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Mechanical Characterization of a Peninsular Gneiss Rock Dust Flour Reinforced Aluminium Metal Matrix Composites

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ABSTRACT

The objective of this research is to evaluate the effects of dry sliding and mechanical wear on a compound of Al7068 and rocky soil that was produced by the liquid metallurgical process at a range of weight fractions (2.5 percent, 5 percent , 7.5 percent, and 10 percent). Rock dust typically consists of particles that are 200 microns in size when measured as a whole. Castings of Al7068 alloys were carried out without the use of any stone powder for the purpose of laying the foundation for the investigation.

A comparison was made between the hardness and tensile characteristics of these composites and those of an alloy and composites that had not been put through the T6 heat treatment. In addition, the tribological properties of these composites were analysed by employing a Pin-on-Disc apparatus with a number of distinct parameters, such as a constant velocity of 2 metres per second and variable weights of 0.5, 1, 1.5, 2, 2.5, and 3 kilogrammes. The results of this analysis were then compared to the results of other similar studies. When the percentage of rock dust used in composites is increased to 10 percent by weight, both the wear resistance and the mechanical characteristics of the composites are enhanced.

Keywords: Rock floor, Microstructure, dry sliding wear, SEM

1. Introduction

Rocks of the peninsular gneiss type have been found all throughout the Indian peninsula, even in rural areas of Bangalore. This stone is used in a variety of aesthetic applications, including wall cladding, tiles, bricks for brickwork, and other similar products. One of the advantages of this kind of stone is that it is simple to cut and shape into the dimensions and form that are wanted. As a direct consequence of this, it is the most challenging rock in all of South India. When you cut this kind of rock, fine dust particles are produced, quite similar to the dust that results from chopping wood or the fly ash that results from burning coal. This rock powder has a colour that is described as being white.

This stone flour is only suitable for use as a barrier for the soil layer; it cannot be used for any other purpose. Both biotic (components that were previously alive, such as plants and insects) and abiotic (components that are no longer alive) make up soil (non-living factors such as minerals, water and air). The presence of this rock dust, after it has settled on the surface of the soil, acts as a barrier to the growth of plants and has an effect on the habitat of organisms.

Aluminum alloys are utilised in a broad variety of applications in the automotive and aerospace industries because of its low weight, great heat conductivity, and high solid potential. These characteristics make aluminium alloys ideal for usage in these fields. Pistons and engine blocks are only two examples of standard components. The aluminium alloy 7068 is the strongest commercially accessible form of aluminium, and its strength is comparable to that of certain steels. Al-alloy 7068 was created specifically for use in the military. Al-alloy 7068 is currently being used or considered for applications in the aerospace industry and the automotive industry, such as valve bodies and connecting rods. It is also being used for clinical devices, such as prosthetic limbs, as well as recreational products, such as bicycles and mountaineering equipment [1]. The

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excellent strength, fracture toughness, and wear resistance that composites built of Al-alloys provide make them appealing for a variety of different applications.

In order to study the mechanical properties of Al6061-B4C (Boron Carbide) and Al6061-Gr, C. Muthazhagan et al. [2] carried out a standard heat treatment operation on the two materials (Graphite). The production of Al- MMCs was accomplished with the use of liquid metallurgy. Aluminum that had been reinforced with boron carbide (5, 10, and 15 percent) and graphite was used to make the composites, which were produced in a number of different volume percentage phases (5, 10 and 15 percent). In order to improve the composites' mechanical properties, a treatment with heat was applied to the fabricated components after they were made. There has been research done on the impact of the composites Al6061-Gr and Al-B4C. Investigations of the microstructure have also been carried out. It has been found that including graphite into an aluminium matrix lowers the material's ductility, hardness, and closing tensile strength, but incorporating boron carbide into the matrix raises the composites' level of hardness.

The tribological behaviour of hybrid MMCs reinforced with SiC, Al2O3, and graphite (Al6061-T6) composites was studied by SatpalKundu et al. [3]. The samples were made by a process called stir casting. Incorporating ten percent silicon carbide and five percent alumina (SiC+ Al2O3) into the Al-alloy resulted in the alloy's increased strength. According to a research that looked at the mechanical and tribological characteristics of both materials, the mechanical qualities of the composite were found to be superior than those of the alloy. The matrix of Al7068 was mixed with graphite (Gr), which resulted in the creation of a hybrid composite. Following a series of dry sliding wear tests on the hybrid composite, it was found that the wear and tear resistance of the hybrid composites was much higher than that of the Al6061-T6 alloy. The assessments were conducted based on load, sliding velocity, and sliding distance, which are the three key elements that have the most impact on the price of wear. The Design of Experiments (DOE) method, also known as the Taguchi methodology, the signal-to-noise ratio, and analysis of variance (ANOVA) were all used in this study to evaluate the damaging behaviour of hybrid MMCs.

The mechanical characteristics of hybrid aluminium metal matrix composites (MMCs) that were reinforced with silicon carbide particles and graphite, a common kind of solid lubricant, were examined by N. Nanda Kumar and colleagues [4]. Two different composite units have been produced: the first set of composites is made up of Al6061, and it is reinforced with varying amounts of Silicon Carbide particles (SiC) and graphite by weight (Gr). The second composite set is made up of Al6061 that has been strengthened with alumina (Al2O3) and graphite (Gr), which is a potent lubricant and is located in a secure nation. Both composites are produced by a process known as liquid metallurgy (Stir Casting Method). Samples of mechanical home goods were provided for evaluation purposes. Characterization of the test samples for the surface morphology of composites was carried out with the use of a scanning electron microscope (SEM). When compared to Al6016 alloy, the findings demonstrated that hybrid composites had higher mechanical properties.

It was hypothesised by Sachin Y [5] that aluminium and the alloys made from it had weak tribological characteristics, which may cause them to seize under certain conditions. Aluminum steel matrix composites came to be as a consequence of a strong desire to develop new materials that had a higher resistance to wear and increased tribological characteristics. As a result of this desire, aluminium steel matrix composites came into being.

According to the findings of Suresh S and colleagues [6], the performance of a metal matrix composite reinforced with ceramic particles was superior to that of the researchers' unreinforced matrix alloy.

According to the findings of an investigation conducted by N. Radhika and colleagues [7], the incorporation of fly ash particles into aluminium alloy has the potential to save energy-intensive metal, reduce the cost of aluminium goods, and lessen the weight of finished products.

When metal and graphite composites are dry-sliding against one another, a continuous layer of solid lubricant forms on the tribo surface, as stated in the work of F. Akhlaghi et al. [8]. This lubricating layer is produced as a result of shearing Gr particles that have been positioned directly beneath the sliding surface of the composite material. This layer of Gr-rich lubricant lessens the amount of shear stress that is transferred to the material under the contact area, lessens the amount of plastic deformation that occurs in the subsurface region, and prevents metal from coming into touch with other metals.

Because graphite is used as a solid lubricant in the aluminium graphite composite, the strength of the composite is compromised as a consequence. This is one of the limitations of the material.

The wear properties of Al6061-SiC-Al2O3 composites were studied by Umanath, K., et al. [9]. According to the results, the hybrid composite with 15 percent fibre content exhibited a higher resistance to wear than the composite with 5 percent fibre content. The volumetric wear loss of the Al6061-9 percent Al2O3-6 percent Graphite composites was found to be lower than that of the Al6061 matrix, as stated by the research conducted by MadevaNagaral et al. [10]. The worn surfaces were characterised by the use of SEM microanalysis. In the present work, the production and characterization of Al7068/Gr MMCs, in addition to the microstructural, mechanical, and tribological characteristics of these materials, are investigated.

Numerous attempts have been made to synthesise MMC in order to increase its wear resistance qualities by using low-cost reinforcing minerals such as bauxite, corundum, granites, and sillimanite, amongst others. These efforts have been successful in certain instances. The increasing need for cost-effective reinforcement has sparked an interest in the use of waste materials such as fly ash and rock dust as reinforcing agents. The process of cutting or crushing Peninsular Gneiss Rock results in the production of rock dust.

As a direct result of this, the work that is being done here makes an attempt to use rock dust as a reinforcing material and aluminium as a matrix material. The current study studied the mechanical strength of a stir cast rock dust reinforced aluminium metal matrix composite by measuring its tensile strength, hardness, and wear coefficient of friction. Other measures of mechanical strength were also taken into consideration.

2. Materials and Methods

The present study requires two materials to act as a matrix and reinforcement. The matrix material selected is Al7068with the theoretical density of 2.850 g/cm^{3}was used as a matrix material. The physical properties and chemical composition is as given in Table 1 and Table 2 respectively.

The reinforcement isPeninsular Gneiss Rock Flour.The particle size of Rock flour is 200Microns which was measured in sleeve analyzer. Density is 3.11g/cm3. Colour of Rock Flour is white.The physical properties areas given in Table 3.

Table 1. Chemical Properties of Al7068.

Element	Weight %
Zn	7.5
Mg	2.5
Cu	2.2
Fe	0.15
Mn	0.10
Ti	0.5
Si	0.12
Others	0.15
Al	Balance

Table 2. Physical Composition of Al7068.

Properties	Values
Density	2.85g/cc

Melting Point	476-635°C
Elastic Modulus	73.1GPa
Poisson Ratio	0.23

Table 3. Physical PropertiesRock Flour.

Element	Weight %
SiC	59.62
Al2O3	15.29
MgO	6.54
Ca	6.44
Fe	10.5
K	1.25
S	0.36

3. Fabrication of Composites.

An electric furnace and a mechanical stirrer make up the bulk of the apparatus used in the stir casting experimentation setup. A crucible with a capacity of 3 kilogrammes is included in the electric furnace. The furnace can reach a maximum operating temperature of 1200 degrees Celsius. The furnace has an electrical rating of 230 volts AC and 2 kilowatts. After being cut up into smaller pieces and deposited in the crucible, the ingots of aluminium alloy 7068 weighing around three kilogrammes each were reduced. They have been cooked to a temperature that is around 800 degrees Celsius over normal. In order to remove any remaining moisture, the rock dust particles were warmed for three hours at temperatures ranging from 1300 to 1500 degrees Celsius. After the metal had melted fully, a degassing tablet made of C2Cl6 was added so that the porosity could be reduced and the gases that had been trapped throughout the melting process could be released. At the same time, 0.5 percent of magnesium by weight was added to the material in order to increase its wettability. This was done in order to get the desired effect. Stirring of the molten metal took place at a speed of six hundred and fifty-seven hundred revolutions per minute as a stirrer turned into gradually dropped down to a positive height into the soften. A regulator that was installed on the heater allowed for the speed of the stirrer to be adjusted as needed. Throughout the process of stirring, the warmed particles had been added to the molten metal at a rate that remained constant. Continued stirring occurred for a further 15–20 minutes after that. Following the stirring step, the aggregate was put into the mould, which had already been warmed to 350 degrees Celsius for forty-five minutes. This was done to ensure consistent solidification. The stir casting process was used to manufacture Al7068 bolstered MMCs in weight proportions of 2.5 percent, 5 percent, 7.5 percent, 10 percent, and 15 percent respectively.

3.1. Hardness Test

The hardness take a look at changed into carried out as per ASTM E-18 standards and for figuring out the hardness of substances, Rockwell Hardness tester became used. A common of 5 readings became taken for every sample for hardness measurement. For B scale 1/16" metal ball is used as the indenter. A primary load of 100 kgf and a minor load of 10 kgf are applied.

3.2. Tensile Test

Tension test specimens have been machined according with ASTM E-8 specs and examined at room temperature the use of usual checking out gadget interfaced with a pc. The mechanical traits YS (Yield power) and UTS (Ultimate tensile energy) have been accrued from the gadget's facts acquisition gadget. These average values are primarily based on five test effects for every alloy/condition.

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3.3. Wear Test

Dry sliding wear assessments were performed in accordance with ASTM-G99 standards utilizing a Pin-on-Disc gadget powered with the aid of a D.C. Motor and a counter face disc with a diameter of a hundred and sixty mm and a thickness of 8 mm. The weight reduction approach became used to calculate the wear and tear charge of specimens for take a look at parameters by means of dividing the weight misplaced in sliding by way of the sliding distance. Before and after every take a look at, every specimen became weighed with electronic weighing device to an accuracy of 0.0001g. The wear rate was calculated the use of the common of 5 experiments.

4. Results and Discussion.

4.1. Hardness Test

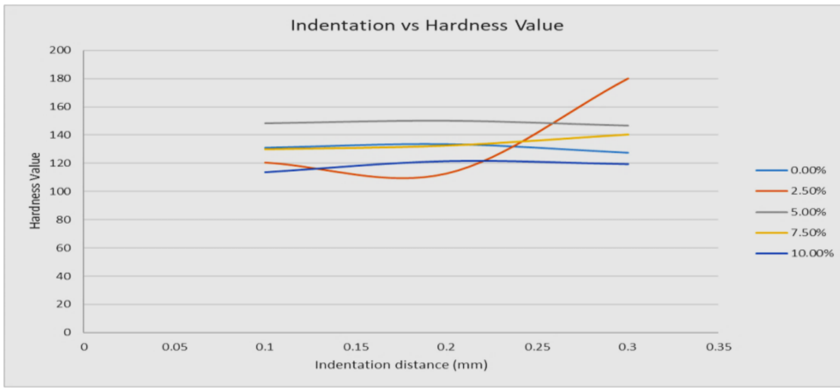

Figure. 1: Hardness values of rock floor reinforced Al7068 alloy composites

Figure 1 gives the hardness plot for the stir cast aluminum alloy Al7068 and its composites with different percentages of rock dust reinforcement. The specimen was prepared using 2.5, 5, 7.5 and 10 wt. % of rock flour. The results indicate that the maximum hardness is seen for the Al7068/2.5% rock dust composite at an indentation distance of 0.3mm. It also indicates that the hardness for the same range of indenta- tion distance is highly varied for the 2.5% rock dust reinforced composite than any other composite under study. This could be due to the low percentage and a very scarce distribution of rock dust in the composite. Considering the average variation between the different specimens, it can be said that 5% rock dust in the Al7068 matrix gives the optimum results.In the overaged condition, the composite with a higher reinforcement fraction shows a much greater hardness value, although its tensile strength may be comparable to those with lower particle fractions.

4.2. Tensile Test

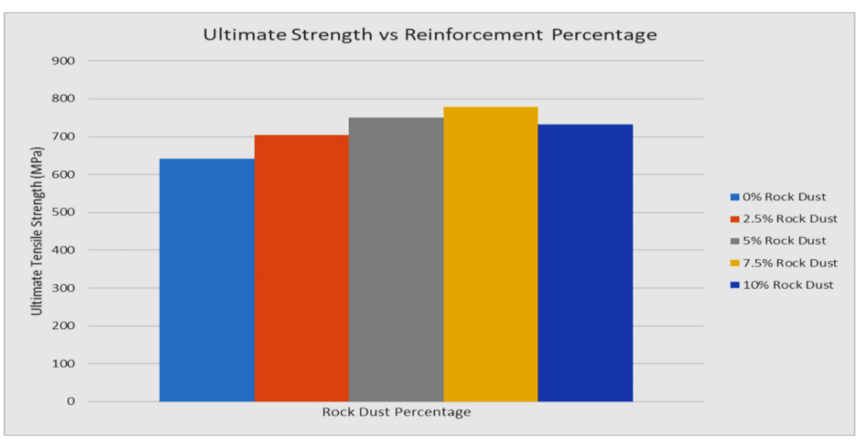

Figure. 2: UTS values of rock floor reinforced Al7068 alloy composites

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Figure 2 gives the plot for the ultimate tensile strength of the as cast aluminum al- loy Al7068 and its composites with 2.5, 5, 7.5 and 10 wt. % rock dust reinforcement. The plot shows that the composite specimen prepared with rock dust reinforcement improve the strength of the aluminium alloy Al7068. The increase rock dust percent- age increases the ultimate tensile strength of the material until 7.5% rock dust but then reduces for the 10% rock dust reinforcement. This could be an indication that the higher concentration of rock dust has a negative effect on the strength of the material by making it highly porous than the other reinforcement percentages. The change in strength of the specimen are 8.9%, 14.5%, 17.6% and 12.5% respectively for 2.5%, 5%, 7.5% and 10% rock dust reinforced composites.Grain refinement at the ma- trix/reinforcement interface induces the strengthening effect of composites, thereby increasing the tensile strength of composites.

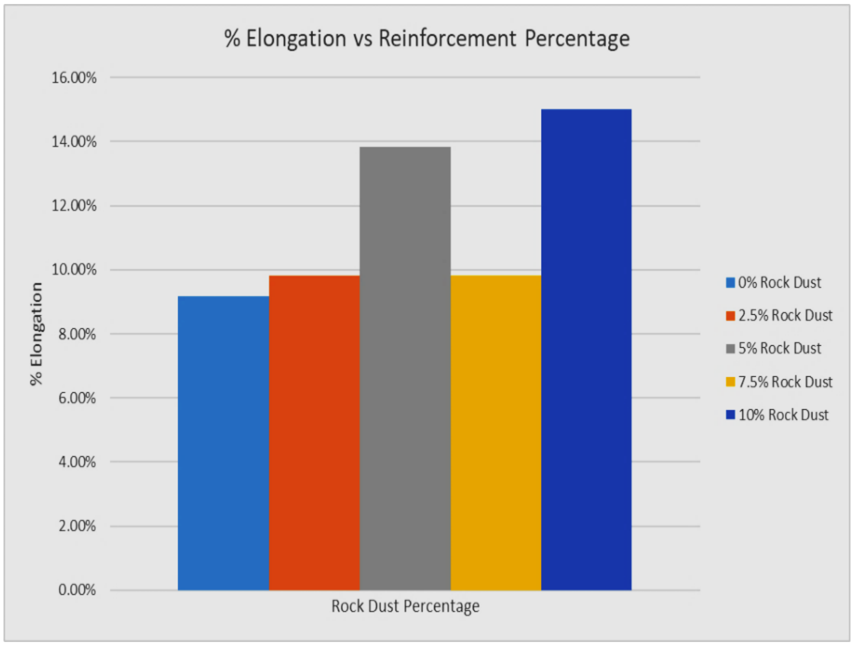
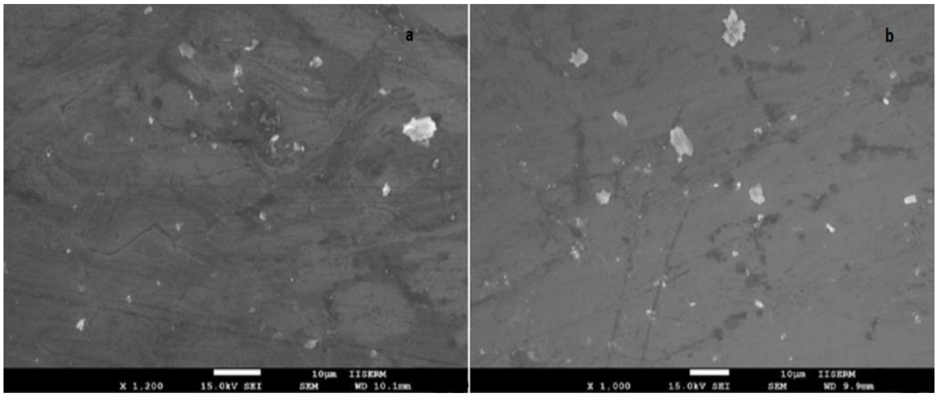


Fig. 3: % Elongation values of rock floor reinforced Al7068 alloy composites

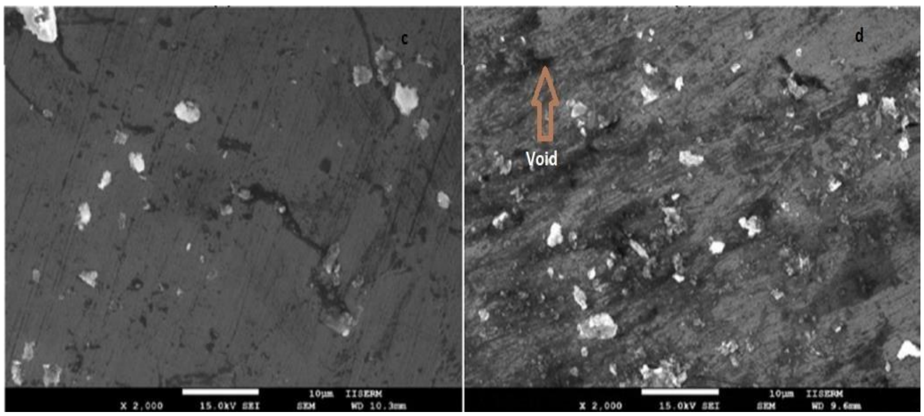
Figure 3 gives the results for the % Elongation of the As-cast and the rock dust re- in forced composite specimen. The composite specimen prepared has the reinforce- ment as rock dust in the percentages 2.5, 5, 7.5 and 10. The results indicate that the lowest elongation is seen in the composite with the 2.5% reinforcement with a value of 9.83%. The highest is seen for the 10% rock dust reinforcement at a value of 15%. This indicates that higher percentages of the rock dust have a negative effect on the %Elongation of the material where lowest %Elongation is preferred. Presence of dimples, micro cracks and micro voids formed due to deboning are the major factors influencing the tensile strength of composites. Addition of rock dust about 7.5% in aluminium alloy decreases the elongation of composites as shown in Fig.3.

4.3. Microstructure

Scanning electron microscope images of prepared composites show the distribution on Rock flour particles in Aluminium7068 matrix. Figure 4(a,b,c,d) shows the fractured surface of tensile specimen. Surface indicates Brittle fracture. The distribution of Rock dust flour particles is fairly homogenous Fig 4a, and Fig4 b. As the reinforcement percentage of rock flour is increased, clusters are formed in the matrix, as shown in Fig 4c; Fig 4d.The voids in the figure indicate ductile type of fracture. Also cracks are propagated near particles [11].



4.a 4.b



4.c 4.d

Figure 4: SEM images of Tensile fractured surface 4**a)**: 2.5%, 4b)5%, 4c) 7.5%, 4d) 10% reinforced Rock flour Al-7068 composites.

4.4. Wear Test

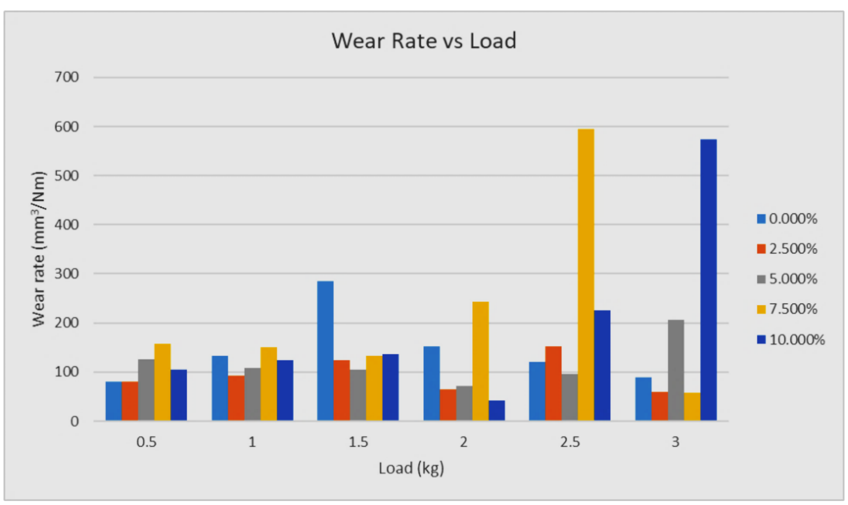


Figure. 5: Effect of load on wear rate of rock floor reinforced Al7068 alloy composites

Figure 5 shows the plot for the wear test results with variation in load for different Percentages of rock dust reinforcement(Speed: 2m/s, load: 10 - 30N). The graph indi- cates that the increase in reinforcement percentage decreased the wear rate. It is also seen that the increase in load has an inverse effect of lower wear rate. At 2.5kg load, the wear rate increases drastically for the rock dust percentage of 7.5%. This is recre- ated for the load of 3kg and 10% load. The lowest wear rate is seen for a load of 2kg load and 10% rock dust reinforcement. The highest wear rate is seen for a load of 2.5kg and reinforcement percentage of 7.5%.It is observed that the coefficient of fric- tion varies with samples. In composites, the reinforcement inside the composite helps the carried out load which in result decreases. The contact region among the pin and disc surface. A massive range of rock dust particles comes in contact with the counter disc and those particles start destructing itself, and as a result will increase the coefficient of friction.

5. Conclusions

From the results obtained, we can conclude that,

a. The hardness of the composite increases with increase in rock dust reinforcement percentage. The optimum value of rock dust reinforcement is seen at 5% rock dust reinforcement.

b. The tensile strength results show that the ultimate tensile strength increases with increase in rock dust percentage till 7.5% reinforcement and then starts decreas- ing.

c. The wear test results show that the optimum percentage of reinforcement for low- est wear in the composite is 10% rock dust reinforcement at 2kg load considering all other parameters as constant.

d. Using Stir casting method, the reinforcement Rock flour is uniformly distributed in Al-7068 matrix which was evident from SEM Images.

Considering the results from all the tests conducted in this paper, it is clear that the Aluminium composite of Al7068 and 7.5% rock dust reinforcement gives the opti- mum results for the mechanical and tribological characteristics of the composite.

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