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Tribological Characteristics of Aluminum Metal Matrix Composites

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***Abstract* - Metal matrix composites (MMCs) constitute an important class of design and weight- efficient structural materials that are encouraging every sphere of engineering applications. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuously dispersed solids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. To produce Al matrix cast particle composites, wettability of the ceramic particles by liquid Al is essential. To improve wettabilty, elements such as Mg and Si are added into Al melt to incorporate the ceramic particles. The present investigation has been focused on the utilization abundant available industrial waste fly ash in useful manner by dispersing it into Al-6061 alloy to produced composites by liquid metallurgy route. Random size fly ash particles were used. The dry sliding wear behavior of the composites in the cast conditions was studied at different loads and different sliding velocities with the help of Pin-On-Disc wear test machine. The worn surfaces and wear debris were analyzed using scanning electron microscope.**

I. INTRODUCTION

Aluminum alloy composites (AACs) are becoming potential engineering materials offering excellent combination of properties such as high specific strength, high specific stiffness, electrical and thermal conductivities, low coefficient of thermal expansion and wear resistance. Because of their excellent combination of properties, AACs are being used in varieties of applications in automobile, mining and mineral, aerospace, defense and other related sectors.

In the automobile sector, Al composites are used for making various components such as brake drum, cylinder liners, cylinder blocks, drive shaft etc. In aerospace industries, Al composites are used essentially in structural applications such as helicopter parts (parts of the body, support for rotor plates, drive shafts), rotor vanes in compressors and in aero-engines. Lightweight body armour plate, track shoes of vehicles are also tried out for defense sectors.

In general, Al composites are classified into two major groups depending upon the aspect ratio of the reinforcements. In the first category, the aspect ratio (l/d, l : length, d : diameter) is varied in the range of 100 – 10,000 in which, fibers are reinforced in metal matrix to achieve properties required for structural applications. In the second category, the aspect ratio of the reinforcement is in the range of 1-5 in which, the reinforcements are equiaxed in shape (particle/ whiskers); such type of Al composites are in great interest in tribological application.

In preparing metal matrix composites by casting method, there are several factors that need considerable attention, including: The difficulty of achieving a uniform distribution, wettability between two main substance, porosity and chemical reaction between the reinforcement material and the matrix alloy.

In order to achieve the optimum properties of the metal matrix composites, the distribution of the reinforcement material in the matrix alloy must be uniform, and the wettability or bonding between these substances should be optimized. The porosity levels need to be minimized, and chemical reactions between the reinforcement materials and the matrix alloy must be avoided.

Dry sliding wear tests of aluminum alloy Composites were carried out using Pin-on-disc wear test apparatus under varying applied load, speed and distance. The pin samples were Φ10mm and 30mm in length. The wear rate was computed from weight loss measurement (accuracy level of 0.0001g).

In recent years, much research work was devoted to develop aluminum metal-matrix composites and to investigate their mechanical and tribological properties. The wear properties of composites depend on the amount, size, shape and distribution of fibers, hard or soft particles filled in matrix. Generally it is an accepted opinion, that fibers and hard particles increase the strength and wear resistance of composites, but decrease their ductility. Soft particles acting as lubricant decrease the coefficient of friction, the ductility and the strength of filled matrix. The undesirable effects of reinforcing elements and solid lubricants lead sometimes to unexpected properties of manufactured composites.

The present work has been focused on utilization of fly ash and glass fiber in useful manner by dispersing it in aluminum matrix to produce composite. In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides, was used as the reinforcing phase and to increase the wetabbility magnesium and silicon were added. Composites were produced with different percentages of reinforcing phase. E glass consists of Alumina-calcium-borosilicate glasses with a maximum alkali content of 2% w/w used as general purpose reinforcement where strength and high electrical resistivity are required together with Advantex accounts for over 90% of all GRP reinforcements produced today.

II. LITERATURE REVIEW

Various works has been carried out on wear test**.** Many authors have contributed their suggestions on this. But the authors whose contribution is useful for us are listed below.

Subhakanta et.al was studied the Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersions used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by- product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications.

Dinesh. A et.al has been made to study the influence of wear parameters like applied load, sliding speed, percentage of reinforcement content and sliding distance on the dry sliding wear of the composites. A plan of experiments, based on the techniques of Taguchi, was performed to acquire data in controlled way. An orthogonal array and the analysis of variance were employed to investigate the wear behavior. The objective is to establish a correlation between dry sliding wear behaviors of hybrid composites with wear parameters. These correlations were obtained by multiple regressions. Finally, conformation tests were done to make a comparison between the experimental results foreseen from the mentioned correlations.

Shuvendu Tripathy et.al was studied the conventional monolithic materials have limitations with respect to achievable combinations of strength, stiffness, and density. In order to overcome these shortcomings and to meet the ever-increasing engineering demands of modern technology, metal matrix composites are gaining importance. In recent years, discontinuously reinforced aluminum based metal matrix composites have attracted worldwide attention as a result of their potential to replace their monolithic counterparts primarily in automobile and energy sector.

Arun Kumar M.B et.al was studied on flyash-eglass-Al6061 alloy composites having 2 wt%, 4 wt%, 6wt% and 8wt% of flyash and 2 wt% and 6wt % of e-glass fiber were fabricated by liquid metallurgy (stir cast) method. The casted composite specimens were machined as per test standards. The specimens were tested to know the common casting defects using ultra-sonic flaw detector testing system. Some of the mechanical properties have been evaluated and compared with Al6061 alloy. Significant improvement in tensile properties, compressive strength and hardness are noticeable as the wt % of the flyash increases. The microstructures of the composites were studied to know the dispersion of the flyash and e-glass fiber in matrix. It has been observed that addition of flyash significantly improves ultimate tensile strength along with compressive strength and hardness properties as compared with that of unreinforced matrix.

A. Objectives

1. Using fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.
2. Studying the wear behavior of Al alloy metal matrix composites.
3. Decrease density with minimum wear.

III. EXPERIMENTAL SETUP

A. *FABRICATION OF MMC*

Fabrication work include following objectives

To design the experimental procedure to be followed during the preparation of the composites

1. Fabrication of Die Fixtures for clamping of metallic molds.
2. Fabrication of hybrid composites.
3. Heat treatment to the fabricated hybrid composites.
4. Finishing operations.

B. *Planning Of the Experiment*

The purpose of the experimental investigation is to analyze the wear behavior of the Hybrid composite under different compositions of the reinforcing materials. For this, fabrication of hybrid composite is carried out for various combinations of matrix and reinforcing materials.

The matrix material used for this purpose is Al6061. This alloy of aluminum is best suitable for mass production of light weight metal casting. This is a heat treatable and age Hardenable alloy of aluminum consisting of magnesium and silicon as major alloying elements. The composition of Al6061 alloy is given in the following table 3.1

Table3.1 chemical composition of Al6061 alloy (wt%).

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Be	V	Al
0.92	0.76	0.28	0.22	0.10	0.07	0.06	0.04	0.003	0.01	Bal

The reinforcing materials used for the purpose are fly ash and E-glass fibers particles. E-glass fiber of 2-3mm length is used as the reinforcing material.

C. SPECIMENS

Different combinations of the Aluminum, Flyash and E-glass are prepared which are given below

- **Set no 01:**
  - Al 6061 + 5% Fly ash + 0% Glass Fiber (Al0500)
  - Al 6061 + 10% Fly ash + 0% Glass Fiber (Al1000)
  - Al 6061 + 15% Fly ash + 0% Glass Fiber (Al1500)
  - Al 6061 + 20% Fly ash + 0% Glass Fiber (Al2000)
- **Set no 02:**
  - Al 6061 + 5% Fly ash + 5% Glass Fiber (Al0505)
  - Al 6061 + 10% Fly ash + 5% Glass Fiber (Al1005)
  - Al 6061 + 15% Fly ash + 5% Glass Fiber (Al1505)
  - Al 6061 + 20% Fly ash + 5% Glass Fiber (Al2005)
- **Set no 03:**
  - Al 6061 + 0% Fly ash + 0% Glass Fiber (Al0000)
- **Set no 04:**
  - Al 6061 + 5% Fly ash + 10% Glass Fiber (Al0510)
  - Al 6061 + 10% Fly ash + 10% Glass Fiber (Al1010)
  - Al 6061 + 15% Fly ash + 10% Glass Fiber (Al1510)
  - Al 6061 + 20% Fly ash + 10% Glass Fiber (Al2010)
- **Set no 05:**
  - Al 6061 + 0% Fly ash + 5% Glass Fiber (Al0005)
  - Al 6061 + 0% Fly ash + 10% Glass Fiber (Al0010)
  - Al 6061 + 0% Fly ash + 15% Glass Fiber (Al0015)
  - Al 6061 + 0% Fly ash + 20% Glass Fiber (Al0020)

D. EXPERIMENTAL PROCEDURES

In order to characterize the dry-sliding wear behavior of the test specimens, wear tests were performed using a Pin-on-disc or dry sliding machine, which is shown in figure 3.3. Circular pins of diameter 10 mm and height 30 mm was used as a test specimen. That is shown in figure 3.2. The test specimen was gripped in the wear testing machine to avoid rolling during the test.

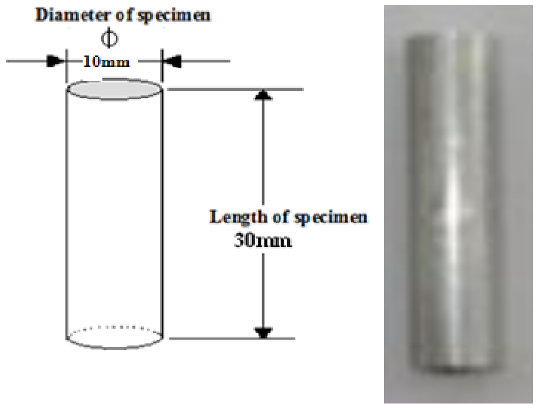

Figure. 3.2 Standard specimen

The wear parameters chosen for the experiment were: Sliding speed in rpm, Load in N and Sliding distance in m. The wear test was conducted for different speeds 200,350 & 500 rpm. & load of 20, 40, &60 N. The wear rate was computed from weight loss measurement (accuracy level of 0.0001g).Care has been taken that the specimens under test are continuously cleaned with woolen cloth to avoid the entrapment of wear debris and to achieve uniformly in experiential procedure. The test pieces are cleaned with acetone and after each test.

Figure3.3: Dry sliding wear machine.

IV. RESULT AND DISCUSSION

A. Effect of applied load on wear rate.

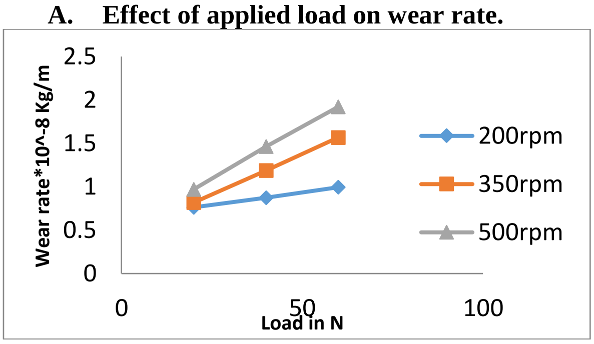

Figure4.1. Effect of variation of load on wear rate value of composite material Al0500.

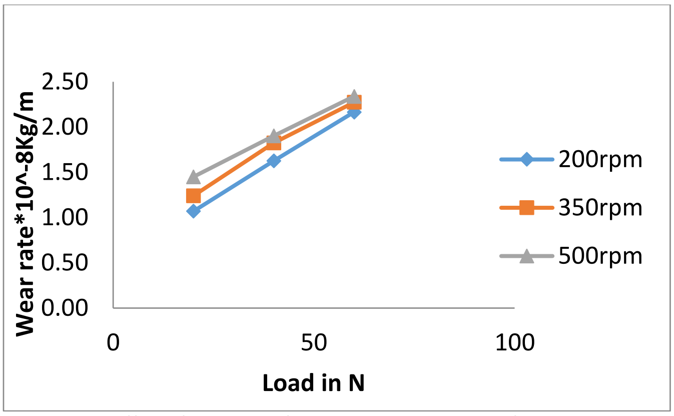

Figure4.2. Effect of variation of load on wear rate value of composite material Al1000.

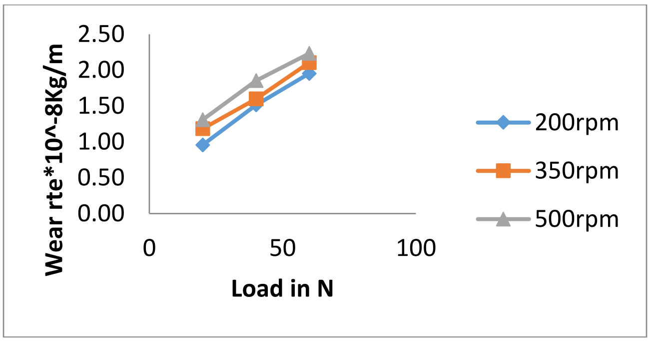

Figure4.3. Effect of variation of load on wear rate value of composite material Al1500.

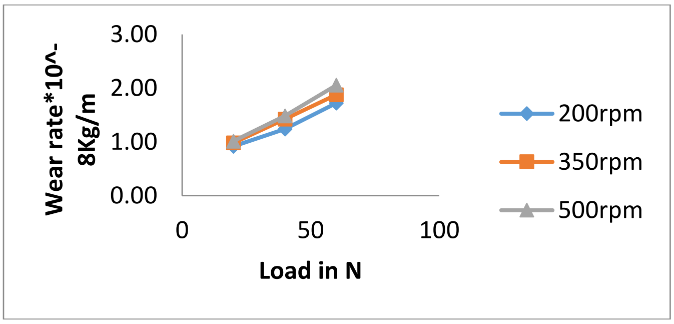

Figure4.4. Effect of variation of load on wear rate value of composite material Al2000.

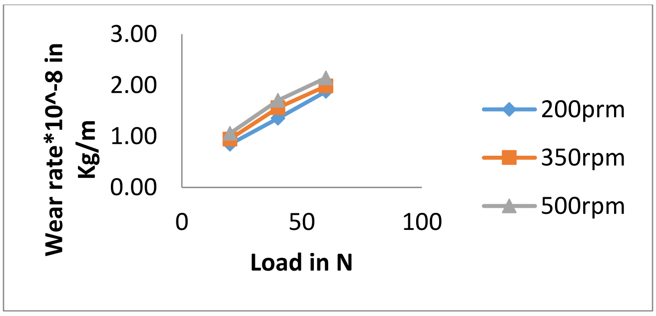

Figure4.5. Effect of variation of load on wear rate value of composite material Al0505.

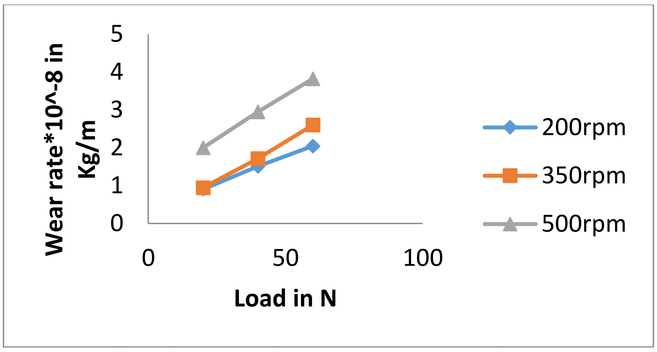

Figure4.6. Effect of variation of load on wear rate value of composite material Al1005.

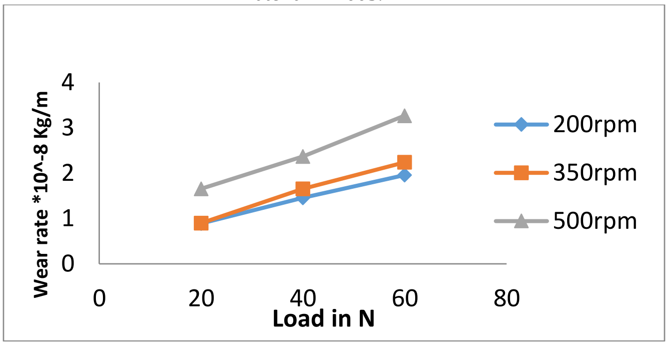

Figure4.7. Effect of variation of load on wear rate value of composite material Al1505.

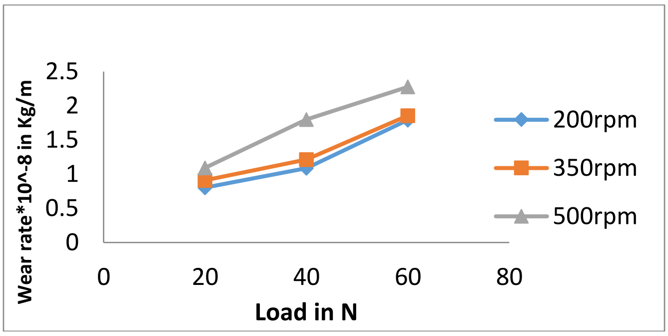

Figure4.8. Effect of variation of load on wear rate value of composite material Al2005.

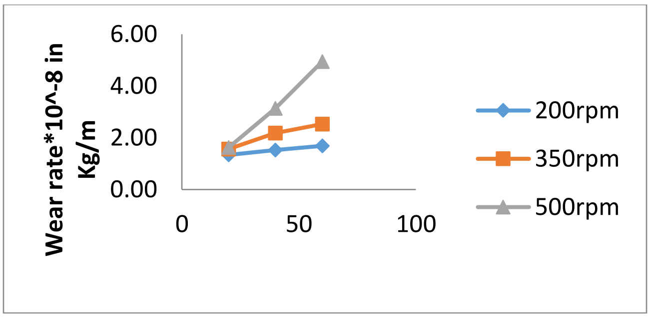

Figure4.9. Effect of variation of load on wear rate value of composite material Al0000.

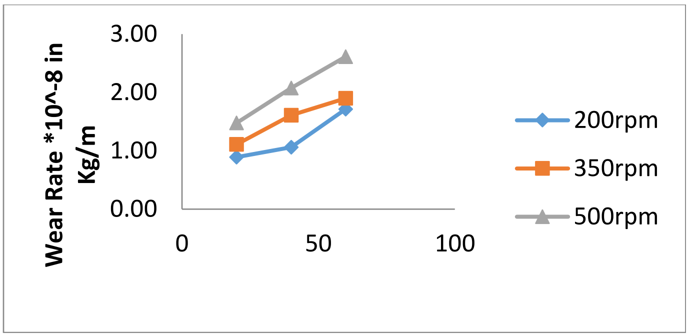

Figure4.10. Effect of variation of load on wear rate value of composite material Al0510.

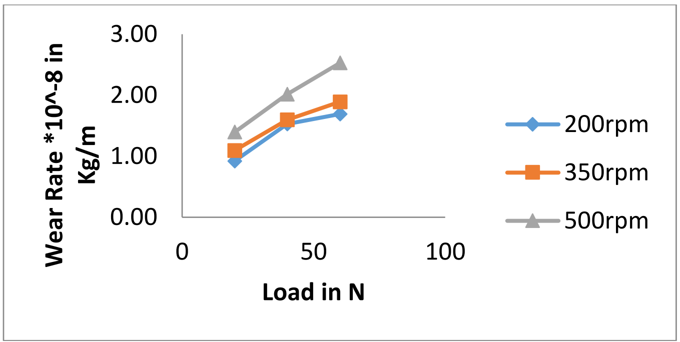

Figure4.11. Effect of variation of load on wear rate value of composite material Al1010.

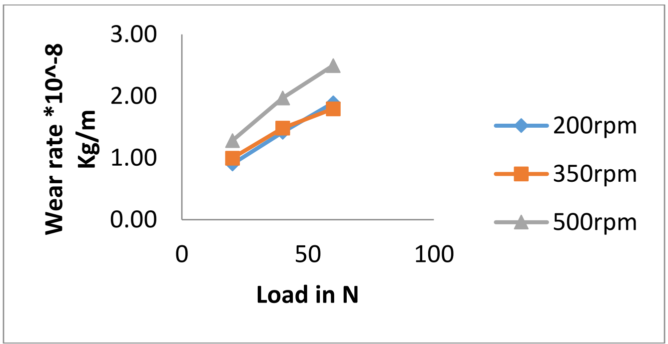

Figure4.12. Effect of variation of load on wear rate value of composite material Al1510.

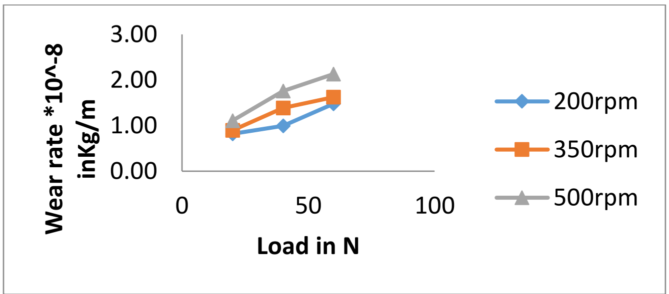

Figure4.13. Effect of variation of load on wear rate value of composite material Al2010.

The above figure shows the effect of applied load on wear rate of Aluminum alloy and it's composite. When load applied is low, the wear loss is quite small, which increases with increase in applied load. It can be considered that, it is quite natural for the weight loss to increase with load.

B. *Effect of fly ash on wear rate.*

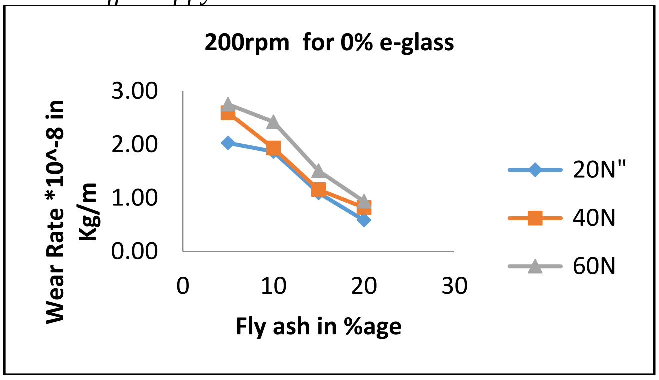

Figure4.14. Effect of variation of fly ash on wear rate value of composite material.

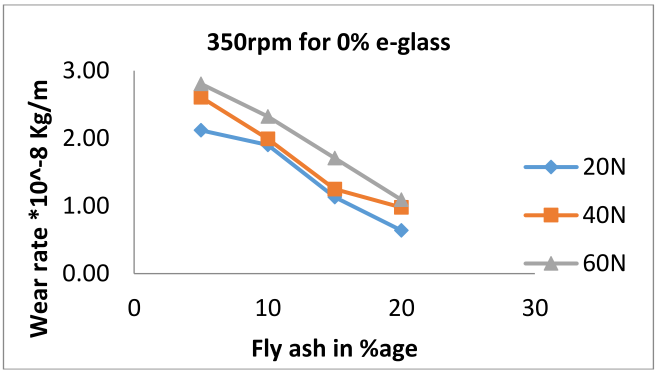

Figure4.15. Effect of variation of fly ash on wear rate value of composite material.

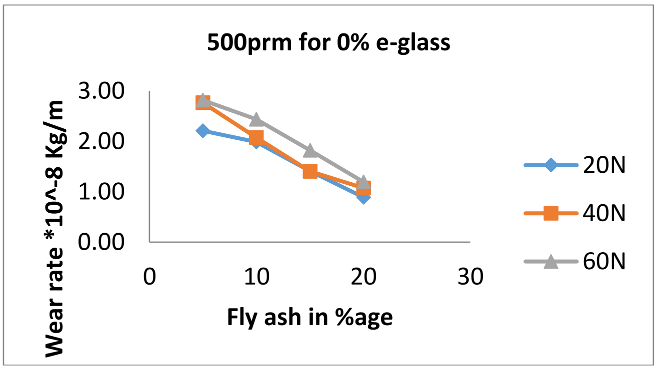

Figure4.16. Effect of variation of fly ash on wear rate value of composite material.

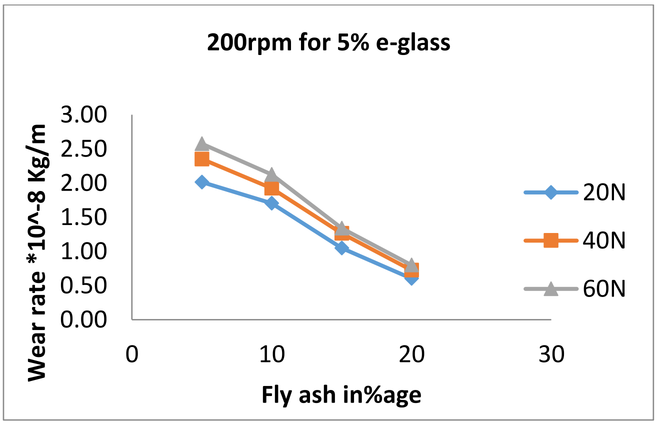

Figure4.17. Effect of variation of fly ash on wear rate value of composite material.

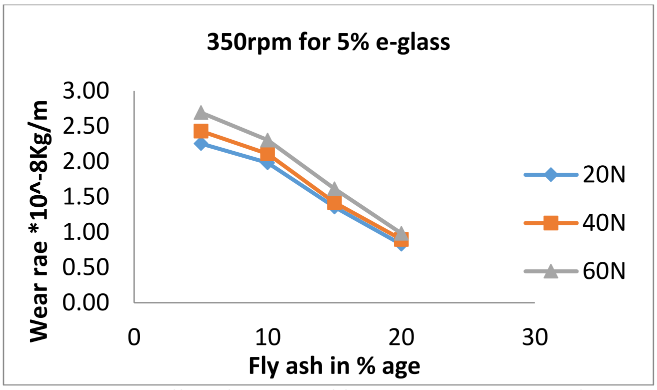

Figure4.18. Effect of variation of fly ash on wear rate value of composite material.

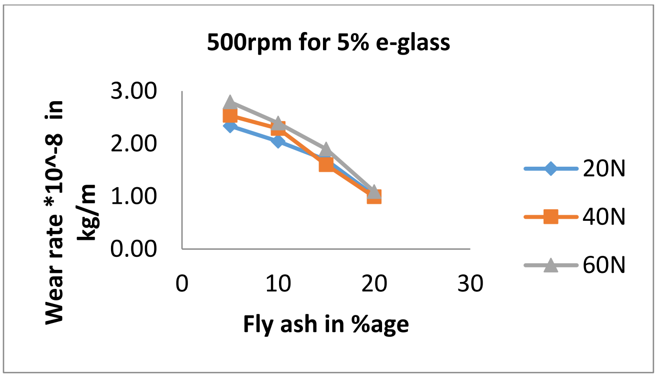

Figure4.19. Effect of variation of fly ash on wear rate value of composite material.

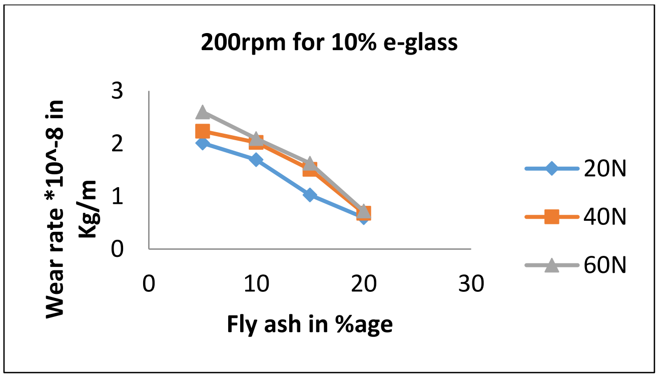

Figure4.20. Effect of variation of fly ash on wear rate value of composite material.

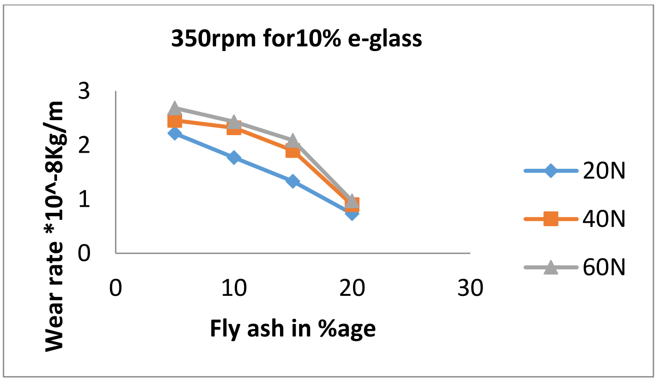

Figure4.21. Effect of variation of fly ash on wear rate value of composite material.

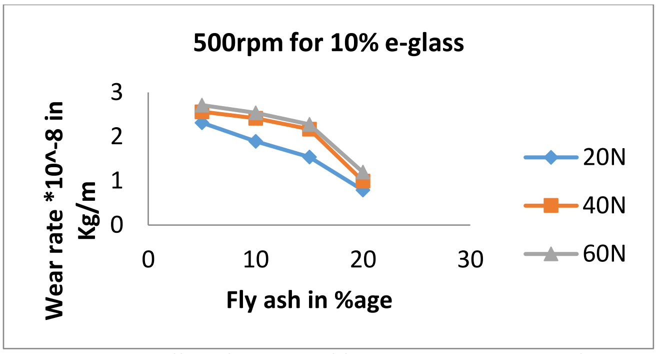

Figure4.22. Effect of variation of fly ash on wear rate value of composite material.

C. Effect of Time on Wear Rate.

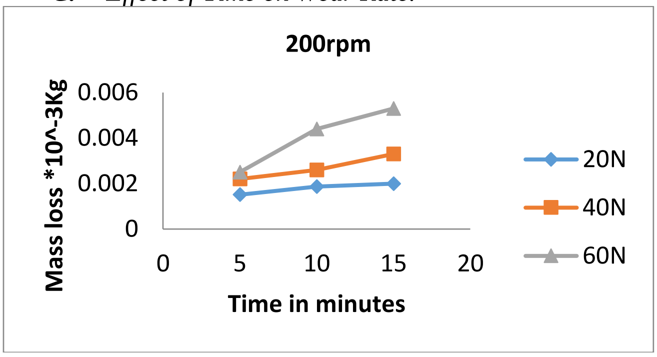

Figure4.23. Effect of variation of time on wear rate value of composite material.

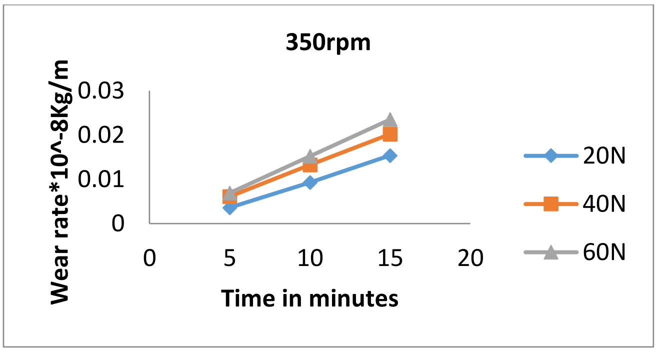

Figure4.24. Effect of variation of time on wear rate value of composite material.

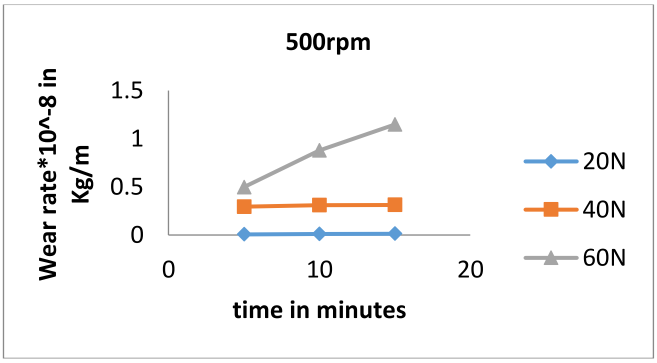

Figure4.25. Effect of variation of time on wear rate value of composite material.

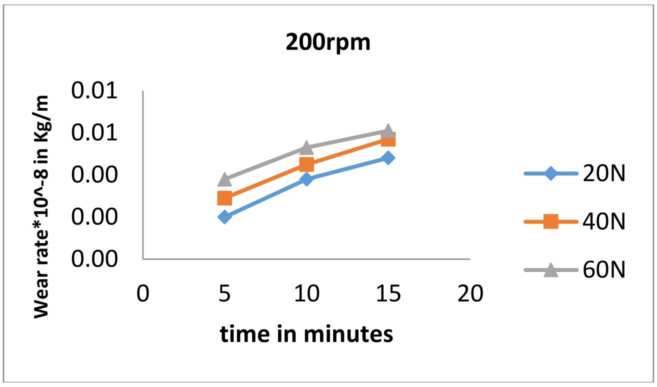

Figure4.26. Effect of variation of time on wear rate value of composite material.

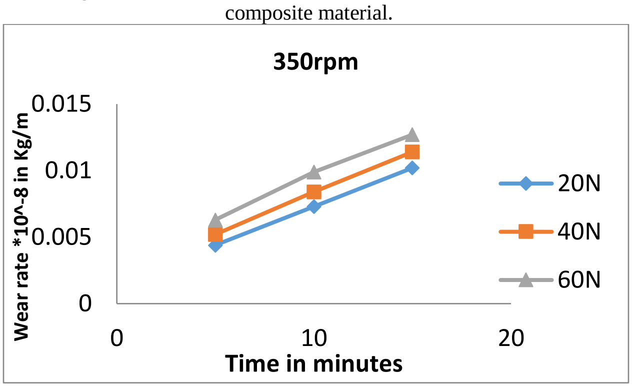

Figure4.27. Effect of variation of time on wear rate value of composite material.

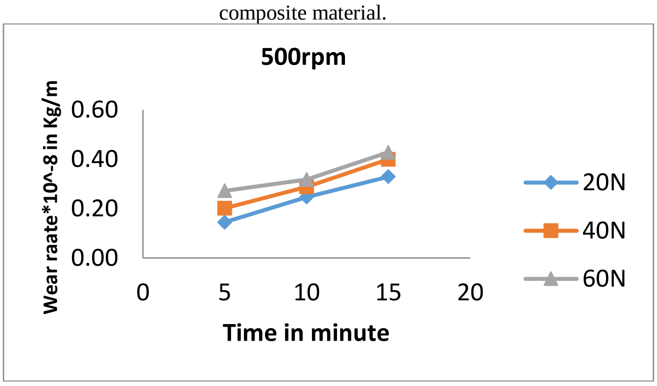

Figure4.28. Effect of variation of time on wear rate value of composite material.

The above figure shows the effect of time on wear rate of Aluminum alloy and it's composite. When time is low, the wear loss is quite small, which increases with increase in time. It can be considered that, it is quite natural for the weight loss to increase with time.

D. Effect of speed on wear rate.

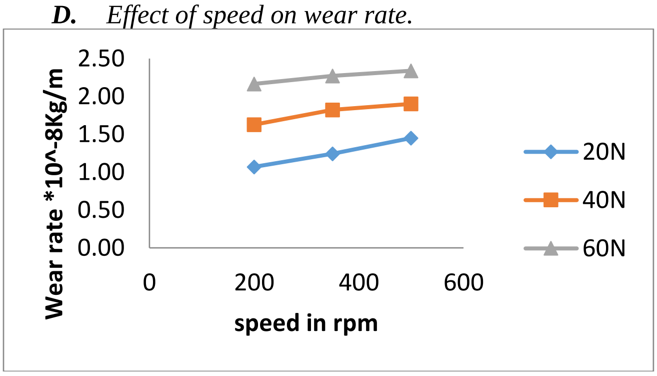

Figure4.29. Effect of variation of speed on wear rate value of composite material Al1000.

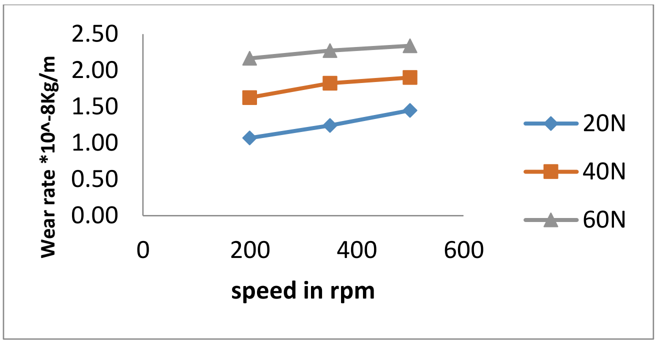

Figure4.30. Effect of variation of speed on wear rate value of composite material Al1500.

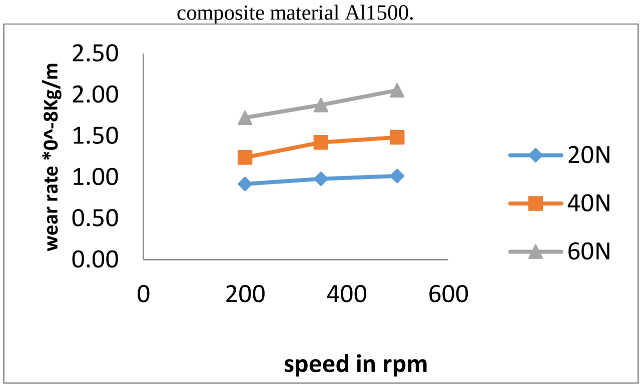

Figure4.31. Effect of variation of speed on wear rate value of composite material Al2000.

The above figure shows the effect of speed on wear rate of Aluminum alloy and it's composite. When speed is low, the wear loss is less, which increases with increase in speed. When speed increases, sliding distance also increase as a result wear rate more.

E. Effect of E-Glass on wear rate.

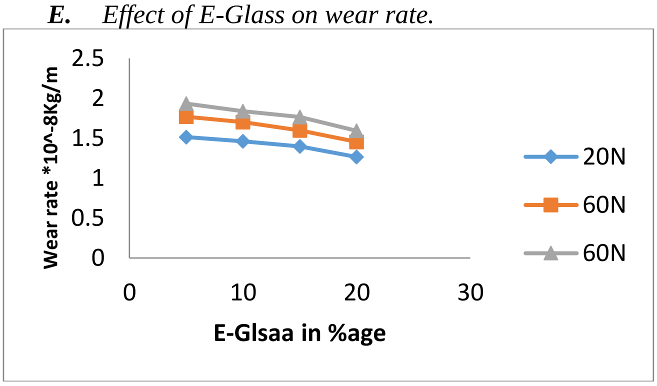

Figure4.32. Effect of variation of E-glass on wear rate value of composite material at 200rpm.

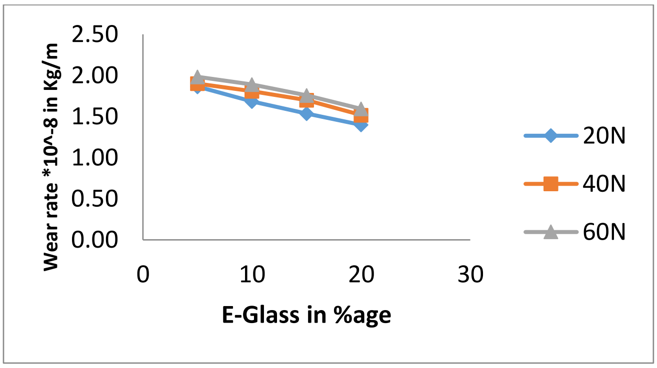

Figure4.33. Effect of variation of E-glass on wear rate value of composite material at 350rpm.

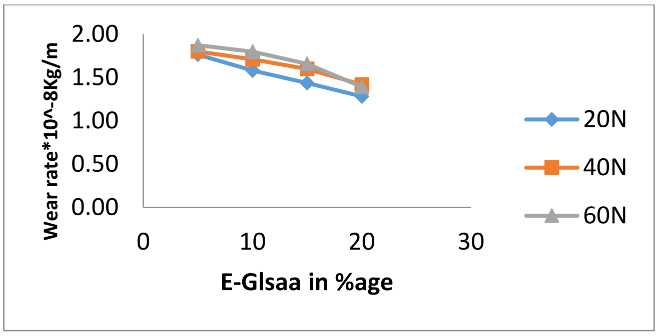

Figure4.34. Effect of variation of E-glass on wear rate value of composite material at 500rpm.

The above figure shows the effect of E-Glass on wear rate of aluminum alloy and it's composite. When E-Glass content is in low percentage, the wear rate is more, by increasing the percentage of E-Glass in aluminum alloy wear rate quite decreased.

V. CONCLUSIONS

From the experimental analysis carried out on 6061 Aluminum under varied material conditions and the process parameters, the following conclusions were derived.

- The dry sliding wear rate of composites and the matrix material alloy increased with the load applied.
- The wear rate has decreased significantly with the incorporation of fly ash in Al alloy.
- The dry sliding wear rate of Al 6061alloy composites material increased with the time and speed.
- The dry sliding wear rate of Al6061alloy composites material quit decrease with increase in the percentage of E-glass.
- Fly ash up to 20% by weight can be successfully added to Al by stir casting route to produce composites.

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