hardness and better wear resistance compare to Al-Grp composites. Hardness and wear loss is quantified for all the test samples and reported.**

***Keywords:* 3-body abrasive wear, Red mud particulates, ASTM-G65**

I. INTRODUCTION

In the recent years, usage of composites is steadily increasing due to their better physical properties and mechanical properties. The prepared composite will be stronger, lighter and economic than the constituting materials, which form that composite. Composites are further classified in metal matrix composites(MMC's), Polymer matrix composites(PMC's)and Ceramic matrix composites(CMC's) based on the type of matrix material [1].Due to Wide Range of applications in aircraft components, space systems and high-end or "boutique" sports equipment's, MMC's are the most promising composites. MMC's have higher Temperature capability, higher transverse stiffness and strength and higher electrical and thermal conductivity [2]. In particular Aluminium 8011 exhibits good properties like cast ability, corrosion resistance and high strength to weight ratio. Wear is defined as deformation of material on the surface due to interaction between two contacting surfaces. The different types of wear are abrasive, adhesive, fretting, erosion and fatigue. Abrasion wear leads to greater loss of metal surface compared to other types. Depending upon the number of contacting surfaces, abrasive wear is classified into two-body abrasive wear and three-body abrasive wear. Two-body abrasive wear occurs when the grits or embedded hard particles leads to loss of metal of opposite solid surface due to hard protuberance[3].In three-body abrasive wear, the grits are free to roll or slide between the contacting surfaces and are responsible for the removal of metal from the surface. Hence the wear rate is higher in three-body abrasion than two-body abrasion. Majority of the abrasion that occurs in Agricultural and Industrial equipments is three-body abrasion. [4] Learnt that the grit spends 90% of its time rolling between the contacting surfaces and only 10% of time in abrading the sliding surfaces.In thermal power plants, fluid slurry conveying and other industrial applications where material is conveyed, the hard materials will be in-contact with parts of conveyors. Process like carrying pulverized coal to boiler employs conveying system where in the pulverized coal is pumped through piping system using pumps. Both the surfaces of piping and pumps

surfaces come in contact with hard particles which are impurities present in the coal. In case of pulverizing coal mill, the mill components like grinding ring, grinding balls and other component of the mill are exposed to different hard particles. In

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case of ore dressing and ball milling the surfaces are exposed to hard materials which are in different static and dynamic conditions. All the above cases, the common feature are 'two bodies' which are in cont act while transferring load and displacement from one object to other object. Apart from many are also exist, relative motions between the two objects. This type of loading and dynamic conditions gives rise to elastic, inelastic and surface damage of both the objects. In the present study we are proposing to conduct abrasion test and erosion test to evaluate the elastic, inelastic and damage of objects. The different loading conditions are achieved in case of abrasion test by varying normal load. Different relative sliding velocities are simulated by varying wheel speed. Sand with known size distribution is used to simulate different geometry of hard particles.

II. EXPERIMENTAL DETAILS

A. Materials and casting

Commercially available Al-8011 Al-Fe-Si alloy with 0.60-01% Fe and 0.50-0.90% Si was chosen as matrix material. Red mud (bauxite residue) from HINDALCO, Belgum and Graphite powder of an average size of 50 microns were used as reinforcement, Graphite powder has physical properties like good electrical and thermal conductivity, high purity, and temperature stability. Graphite is a well-recognized solid lubricant which also has the advantage of low density. In graphite reinforced Aluminium Matrix Composites (AMCs), Graphite serves as a solid lubricating layer between the composite and rubbing surface helping in reduction of composite wear and does not need any additional solid and liquid lubrication [7]. The chemical properties of Al-8011 and RMp are tabulated in table 1 and 2. Al-8011 was melted in electrically controlled resistance furnace. The wetting agent Mg, and reinforcements RMp, Grp and cast iron mold were preheated to 300oC in electric oven in order to ensure the zero moisture. Preheated mixture of wetting agent and reinforcement was pouredinto the vortex of Al-8011 melt separately at750oC. The stirring action was continued for next 3mins for proper distribution of RMp in the matrix alloy. At the temperature of 800oC the melt from the graphite crucible was poured into the cast iron mold and allowed for solidification. During stir casting process degassing tablet and cover flux was used to remove the dissolved hydrogen from the melt and to form a barrier coating on hot melt to prevent the melt from oxidation and atmosphere humidity.

Table-1. Chemical composition of Aluminium 8011[1].

Element	Al	Fe	Si	Mn	Zn	Cu	Ti	Cr	Mg
Content (%)	97.3 - 98.9	0.60 - 1	0.50 - 0.90	≤0.20	≤0.10	≤0.10	≤0.08	≤0.050	≤0.050

Table-2. Chemical composition of red mud [1].

Element	Al_2O_3%	Fe_2O_3%	SiO_2%	TiO_2%	Na_2O%	CaO%	LOI%
Content (%)	18.34	45.93	7.23	9.56	3.42	1.0015	8.00145

B. Abrasive wear studies

The schematic representation of rubber wheel test or 3 Body abrasive wear test set up is shown in Figure 1. The specimen was cleaned with acetone and then dried. Its initial weight was determined in a high precisiondigital balance before it was mounted in the sample holder. In this study, silica sand of density 2.6 g/cm^3 was used as the abrasive. The abrasive particles of 300 grit silica sand were angular in shape with sharp edges.

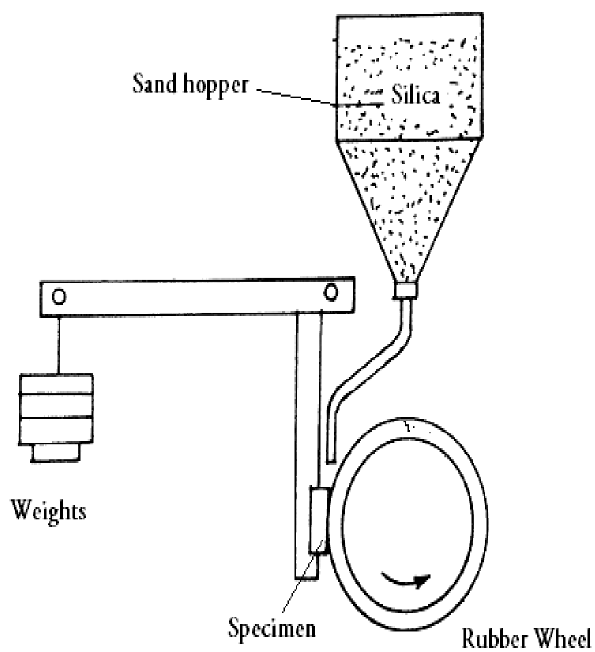


Fig-1:3-Body abrasive wear test set up [4].

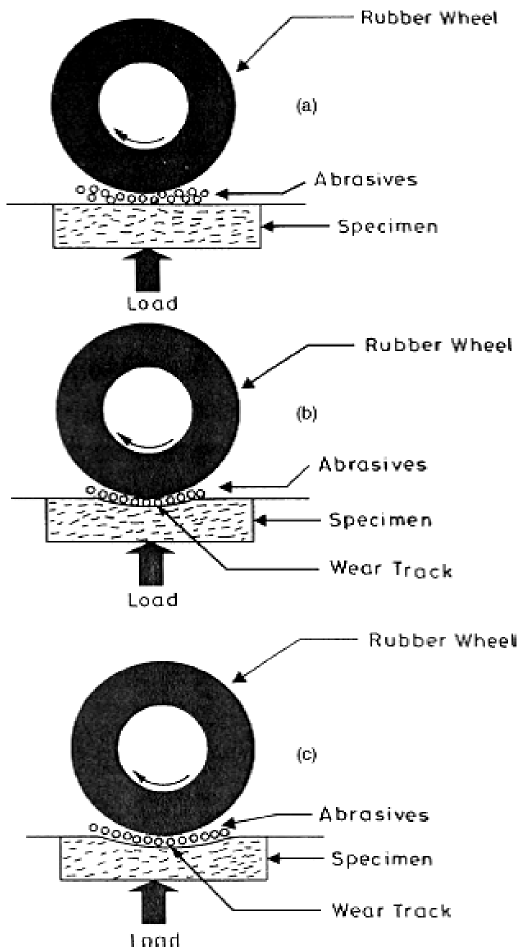


Fig-2: Schematic representation of failure modes of composites under three-body abrasion [4].

The abrasive particles were fed at the contacting face between the rotating rubber wheel made of rubber and the test sample. The diameter of the rubber wheel used was130 mm, width 10mm. The test specimen was pressed against the rotating wheel at a specified load of 10, 20 and 30 kg by means of lever arm and time taken to the test was 10, 20, and 30 min. The tests were conducted at a rotational speed of 200rpm.The feed rate of the abrasive particles were 280±10 g/min. The rotation of the abrasive wheel was such that its contacting face moves in the direction of sand flow.

III. RESULTS AND DISCUSSIONS

Microstructure

Figure 3 (a), (b)& (c) shows the SEM photographs of Al-8011 alloy, Al- Grp and Al- RMp composite. SEM images show fairly good uniform distribution of reinforcement in the matrix alloy

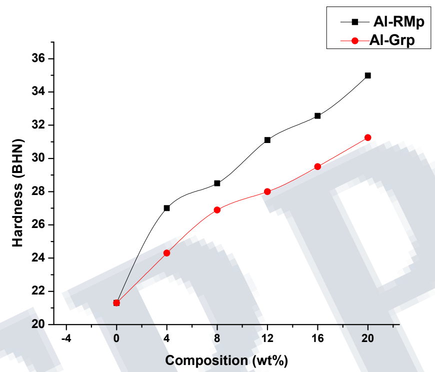
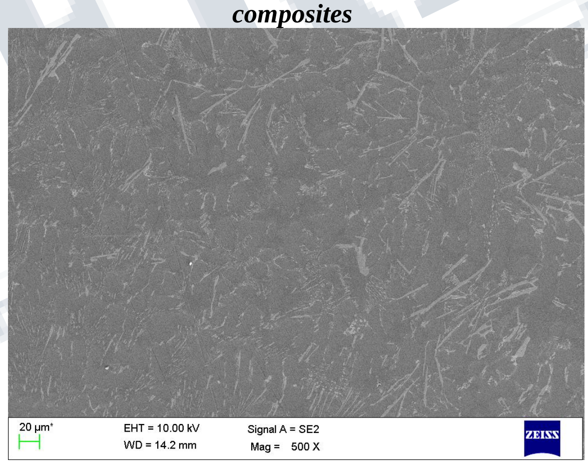
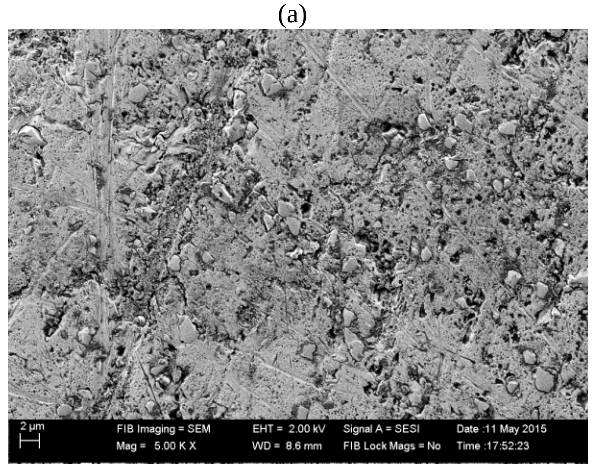


Fig-4: Hardness values of base alloy and composites



(a)



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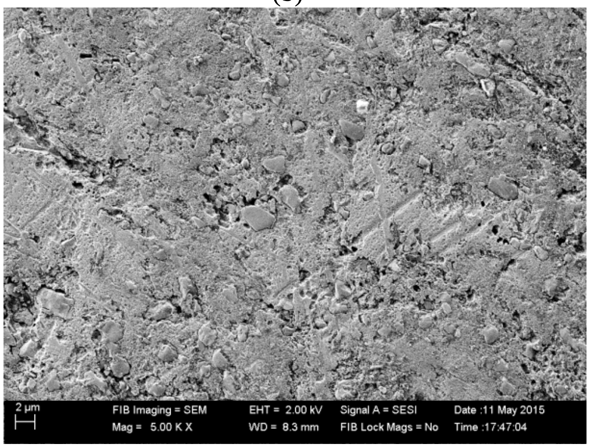
(b)

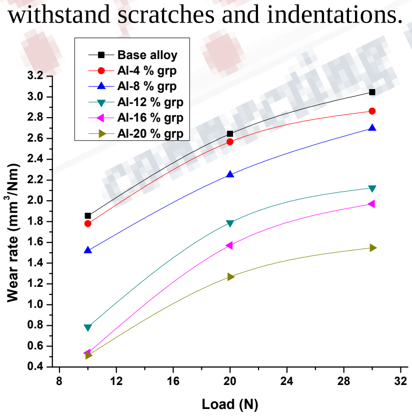


(c)

Fig. 3: SEM micrographs (a) As cast Al-8011 (b) Al-Grp composite (c) Al-RMpcomposite

C. Wear behaviour

From the obtained results it is cleared that the presence of reinforcement in the alloy will affect the wear behaviour of the composite. Results of this wear test of Al-Grp and Al-RMp composites are shown in figure 5(a) and 5(b) respectively. The graphs are plotted against the applied and wear rate by keeping time constant (30 min).These graphs reveal that the wear resistance of composite increases when reinforcement content is increased from 4 % to 20%. They also show that reinforced composite gives good wear resistance thanbase alloy. This can be compared with the hardness of the prepared composite; if the hardness is more in the material that will withstand scratches and indentations.



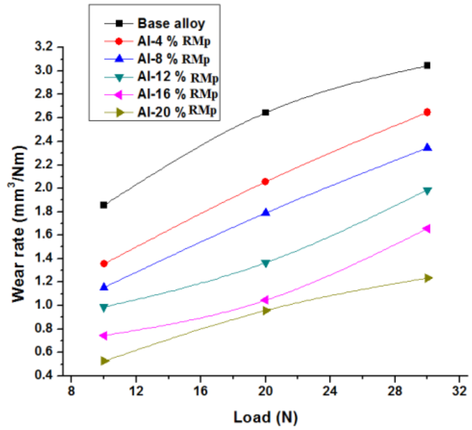


Fig-5:Wear rate of composite (a) Al-Grp (b)Al-RMp composites

IV. CONCLUSIONS

Red mud is the waste generated product from alumina plant which can be successfully used as a reinforcing material to produce the particle reinforced aluminium matrix composites to be used in the casting environment. Both red mud and graphite can be successfully used in the place of conventional aluminium intensive materials, and reduction in the usage of about 20 percent of matrix material could be achieved. There is a good dispersion of red mud and graphite in Al-8011 which improves the hardness and wear resistance of the composite and also we can conclude that wear resistance and hardness of Al-RMp composite is more when compare to Al-Grp composite.

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