Tribological Charactristics Of Al6061Reinforced With Granite Particulates

Koli Gajanan Chandrashekhar, Dr. D. P. Girish, A.A. Katkar

Abstract: This study mainly focuses on synthesis of AA6061 composites reinforced with granite particles using stir casting technique. The microstructure of Al6061 alloy and Al6061-granite composites were studied using scanning electron microscope. Friction and wear behavior of Al6061 alloy and Al6061-granite composite were evaluated under varied loads and sliding velocities using tribometer in accordance with ASTM-G99 standard. SEM of composites reveals that distribution of granite particles is homogenous in matrix material. Friction and wear tests demonstrate addition of granite particles in Al6061 alloy has led to fall in wear rate and friction coefficient. Rise in the applied load enhances the wear rate and drops the friction coefficient for all the combinations studied. Increase in sliding speed increases both friction coefficient and wear rate. However, at all the loads and sliding speed, Al6061-granite composite displayed lowest wear rate and friction coefficient.

Index Terms: Aluminum matrix composites Stir casting, Microstructure, Friction and wear properties.

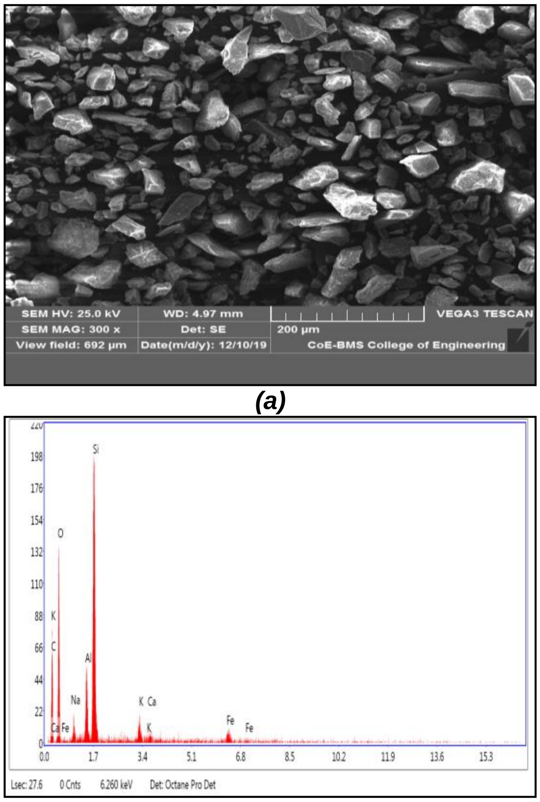
1 INTRODUCTION

Aluminum based metal matrix composites have demonstrated outstanding performance compared to their monolithic alloys. Primary attribute of aluminum-based composite is excellent strength to weight ratio. There is a wide opportunity for engineers to manipulate the properties of aluminum-based composites with appropriate reinforcements suitable for many engineering applications [1-4]. Aluminum composites are now being designed as wear resistant materials suitable for sliding contact applications. Various researchers have studied friction and wear performance aluminum composites reinforced with ceramic materials. Most commonly used ceramics for developing wear resistance applications SiC [5], TiB2 [6], TiC [7], Al2O3[2,5], BN [8], etc. these ceramics are categorized under synthetic reinforcements which has complex processing techniques resulting in cost of the composites. Sharma et al [9] have presented wear behavior of red mud reinforced Al2024 based aluminum composites. They have studied the effect of Redmud content, load and velocity on wear characteristics of composites. Composites were manufactured using casting method. Effects of input parameters were analyzed using surface method response. They have reported that sliding speed is the utmost prominent element which affects the wear behavior of composites trailed by load and Redmud content. Raja et al [10] have reported on wear behavior of industrial waste flyash reinforced aluminum-based metal matrix composites. Composite were prepared using stir casting process. Uniform distribution of Flyash particles were achieved with by casting process. Pin with disc equipment was used to conduct friction and wear assessment under different load and velocities. They have confirmed that there is a significant reduction in frictional force and wear rates after addition of fly ash particle in aluminum matrix. David et al [11] have developed Al6061 based composite reinforced with flyash by compo casting technique. A maximum of 12wt% flyash particles were added in to molten aluminum for manufacturing composites. Wear tests were conducted at elevated temperatures. Flyash reinforced composites developed by compo casting were effective in enhancing the wear performance of the composites. Alternatively, a group of materials is available as industrial waste material exhibit superior physical and mechanical properties as reinforcing particles which includes redmud, flyash, granite particles etc. Mechanical and tribological performance of industrial waste reinforced aluminum composites including redmud and flyash were studied by various researchers. However, meager information is available as regards composites reinforced with granite particles. Granite particles are inexpensive materials and are abundantly available as industrial waste and known for its high hardness [12-16]. Considering the wide scope available for developing wear resistant metal matrix composites objective of the present investigation is to synthesis granite reinforced Al6061 based composites and to characterize its friction and wear behavior. Composite fabrication was prepared by inexpensive and simple stir casting technique with varying weight percentage of granite particles. The fabricated composites were imperiled to microstructural characterization and hardness test. Further, friction and wear parameters were assessed using pin and disc tribometer.

2 EXPERIMENTAL DETAILS

Granite reinforced aluminum 6061 based composite is prepared utilizing stir casting procedure. Stir casting is the most evident and affordable technique for the manufacturing aluminum-based metal matrix composites because of simplicity of preparing and applicable for large scale manufacturing. Table 1 shows the composition of Al6061 alloy utilized in this investigation. Fig. 1 (a)-(b) shows the scanning electron microscope (SEM) of granite particles and its EDAX pattern utilized in this investigation. The granite particle size is in the range of 20-60 microns with irregular shape.

- *Author G. C. Koli is currently working as assistant professor in department of mechanical engineering at Sanjeevan Engineering & Technology Institute, Panhala Kolhapur, Maharashtra India*
- *Co-Author D.P. Girish is currently working as professor indepartment of mechanical engineering at Government Engineering College, Ramanagar, Karnataka India*
- *Author A.A. Katkar is currently working as assistant professor in department of mechanical engineering at Sanjeevan Engineering & Technology Institute, Panhala Kolhapur, Maharashtra India*



(a)

(b)

***Fig.** 1. SEM (a) and EDAX (b) of granite Powder*

The schematic of the stir casting arrangement used in this study is appeared in Fig. 2. This arrangement comprises of three fundamental parts namely melting chamber, graphite crucible and stirring unit. Initially, AA6061 alloy was heated to a temperature of 800^{o}C for complete melting. Vortex was achieved in liquid aluminum using mechanical stirrer, preheated granite particles were slowly filled in to molten aluminum alloy and stirring was continued a speed of 400 rpm for 10 minutes. A maximum of 8wt% granite particles were successfully added to Al6061 alloy. After mixing, the composite mixture was solidified by pouring in to preheated cast iron moulds. Prior to transfer, composite mixture was degassed using hexachloroethane degassing tablets. Solidified Al6061 alloy and composites was machined using electric discharge machine for characterizing microstructure, hardness and friction and wear behavior. Scanning electron microscopy studies were carried out using JSM 840a Jeol with EDAX Facility at BMS college of Engineering, Bangalore, India to analyze the dispersion of granite particles. Hardness was evaluated using Brinell hardness tester. Pin and disc equipment were utilized to evaluate the tribological behavior of Al6061-granite composites. In order to evaluate the behavior of granite reinforced Al6061 alloy varied load and sliding conditions, wear tests were carried out under load varying from 20-100N and sliding speed varying from 0.314 m/s to 1.57m/s. ASTM-G99 test procedure was followed to conduct wear test. Test specimens were cut from the cast alloy and its composites using electric discharge machining. Pin type samples were utilized as specimens for test as shown in Fig. 3. Wear test were carried out on metallographically polished sample under dry sliding condition at room temperature. EN-32 steel material with 8 mm thickness and 160 mm diameter, 1-micron surface roughness was used a counterface disc.

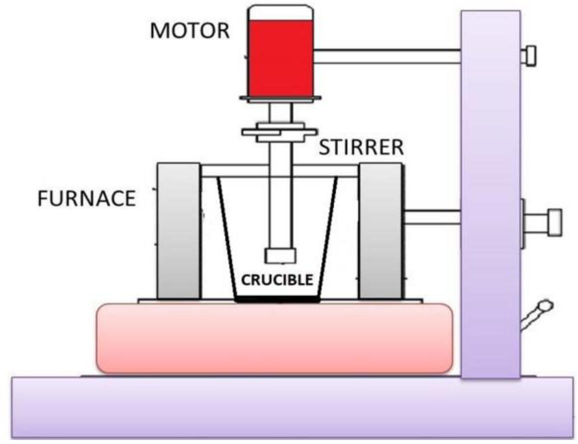


***Fig. 2**. Schematic diagram of Stir casting process*

TABLE1
Composition of Al6061 Alloy

Chemicals	Si	Ti	Fe	Mn	Zn	Cu	Mg	Cr	Other	Al
Wt. (%)	0.4-0.8	0.15	0.7	0.15	0.25	0.40	0.8-1.2	0.35	0.05	Balanced

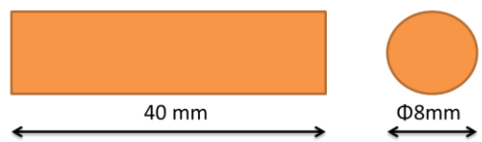
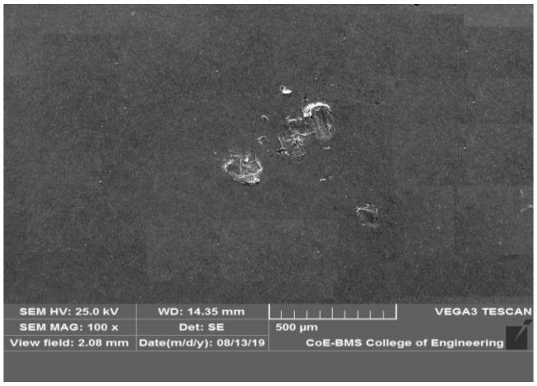


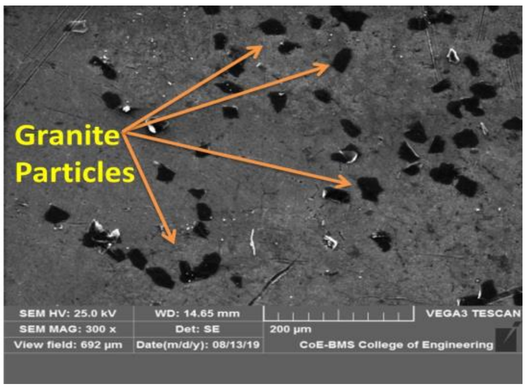
***Fig. 3**. Schematic diagram of wear test specimen*

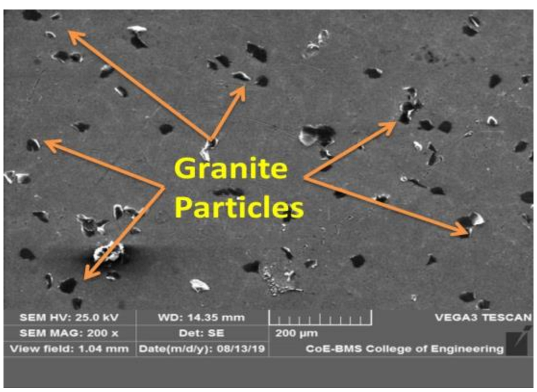
3 RESULTS AND DISCUSSION

3.1Microstructure

Fig. 4 shows the scanning electron micrographs of Al6061 alloy and Al6061-granite composites developed by stir casting process. SEM images were captured for different weight percentage of granite particles. In case of the alloy, it appears that few micro pores were present with intermetallic precipitates.

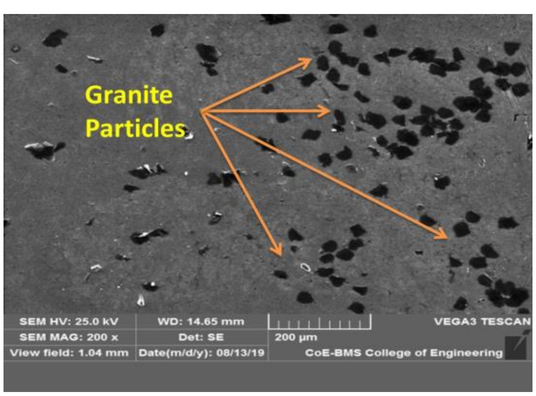






(a)
(b)
(C)
(d)

Fig. 4.*SEM of Al6061 alloy and Granite reinforced composites(a)Al6061 alloy, (b)Al6061+4wt%Granite, (C)Al6061+6wt%Granite, (d)Al6061+8wt%Granite*



Composites show presence of black granite particles throughout the matrix. Distribution of granite particles in Al6061 alloy is comparatively uniform in all the composition presented. The bonding of granite particles with aluminum matrix is good with clean interface indicating high quality of the composite. Probably the optimum conditions adopted during stir casting process has led to uniform dispersion of granite particles.

3.2 Hardness

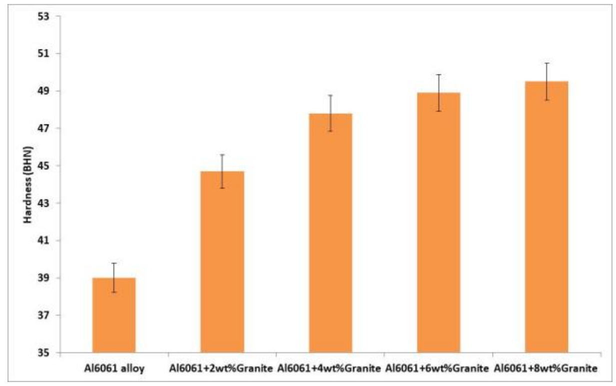


Fig. 5*. Graphical representation of hardness*

Fig. 5 presents the graphical representation of variation of Brinell hardness with different granite content in the Al6061 alloy. It is visible from the graph that there is tremendous improvement in the hardness with adding of granite particles. All the composite demonstrates higher hardness with presence of granite particles when equated with unreinforced aluminum alloy. A maximum of 16% and 26% improvement is achieved with addition of 2wt and 8wt% granite particles in Al6061 alloy matrix respectively. Higher hardness of the granite particles tends to contribute to improvement in the bulk hardness of the matrix material resulting in the higher hardness of the composite. Extensive grain refinement caused by the addition of granite particles in aluminum alloy also responsible for the improved hardness. In addition to this, large difference in coefficient of thermal expansion between granite particles and aluminum matrix leading to increased dislocations densities at the interface and contributes to higher hardness. Further, uniform dispersion of granite particles and good metallurgical bond between matrix and reinforcement are the important quality aspects which plays significant role in improving the mechanical properties of the composites.

3.3 Coefficient of Friction

3.3.1 Influence of Reinforcement

Effect of granite content on friction coefficient of Al6061 based composites are present in the Fig. 6 the effect of granite content was evaluated under the constant sliding velocity and load of 0.314 m/s and 20N respectively. The friction coefficient appears to be decreases consistently with increase in the granite content in the aluminum matrix. The lowest values of friction coefficient were recorded for the composite reinforced with 8wt% granite content. The coefficient of friction with 8wt% granite particles was 0.38 and 0.51 was recorded for Al6061 alloy which is found to be highest among alloy materials studied. Thus, a maximum reduction of 26% is recorded which is reasonably higher value compared to unreinforced alloy. Adding of granite particles in aluminum matrix reduces the contact area during the wear test which is the main reason for the reduction in friction coefficient. Augmented granite content minimizes the actual area of contact of the test specimen on the counter disc surface and contributes to lower coefficient of friction. Unreinforced alloy gets maximum exposure due to absence of granite particles. The matrix material adjacent to reinforced phase undergoes wear first followed by protruded granite particles. Protruded granite particles which come in contact with the counter disc surface reduce the friction coefficient.

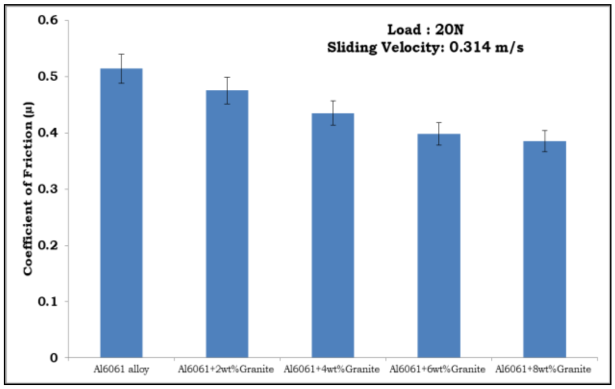


Fig. 6*. Variation of COF with granite content*

3.3.2 Influence of Load

Influence of load on friction coefficient of Al6061 based granite added composite is displayed in the Fig. 7 experiments were carried out under a constant sliding speed of 0.314 m/s with loads values varied from 20N to 100N to study the consequence on friction coefficient. Friction coefficient declines with rise in the load from 20N to 100N gradually. Al6061 alloy reinforced with 8wt% granite particles exhibited lowest friction coefficient under all the load values studied whereas unreinforced alloy exhibited highest value. For 8wt%granite reinforced composite friction coefficient value was 0.38 which is lower compared to 0.51 for unreinforced alloy at 20N load. At 20N load condition a maximum of 25.5% reduction in friction coefficient was observed compared to Al6061 alloy which is fairly higher value. Similarly, at a load of 100N and 0.314 m/s composite reinforced with 8wt% granite particles exhibited friction coefficient of 0.19 and Al6061 alloy has shown a value of 0.30. This amount to a maximum of 37% reduction in the friction coefficient even under higher loading conditions. The decrease in the friction coefficient with increase in the load may be attributing to fact that during tribo test the sliding action between test specimen and counterdisc generates heat at the interface. The heat generated softens the specimen surface at the interface due to increased temperature. The interfacial temperature rises with growth in the applied load and oxidizes the surface resulting in the lower friction coefficient. Further, it is also important to mention that, presence of granite particle helps to reduce the friction coefficient by minimizing direct contact between test specimen and counter disc as discussed earlier.

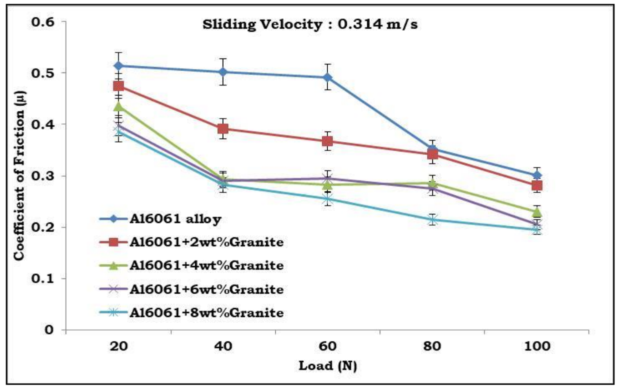


Fig. 7*. Effect to f load on friction coefficient*

3.3.3 Influence of Sliding Velocity

Fig. 8 shows the graphical representation of effect of sliding velocity on friction coefficient of granite reinforced Al6061 composites. Difference of friction coefficient with regarding sliding velocity was recorded in the range of 0.314m/s to 1.57 m/s at a constant load of 20N. it is seen that the friction coefficient is found increased with increase progressively in the sliding velocity from 0.314m/s to 1.57m/s. At all the speed calculated the lowest friction coefficient was documented for 8wt% granite particles. Whereas highest friction coefficient was recorded for unreinforced Al6061 alloy under all the sliding velocities tested. At lower sliding velocity of 0.314m/s the friction coefficient values recorded were 0.51 and 0.38 for composite reinforced with 8wt% granite particle and unreinforced alloy respectively. In the same way, at higher sliding velocity of 1.57m/s the friction coefficient for Al6061 alloy was 0.70, where for composite reinforced with 8wt% granite particles the friction coefficient value was 0.49. The decrease in friction coefficient value of composite was about 28.6% compared to unreinforced alloy. This reduction is relatively an incredible reduction in friction coefficient compared to previous case. The rise in the friction coefficient with increase in the velocity may be due to failure protective oxidized surface layer on the test samples which is formed during sliding action. Excessive heat generated and continuous increase in shear stress at the interface leads to breakdown of shielding oxide layer and raises the coefficient of friction.

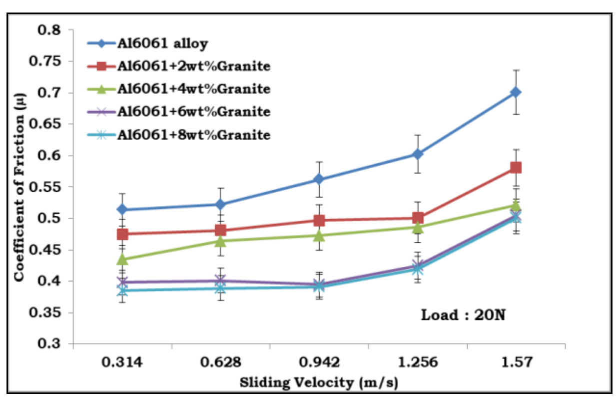


Fig. *8. Graphical representation of friction coefficient with sliding velocity*

3.4 Wear

3.4.1 Influence of Reinforcement

Fig. 9 presents the consequence of granite content on wear rate of Al6061 alloy and Al6061-granite composite. Result of granite content on wear rate was evaluated at a load of 20N and sliding velocity of 0.314m/s. Progressive lessening in wear rate is observed with rise in the granite content in Al6061 alloy. For all the cases studied, wear rate of composite reinforced with granite particles much lower compared to unreinforced alloy. The lowest wear rate of 31X10-3 was recorded for composite reinforced with 8wt% granite particles, whereas unreinforced alloy displayed a wear rate of 55X10-3 mm3/m under identical test values. This decreased wear rate is about 44% which very substantial value with addition of 8wt% granite particle in aluminum matrix. It is very clear that addition of granite particles in aluminum matrix is operative and vital in bringing down the wear rate of the composite to a noteworthy percentage. The main reason behind reduction in wear rate of the composite with adding of granite particle in aluminum matrix is higher hardness of the composite. Addition of granite particles in Al6061 alloy enhances the bulk hardness of the composite leading to lower wear rate. Another fact is the load bearing capability of the granite particles, enhanced load bearing capability of granite articles compared to soft matrix contribute to reduction in wear rate. It is also important to note that hardness value increases with increase in the granite percentage correspondingly reducing the wear rate. As per well-known Archard's law, wear resistance of the materials increases with rise in the hardness. Further, uniform dispersion of granite particles also helps in reducing the wear rate by withstanding large amount of applied load.

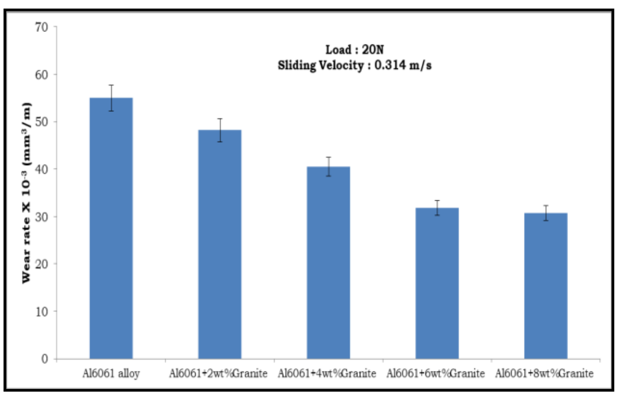


Fig. 9. *Wear rate variation with granite content*

3.4.2 Influence of Load

Fig. 10 presents the graphical representation of variation of wear rate with granite content in Al6061 composite. Effect of load on wear rate was recorded by varying the load from 20N to 100N. The value of sliding velocity was fixed at 0.314m/s. Wear rate is institute to be increased gradually with rise in the load from 20N to 100N. Al6061 alloy reinforced with 8wt% granite particles has exhibited lowest wear rate compared to unreinforced alloy under all the load conditions studied. Wear rate values of 31X10-3mm3/m and 55X10-3 mm3/m were observed for Al6061 alloy and composite reinforced with 8wt% granite particles respectively for 20N load. Addition of 8wt% granite in Al6061 matrix has a maximum of 44% reduction in wear rate which is remarkably higher value when compared with unreinforced alloy. Likewise, for 100N load highest wear rate value recorded was 64X10-3 mm3/m for Al6061 whereas for composite reinforced with 8wt% granite particles the wear rate was 38X10-3 mm3/m. the decrease in wear rate is about 41% which is a remarkable reduction for composite added with 8wt% granite particles. Increase in applied load leads to softening of aluminum matrix resulting in higher wear rate. This is because of friction heat generated at the interface between test specimen and counterdisc. In addition to this, realization of protective oxide layer on the exterior of the test specimen becomes unstable at higher load conditions and undergoes fracture. Due to this fresh surface is exposed resulting in increased wear rate. With presence of hard granite particles in composites wear is significantly lower compared to unreinforced alloy.

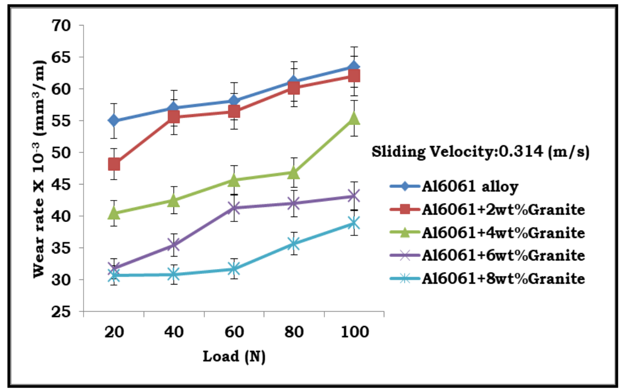


Fig. 10. *Graphical representation of difference in wear rate with load*

3.4.3 Influence of Sliding Velocity

Fig. 11 displays the graphical representation of sliding speed effect on wear rate of Al6061 and its composites. Consequence of sliding velocity on wear rate was studied by varying the sliding velocity from 0.314m/s to 1.57m/s. a constant load value of 20N was maintained for all the test. It is seen from the figure that there is a rise in the wear rate with growth in the sliding velocity. For the composite reinforced with 8wt% granite particles demonstrated lowest wear rate at all the velocities studied. Whereas unreinforced Al6061 alloy shows highest wear rate for all the velocities. At a sliding speed of 0.314m/s the highest and lowest wear rate recorded was 55X10-3mm3/m and 31X10-3mm3/m for the materials Al6061 alloy and composite reinforced with 8wt% granite particles respectively. Appreciable reduction of 44% in wear rate was recorded for composite reinforced with8wt% granite particles compared to matrix material. Likewise, wear rate of 67X10-3mm3/m and 43X10-3mm3/m was recorded for the Al6061 alloy and Al6061 alloy reinforced with 8wt% granite particles respectively tested under sliding velocity of 1.57m/s. The wear rate value decreases by 36% with addition of 8wt% granite particles in aluminum matrix. However, for all the materials studied there is continuous growth in wear rate with rise in velocity. The excessive plastic deformation and failure of protective oxide layer present on the surface of test sample at higher velocities are the main factors for increased wear rate with increase in sling velocities as disused earlier. The increase in the frictional resistance due to higher sliding velocities causes welding of the contact surfaces and leads to severe plastic deformation on the surface of the test specimen.

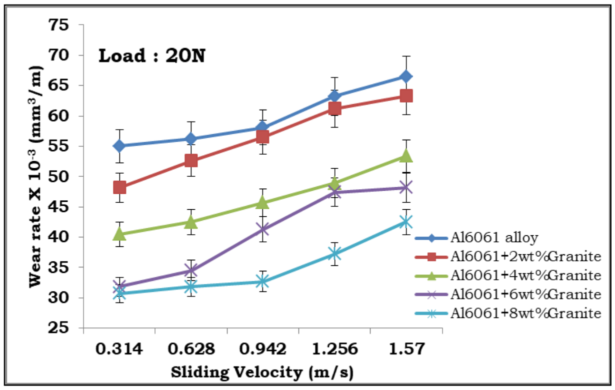


***Fig. 11**. Variation of wear rate with sliding velocity*

4CONCLUSIONS

This works investigates the effect of granite content on the microstructure and friction and wear performance of Al6061 based composites. Following are the conclusions drawn from this investigation,

1.Microstructure studies disclose even dispersal of granite in the aluminum matrix with good metallurgical bond.

2.Improvement in the hardness was found with increase in granite content in aluminum matrix.

3.Incredible drop in friction coefficient is recorded with increase in of granite particles content in aluminum. Coefficient of friction drops with rise in load and increases with increase in sliding velocity for all the combinations.

4.Maximum of 44% reduction in wear rate is observed with 8wt% granite content. Wear rate rises with rise in load and sliding velocities. For the entire loads and velocities tested, composites display lower wear rate compared to alloy.

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