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COMPARATIVE STUDY OF EFFECT OF ABRASIVE PARTICLE SIZE ON SAND SLURRY EROSIVE WEAR BEHAVIOR OF (Al6061-SiC) and (Al6061-SiC-Gr) COMPOSITES

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ABSTRACT

Slurry Erosive Wear has drawn a major attention in the present industrial era, which has become topic of hot discussion especially in the field of marine and chemical industries. Hence it is high time to develop a system of material which can assist in reducing the damage encountered due to Slurry Erosive Wear. In this regard present investigation deals with a comparative study of effect of abrasive particle size on sand slurry erosive wear behavior of Aluminium based metal matrix composites (Al6061-SiC) and Hybrid Composites (Al6061-SiC-Gr). Other parameters which are considered for the study are, effect of time, speed, and slurry concentration. Experimental results are supported by Scanning Electron Microscopy [SEM] which clearly gives an insight into the wear occurred due to slurry.

Keywords: Slurry Erosive Wear, Composites, Metal Matrix Composites (MMCs), and Hybrid Composites.

1. INTRODUCTION

Composite material is defined as a system of material which is composed of a mixture or combination of two or more constituents which differs in form and or material composition and is essentially insoluble in each other. The structural composites constituent mainly consists of an assembly of two materials of different nature. In general one material is discontinuous and it is called as reinforcement, such as fibers, particles, and flakes, and other material is mostly less stiff and weaker it is continuous and it is called as matrix. The matrix is a body constituent serving to enclose the reinforcement and gives the composite its bulk form.

The applications of composite materials and structural elements composed of composite materials have been widely spread in the last few decades. The motivation for this development is the significant progress in material science and technology of composite constituents. The requirements for high performance is not only in aircraft and aerospace structures but also in advanced fields such as Automobile, Electrical and Electronic devices, Marine and Recreational Industry.

Slurry: Slurry is, in general, a thick suspension of solids in a liquid. The principal materials used to create slurry seal are aggregate, asphalt emulsion, and filler, which are mixed together according to a laboratory's design-mix formula. Water is also added for workability. Asphalt emulsions serve as a binder, holding the crushed aggregate together and bonding the new slurry surface to the old surface over which it is being applied.

Erosive Wear: Erosive wear can be defined as the process of metal removal due to impingement of solid particles on a surface. Erosion is caused by a gas or a liquid, which may or may not carry, entrained solid particles, impinging on a surface. When the angle of impingement is small, the wear produced is closely analogous to abrasion. When the angle of impingement is normal to the surface, material is displaced by plastic flow or is dislodged by brittle failure.

2. Material Selection

The following materials are selected for the preparation of Metal Matrix Composites and Hybrid Composites.

2.1 Matrix Material

Al6061 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. It possesses good mechanical properties and exhibits good formability. It is one of the most common alloys of aluminum widely used for general purpose applications. .

2.2 Reinforcement Materials

Silicon Carbide was chosen as reinforcement owing to its high hardness and low coefficient of thermal expansion. SiC is highly wear resistant and also has good mechanical properties including high strength and thermal shock resistance. The particles size of the reinforcement used is in the range of 20µm to 30µm. The other Reinforcement particle chosen for fabrication of Hybrid Composites along with silicon carbide is Graphite. Finely powdered graphite is reinforced in the Matrix along with silicon carbide. The prime reason for choosing graphite powder since it is valued in industrial applications for its self-lubricating and dry lubricating properties. Recent studies suggest that an effect called super lubricity can also account for graphite's lubricating properties.

3. EXPERIMENTAL DETAILS

The brief description of various stages involved in this experimentation is described as follows:

3.1 Process Selection: The process selected for processing composite material is called as vortex method of processing. Figure 1.0 shows the process of vortex method. In this technique preheated particulate reinforcements are added at a predetermined rate into the vortex of liquid metal or alloy to achieve thorough mixing of the reinforcement and the liquid metal. The vortex in liquid metal is achieved by mechanical stirring. After the addition of reinforcement into the vortex, stirring is continued for a period of five minutes, while maintaining the temperature of the molten metal. This is followed by pouring of the composite melt into preheated moulds. This is one of the popular methods used in fabrication of composite material all over the world. Here, the composites can be prepared in large quantities.

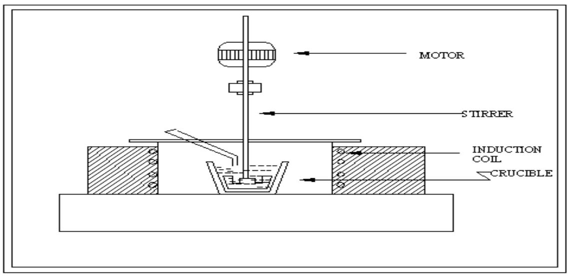


Fig 1. Vortex Technique of Processing Composites

3.2 Preparation of Test Samples: Initially the Aluminium in the form of billets are melted in a induction furnace and during the course of melting the billets the required pre-heated Reinforcements are introduced in to the melt at a suitable stage and poured in to the mold. The melting furnace set up is as shown in figure-2

Fig 2. Induction Furnace Used for Preparaing Composites

After the molten composite is solidified it was be removed from the mold and subjected to machining to produce the required size specimens. The samples were prepared for microstructure, microhardness, and erosive wear studies as per ASTM standard dimensions (Ø8X15). The samples of Base Alloy, Metal Matrix Composites and Hybrid Composites of all the systems studied were prepared for the above tests. The photographs of the samples prepared for the above tests are given in Figure 3

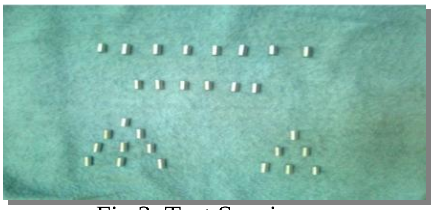


Fig 3. Test Specimens

3.3 Metallographic Studies

a) Optical Micrograph Studies: The samples were ground on the silicon carbide abrasive papers of 300, 600, 800, 1000 & 1200 grit sizes. Grinding was done in successive steps on each abrasive paper. After emery polishing, the samples were thoroughly washed, dried and polished on a velvet cloth using alumina as a abrasive on a two disc polishing machine. A highly polished surface with mirror finish was obtained using a diamond paste of grade 3microns. The samples were etched with Keller's reagent to reveal the grain structure. The highly polished surfaces were observed under Triumph make microscope as shown in Figure 4 and photographs were captured using digital camera.

Fig 4. Photograph of Optical Microscope

b) **Scanning Electron Micrograph:** SEM- Philips make model at Central Power Research Institute, Mysore were used to observe the dispersion of particulates in cast and extruded composites. Fractured surface of Erosive wear samples, surfaces and subsurface of worn samples have been observed. Before observation surfaces were coated by sputtering technique.

c) **Microhardness:** Vickers microhardness test was performed on all the samples both Metal Matrix Composites and Hybrid Composites. The microhardness tests were conducted on the polished samples. The samples were ground and polished. The polished samples were subjected for microhardness tests on Shimadzu microhardness tester. The photograph of the tester is shown in Figure5.

Fig 5. Photograph of Vicker's Hardness Machine

d) Fabrication Details of Slurry Erosion Test Setup

Slurry Erosion test set up was fabricated using a commercially available domestic mixer grinder. This machine consists of a motor with a speed control unit having the specification of a mixer grinder with a maximum speed of 8000 rpm. The sand slurry mixture was filled into stainless steel jar, which had a provision for holding the specimen along with it. The unit is enclosed in a wooden box to avoid shocks. The specimen is held in the specimen holder at an inclination of 0° as per the ASTM standards. The setup is as shown in fig below.

Fig 6. Photograph of Fabricated Slurry Erosion Test Setup.

4. RESULTS AND DISCUSSIONS

Base alloy, Metal Matrix Composites, and Hybrid Composites specimens were processed and subjected to various test, the amount of wear under gone by MMCs and Hybrid Composites are thoroughly studied and compared with each other, and results are given in the form of Graphs and the same is supported by SEM Photographs. The various tests carried out are as follows:

- Microstructure studies
- Microhardness studies
- Slurry Erosive Wear studies.

The parameters which are studied for Slurry Erosive wear analysis are as follows:

- Effect of Abrasive particle Concentration
- Effect of Time on specimen wear
- Effect of speed on Specimen wear
- Effect of Abrasive particle size

i)

4.1 Microstructure Studies

The optical microphotographs of the cast base Aluminium Al6061, its Metal Matrix Composites (Al6061-SiC) and Hybrid composites (Al6061-SiC-Gr) are as shown in Figure 7.1 and 7.2. The micrographs clearly indicate the evidence of minimal porosity in both the base alloy and the composites. The distribution of SiC particles in a matrix alloy is fairly uniform. Further these microphotographs reveal an excellent bond between the matrix alloy and the reinforcement particles.

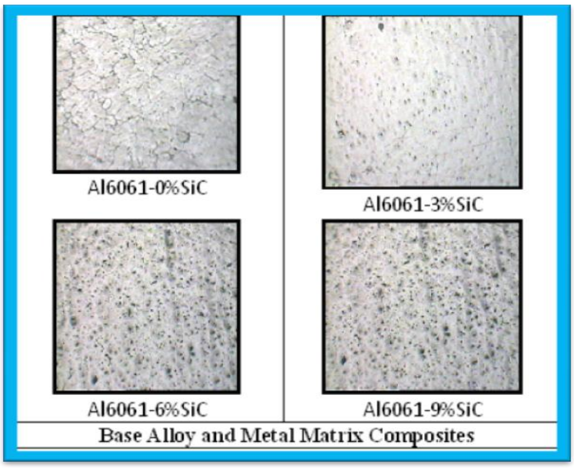


Fig 7.1. Microstructure Photographs of Metal Matrix Composites

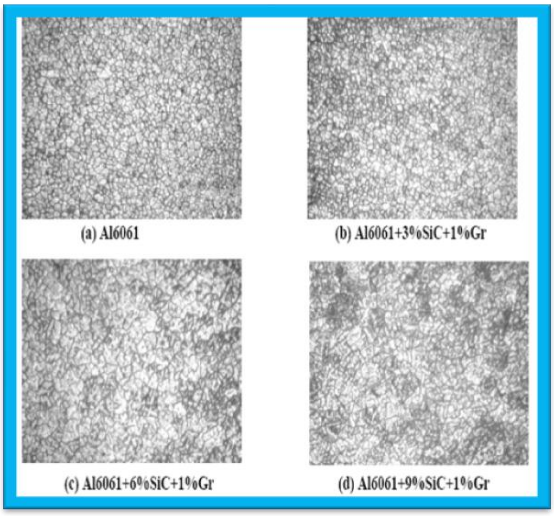


Fig 7.2. Microstructure Photographs of Hybrid Composites

4.2 Microhardness

a) Metal Matrix Composites: It is observed from the figure that the increased content of reinforcement in the matrix alloy results in enhanced hardness of the composite for the composite studied. This trend is similar with the result of other researchers

The enhanced hardness of composites can also be attributed to the fact that the lesser extent of porosity is observed as evident in optical microphotographs. It is reported that higher hardness is associated with lower porosity of the MMCs.

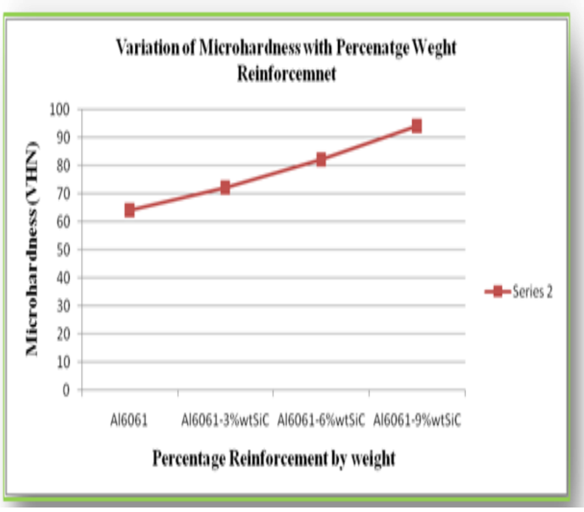


Fig 8.1. Variation of Microhardness in Metal Matrix Composites

b) Base Alloy Al6061 and its Hybrid Composites

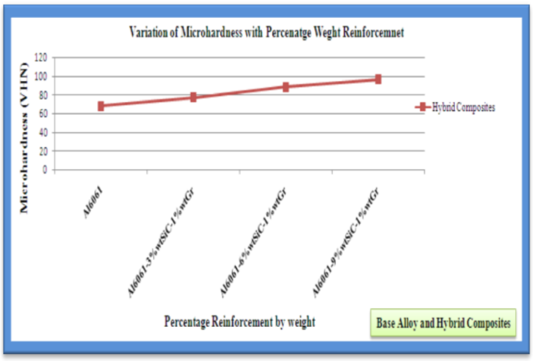


Fig 8.2. Variation of Microhardness in Hybrid Composites

Figure 8.2 Shows the Variation of micro hardness of hybrid composites with increased content of reinforcement. Increased content of reinforcements results in enhanced hardness of Hybrid Composites for a given reinforcement content. Hybrid composites posses higher hardness when compared with Metal Matrix Composites

4.3 Slurry Erosive Wear studies:

a) Effect of Slurry Concentration on Metal Matrix Composites:

Figure 9.1 shows the variation of wear that as occurred on the specimens when the specimen is exposed to slurry media which contains different concentrations of abrasive particles. It is evident from the graph that slurry wear increases as the concentration of abrasive particle increases, but there is a reduction in wear at a particular instant as the content of the Reinforcement increases, this can be attributed to hardness nature of SiC present in the Composite. Figure 9.2 shows the SEM photographs of worn out specimens when it is exposed to different size abrasive particle.

Figure 9.3 and 9.4 shows the graphical variation and worn out specimens SEM photographs of Hybrid Composites, when we compare both Al6061-SiC and Al6061-SiC-Gr it is clearly evident that Hybrid composites offer better wear resistance as compared to metal matrix composites.

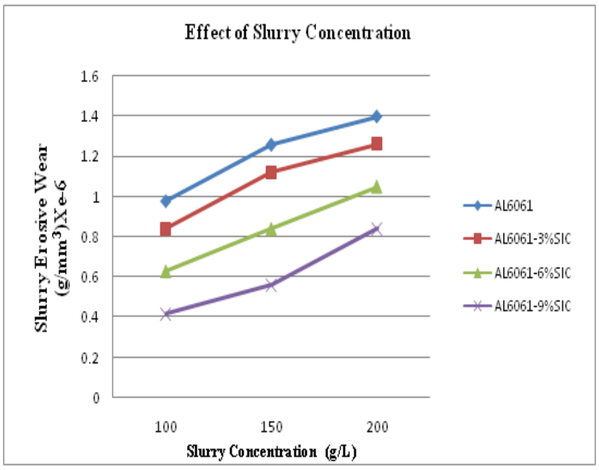


Fig 9.1. Effect of Slurry Concentration in Metal Matrix Composites

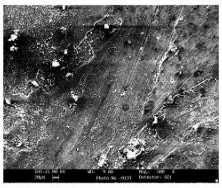
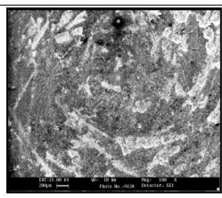
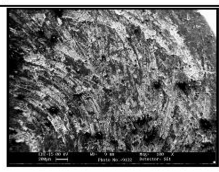
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**150g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**200g/L **Grain Size:** 212GFN

Fig 9.2. SEM Photographs of worn out Specimens due to variation of Slurry Concentration in Metal Matrix Composites

b) Effect of Slurry Concentration on Hybrid Composites:

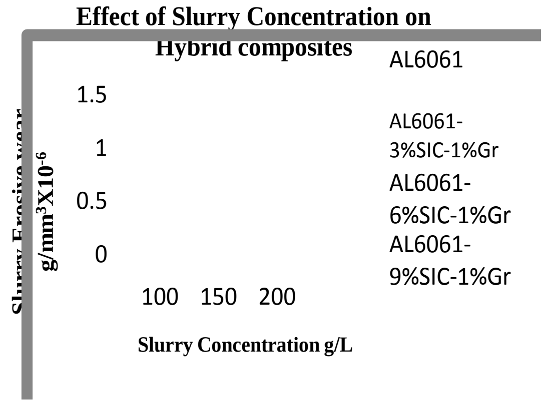


Fig 9.3. Effect of Slurry Concentration in Hybrid Composites

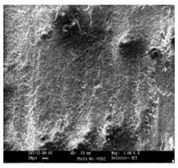
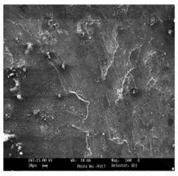
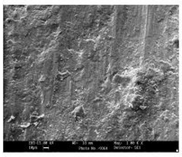
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**150g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**200g/L **Grain Size:** 212GFN

Fig 9.4. SEM Photographs of worn out Specimens due to variation of Slurry Concentration in Hybrid Composites

c) Effect of Slurry speed on Metal Matrix Composites:

Figure 9.5 shows the variation of wear that as occurred on the specimens when the specimen is exposed to slurry media for different speed of rotation. It is evident from the graph that slurry wear increases as Speed of rotation increases, but there is a reduction in wear at a particular instant as the content of the Reinforcement increases, this can be attributed to hardness nature of SiC present in the Composite. Figure 9.6 shows the SEM photographs of worn out specimens when it is exposed to slurry media for different speed of rotation. Figure 9.7 and 9.8 shows the graphical variation and worn out specimens SEM photographs of Hybrid Composites, when we compare both Al6061-SiC and Al6061-SiC-Gr it is clearly evident that Hybrid composites offer better wear resistance as compared to metal matrix composites.

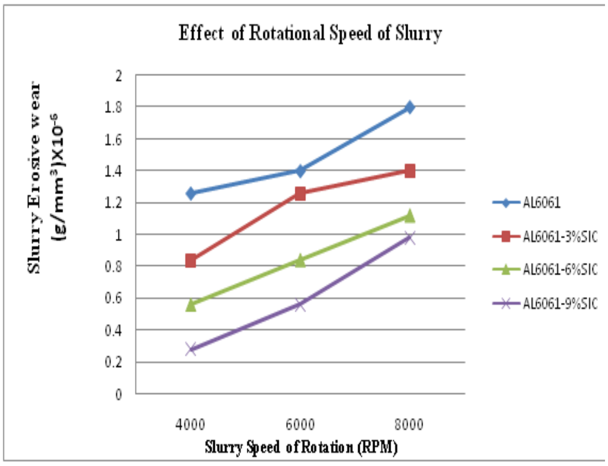


Fig 9.5. Effect of Slurry speed on Metal Matrix Composites.

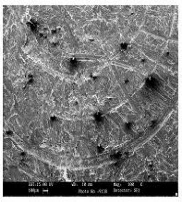
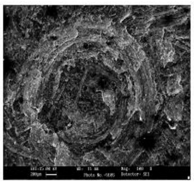
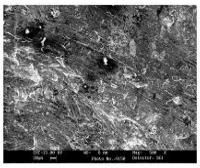
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 4000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 8000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN

Fig 9.6. SEM Photographs of worn out Specimens due to variation of Slurry Speed in Metal Matrix Composites.

d) Effect of Slurry speed on Hybrid Composites:

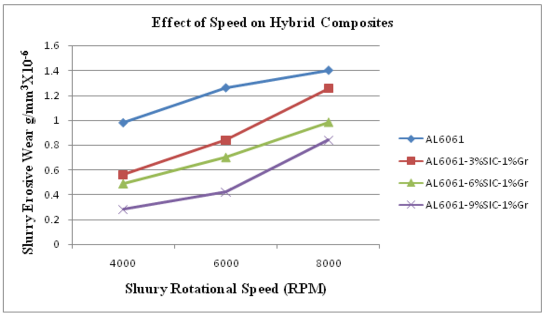


Fig 9.7. Effect of Slurry speed on Hybrid Composites.

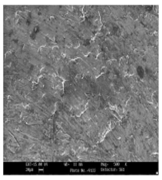
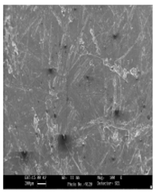
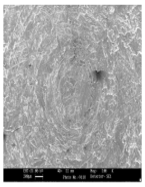
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 4000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 8000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN

Fig 9.8. SEM Photographs of Worn Out Specimens Due to Variation of Slurry Speed in Hybrid Composites.

e) Effect of Time on Metal Matrix Composites:

Figure 9.9 shows the variation of wear that as occurred on the specimens when the specimen is exposed to slurry media for different time duration. It is evident from the graph that slurry wear increases as duration of rotation increases, but there is a reduction in wear at a particular instant as the content of the Reinforcement increases, this can be attributed to hardness nature of SiC present in the Composite. Figure 9.10 shows the SEM photographs of worn out specimens when it is exposed to slurry media for different speed of rotation. Figure 9.11 and 9.12 shows the graphical variation and worn out specimens SEM photographs of Hybrid Composites, when we compare both Al6061-SiC and Al6061-SiC-Gr it is clearly evident that Hybrid composites offer better wear resistance as compared to metal matrix composites.

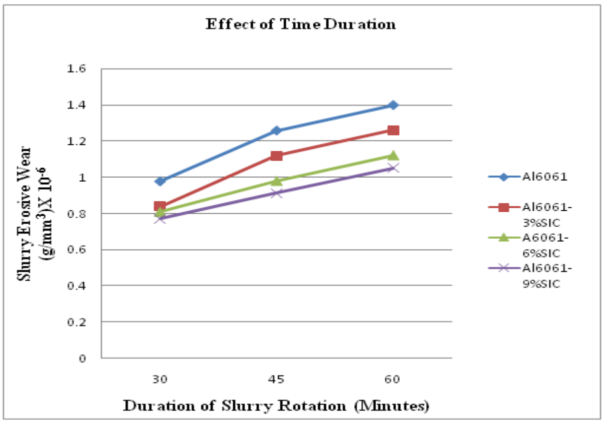


Fig 9.9. Effect of Duration of Slurry Rotation on Metal Matrix Composites.

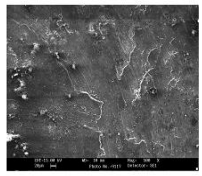
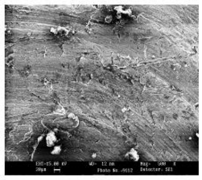
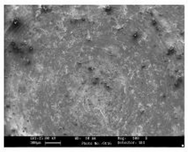
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 45Minutes **Test Speed:** 6000RPM **Slurry Concentration:**150g/L **Grain Size:** 212 GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 45Minutes **Test Speed:** 6000RPM **Slurry Concentration:**200g/L **Grain Size:** 212 GFN

Fig 9.10. SEM Photographs of Worn Out Specimens Due to Variation in Duration of Slurry Rotation on Metal Matrix Composites

f) Effect of Time on Hybrid Composites:

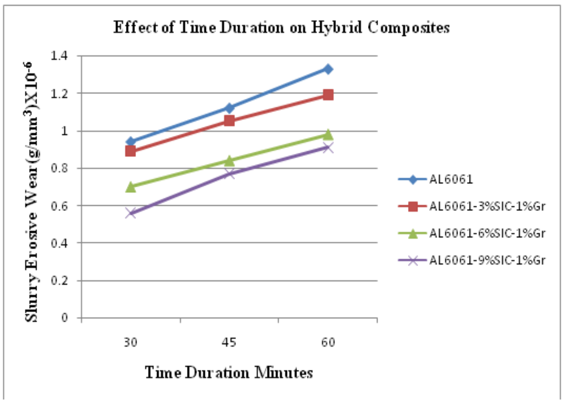


Fig 9.11. Effect of Duration of Slurry Rotation on Hybrid Composites**.**

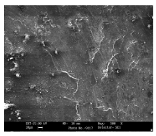
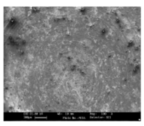
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 45Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 60Minutes **Test Speed:** 6000RPM **Slurry Concentration:**100g/L **Grain Size:** 212GFN

Fig 9.12. SEM Photographs of Worn Out Specimens Due to Variation in Duration of Slurry Rotation on Hybrid Composites**.**

g) Effect of Abrasive Particle Size on Metal Matrix Composites:

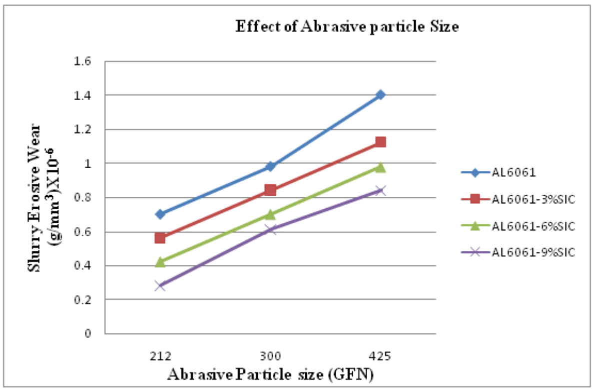


Fig 9.13. Effect of Abrasive Particle Size on Metal Matrix Composites

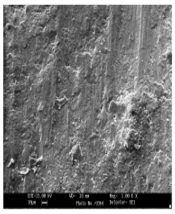
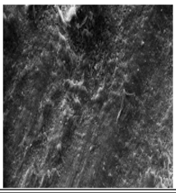
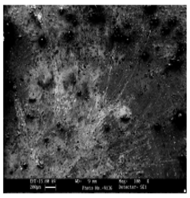
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30 Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 300 GFN
	**Specimen:** Al6061- 3%SiC **Test Duration:** 30 Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 425 GFN

Fig 9.14. SEM Photographs of Worn Out Specimens Due to Variation in Abrasive Particle Size on Metal Matrix Composites.

Figure 9.13 shows the variation of wear that as occurred on the specimens when the specimen is exposed to slurry media which contains different size abrasive particles. It is evident from the graph that slurry wear increases as abrasive particle size increases, but there is a reduction in wear at a particular instant as the content of the Reinforcement increases, this can be attributed to hardness nature of SiC present in the Composite. Figure 9.14 shows the SEM photographs of worn out specimens when it is exposed to different size abrasive particle. Figure 9.15 and 9.16 shows the graphical variation and worn out specimens and SEM photographs of Hybrid Composites, when we compare both Al6061-SiC and Al6061-SiC-Gr it is clearly evident that Hybrid composites offer better wear resistance as compared to metal matrix composites.

h) Effect of Abrasive Particle Size on Hybrid Composites:

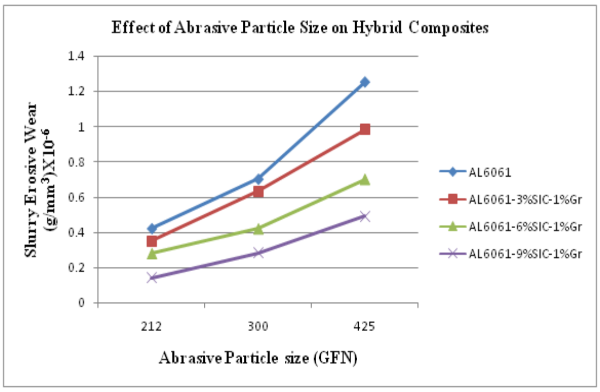


Fig 9.15. Effect of Abrasive Particle Size on Hybrid Composites

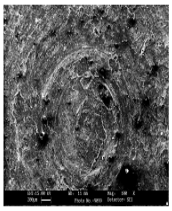
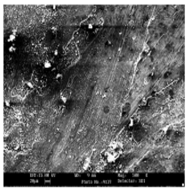
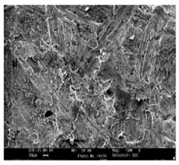
SEM Photo of Eroded Specimen	Test Details
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 212GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 300 GFN
	**Specimen:** Al6061- 3%SiC-1%Gr **Test Duration:** 30Minutes **Test Speed:** 6000RPM **Slurry Concentration:** 100g/L **Grain Size:** 425 GFN

Fig 9.16. SEM Photographs of Worn Out Specimens Due to Variation in Abrasive Particle Size on Hybrid Composites.

5. CONCLUSION

Microstructure studies reveal fairly uniform distribution of SiC particles in the matrix alloy with a good bonding between the matrix alloy and the reinforcement. Microhardness of composites is higher when compared with that of matrix alloy. Increased content of hard reinforcement (SiC) in the matrix alloy leads to enhancement in micro hardness.

The Hybrid composites posses' higher hardness, when compared with the Metal Matrix composites and the Base alloy. There is a significant reduction in slurry erosive wear in the composites with an increase in the percentage weight of the reinforcement in both Metal Matrix and Hybrid Composites. Increase in the concentration of the silica abrasive particles in the slurry has result in increased slurry erosive wear of both Metal Matrix and Hybrid Composites and Al6061 alloy. However, Hybrid Al6061-SiC-Gr composites have better slurry erosive wear resistance when compared to Metal Matrix composites and base alloy under identical test conditions. There is a significant increase in slurry erosive wear of both Metal Matrix and Hybrid Composites and Al6061 alloy. However, Hybrid Al6061-SiC-Gr composites have better slurry erosive wear resistance when compared to Metal Matrix composites and base alloy under identical test conditions. With an increase in test time duration there is an increase in slurry erosive wear of both Metal Matrix and Hybrid Composites and Al6061 alloy. However, Hybrid Al6061-SiC-Gr composites have better slurry erosive wear resistance when compared to Metal Matrix composites and base alloy under identical test conditions. With an increase in Abrasive particle size, there is an increase in slurry erosive wear of Metal Matrix, Hybrid Composites and Al6061 alloy. However, Hybrid Al6061-SiC-Gr composites have better slurry erosive wear resistance when compared to Metal Matrix composites and base alloy under identical test conditions.

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