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Investigation of Effect of Stirring Speed on Mechanical and Corrosive Properties of AMMC

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***Abstract*— Automobiles, spacecraft and ship building uses the materials which are heavy and get corroded because of being used in different environmental conditions. Due to this the fuel consumption is high and life of the parts reduces. To get high fuel efficiency, one of the best way is to reduce the weight of the material. But by reducing the weight of the parts, the strength of the parts will reduce. To overcome this problem, new type of materials are evolved that are composite materials. A composite material is a mixture of two or more materials such as reinforcements of ceramics (in the form of particles, fibres etc.) embedded in a base metal matrix. Particulate reinforced aluminium alloy composites exhibits better mechanical properties than the unreinforced materials.**

Stir casting is the method used for large scale production of Aluminium Metal Matrix Composite (AMMC) because of its simplicity and low cost. The major problem in the fabrication of metal matrix composite materials is the distribution of reinforcement in the metal matrix. The distribution of the reinforcement particle in the base metal matrix is effected by the stirring speed of the stirrer during the fabrication of Aluminium Metal Matrix Composite (AMMC). Therefore, the research on the effect of stirring speed on the mechanical, corrosive and wear properties for the fabrication of AMMC in the stir casting was done. As the composite materials have to work in different environments, their corrosion properties also have equal importance.

Fabrication of Metal Matrix Composite of 6351Al with the reinforcing materials Aluminium oxide (Al_2O_3) at eight different stirring speeds (i.e., 300, 400, 500, 600, 700, 800, 900, 1000 rpm) with a percentage of reinforcement by weight 3%. Then their mechanical, corrosive and wear properties were compared with standard Aluminium alloy 6351. The distribution of the reinforcement (Al_2O_3) in the metal matrix (6351Al) was studied by Scanning Electron Microscopy (SEM). Mechanical properties such as density, hardness, tensile strength, impact strength etc. and corrosive rate were determined. Wear analysis is done for composite samples fabricated at different stirring speeds. The investigation on the stir casting process reveals the optimal stirring speed for fabrication of AMMC.

Keywords—Aluminium Metal Matrix Composite; Aluminum; Aluminum Oxide; Stir Casting.

I. INTRODUCTION

A Composite Material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composite is a multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized.

II. LITERATURE REVIEW TO MMC AND AMMC

Aluminum oxide, commonly referred to as alumina, possesses strong ionic inter atomic bonding giving rise to its desirable material characteristics. It can exist in several crystalline phase which all revert to the most stable hexagonal alpha phase at elevated temperatures. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of application [1].

The influence of various reinforced particles and process parameters on the properties of aluminium based metal matrix composite through stir casting process. The homogeneity and decreased porosity is achieved in Al6061/Alumina composite at 550 ^{0}C. The casting of AlA356 alumina followed by stir casting at the rate of 450 rpm has given good hardness, tensile properties, compressive strength and water resistance [2].

Pure aluminium was used as matrix material and alumina (Al_2O_3) upto 9 wt. % used for the preparation of composite. Three different particle size 75, 105 and 150 micron was used in different wt. % 3, 6 and 9 with different stirring time i.e., 15, 20, and 25 minutes used in manufacturing of the composites. The aluminum metal matrix composite was prepared by stir casting route. Aluminium was melt in a graphite crucible by heating it in the muffle furnace at 800^{0}C temperature. The reinforcement Aluminium Oxide (Al_2O_3) was preheated at 300^{0}C temperature for 1hr to remove moisture from the powder and make their surface oxidized [3].

The metal matrix composite material are prepared with 10% SiC using different stirring speeds and stirring times. The microstructure of the produced composites was examined by optical microscope and scanning electron microscope. The Brinell hardness test was performed on the composite specimens from base of the cast to top. The results revealed that stirring speed and stirring time influenced the microstructure and the hardness of composite. Microstructure analysis revealed that increase in stirring speed and stirring time resulted in better distribution of particles. The uniform hardness values were achieved at 600 rpm with 10 min stirring [4].

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 500^0C and then it is gradually increased upto 900^0C. High temperature of the muffle helps to melt aluminium to alloy quickly, reduces oxidation level, enhance the wettability of the reinforcement particles in the matrix metal. Aluminium alloy Al6061 is used as matrix material. Required quantity of aluminium alloy is cleaned to remove dust particles, weighed and then poured in the crucible for melting. Powder of alumina (Al_2O_3), silicon carbide (SiC) and graphite are used as reinforcement. 1% by weight of pure magnesium powder is used as wetting agent. At a time total 700gtam of molten composite was processed in the crucible. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine and mixed by stirrer with rpm gradually increasing from 0 to 300rpm with help of speed controller [5].

Wear testing was performed on these specimens on a pin on disc wear tester. The unit consists of a pivoted arm to which the pin is attached, a fixture which accommodates discs of a particular diameter, an electronic force gauge for measuring the friction force. The motor driven produces upto 180 rpm. Wear was quantified by varying the parameters like wear track radius and dead weight keeping the machine r.p.m constant for a time interval of 2 minutes. The amount of material removed was calculated with the wear rate [6].

The investigation on the behaviour of crevice and pitting corrosion resistance of the 6061 Al alloy matrix reinforced with SiC_p/Gr was done. The composites studied had a different volume percentage of reinforcements (3% and 10% graphite and 10, 15 and 22% SiC_p. The electrochemical studies were carried out in 3.5% NaCl solution at room temperature. The results of the immersion tests in 3.5% NaCl solution show higher corrosion rates for all the composites than for the matrix alloy. For composites, the corrosion rates increases as the volume percentage of graphite reinforcement is increased and corrosion rates are decreases as the volume percentage of SiC_p reinforcement is increased.

III. EXPERIMENTAL DETAILS

Following steps are carried out in our experimental work:

1. Material selection
2. Composite preparation

2.1 Material selection

Al6351 aluminium alloys has higher strength amongs the 6000 series alloys. They have high corrosion resistance. This alloy is most commonly used for machining. Through relatively a new alloy the higher strength of 6351 has replaced 6061 alloy in many applications. The Al6351 aluminium alloy is used in manufacturing due to its strength, bearing capacity, ease of workability and weld ability.

Table 1: Chemical Properties of Al6351 Matrix Material

Composition	Si	Fe	Cu	Ti	Mg	Mn	Zn	Zr, Sn, Sb
% Composition	0.7-1.3	0-0.5	0-0.1	0-0.2	0.4-0.8	0.4-0.8	0-0.2	0-0.15

Table 2: Mechanical Properties of Al6351 Matrix Material

Properties	Al6351
Elastic modulus(Gpa)	70-80
Density (g/cc)	2.7
Poisson's ratio	0.33
Hardness (HB500)	95
Tensile strength (Mpa)	250
Thermal conductivity(W/m,^{0}K)	180

Aluminium Oxide is fused from high quality bayer aluminium in high temperature. Its hardness is higher but toughness lower compared woth Brown Aluminium Oxide. It has efficient grinding efficiency and low frictional heat. It can withstand to acid and alkali erosion, with high temperature resistance and good thermo stability. The abrasive tools made of it are suitable for grinding high carbon steel, high-speed steel and chilled steel.

Table 3: Properties of Aluminium Oxide

Mechanical	Unit of measure	SI Units
Density	Gm/cc	3.89
Average particle size mesh	μm	125
Porosity	%	0
Elastic	Gpa	375
Shear	Gpa	152
Bulk	Gpa	228
Hardness	Kg/mm2	1440
Compressive	Mpa	2600

2.2 Composite preparation

Aluminium alloy Al6351 was used as a matrix material and the Al_2O_3 particles of size 125 microns were used as the reinforcement materials. The composites were fabricated at different stirring speeds 300 – 1000 rpm stirring speed in steps of 100 rpm and a fixed quantity of 3 % of Al_2O_3 particle. Al 6351 alloy was first preheated at 450^0C for 2 h before melting and Al_2O_3 particulates were preheated at 1000^0C for 1hr 30min and mix with Mg powder to improve the wetting properties by removing the absorbed hydroxide and other gases. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 10 min at different stirring speeds from 300-1000rpm. The stirring speed is controlled by variable speed motor which is equipped with frequency

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controller. Finally the composite slurry was poured in permanent metallic mold of 400 mm x 55 mm x 20 mm size (Figure 4). By using the above procedure, AMMC samples are prepared. Figure 3 shows the schematic diagram of stir casting and stir casting equipment.

Fig.1.Graphite Crucible

Fig.2.Stirrer Setup

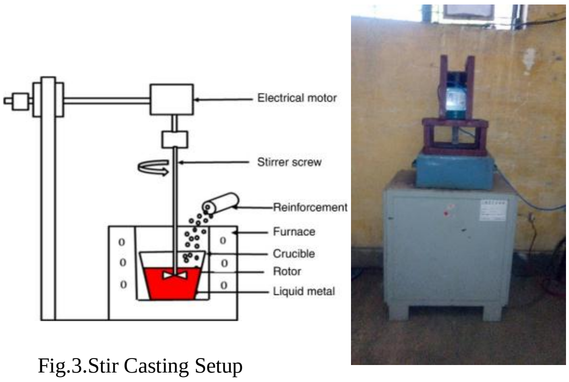

Fig.3.Stir Casting Setup

Fig.4.Mould

IV. RESULTS AND DISCUSSION

Microstructure

Figure 5 shows the optical micrographs of Al6351-Al_2O_3 composites fabricated at different stirring speed. The obtained SEM images shows the uniform distribution of Al_2O_3 particles. The distribution of Al_2O_3 particles in Al6351 influences the physical and mechanical properties of the composites.

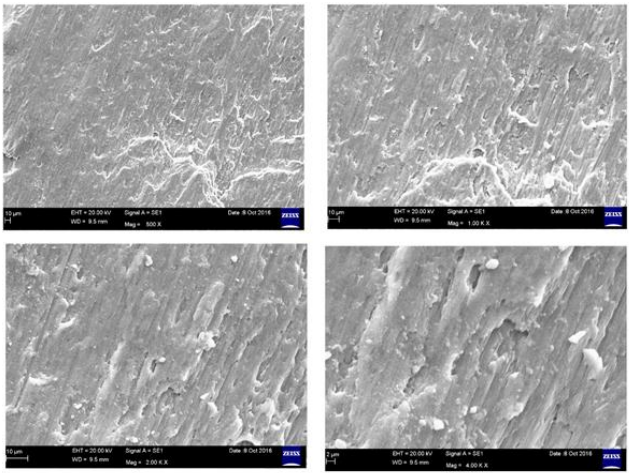

Fig.5.a: Micrographs of Al6351+3% Al_2O_3 at 300rpm stirring speed.

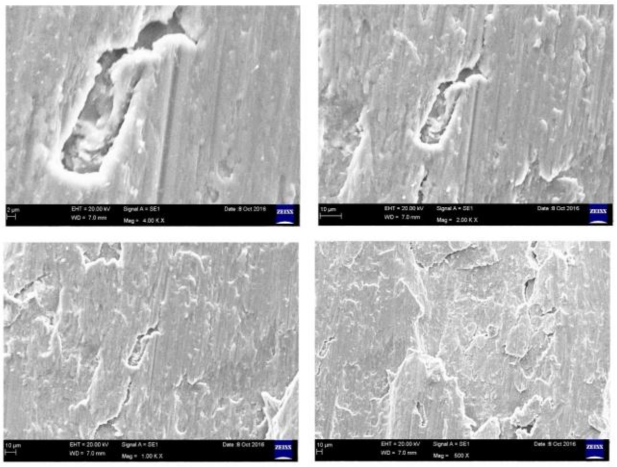

Fig.5.b.Micrographs of Al6351+3% Al_2O_3 at 400rpm stirring speed.

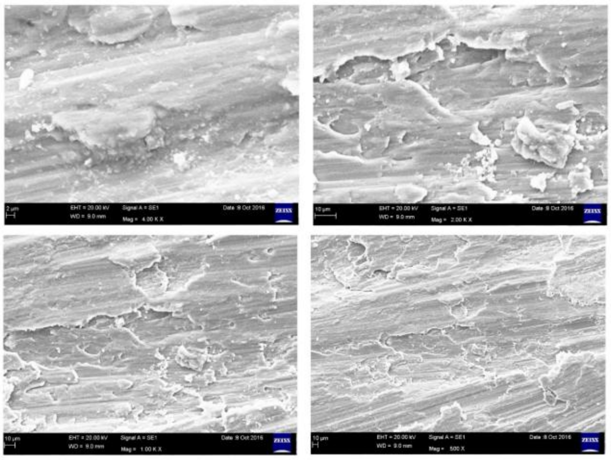

Fig.5.c.Micrographs of Al6351+3% Al_2O_3 at 500rpm stirring speed.

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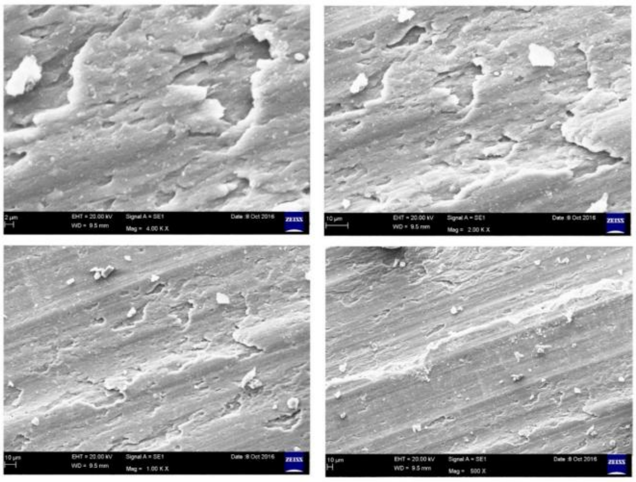

Fig.5.d.Micrographs of Al6351+3% Al_2O_3 at 600rpm stirring speed.

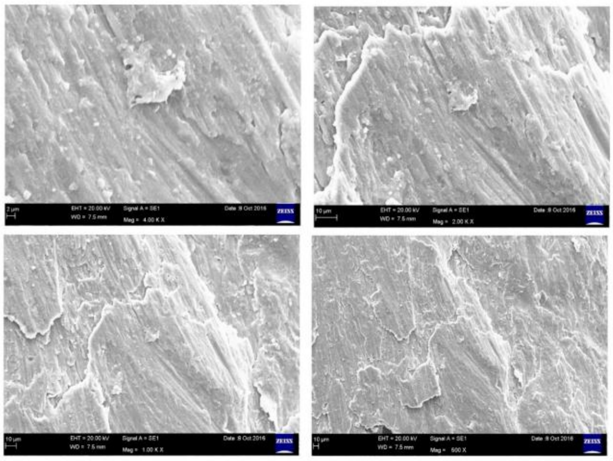

Fig.5.e.Micrographs of Al6351+3% Al_2O_3 at 700rpm stirring speed.

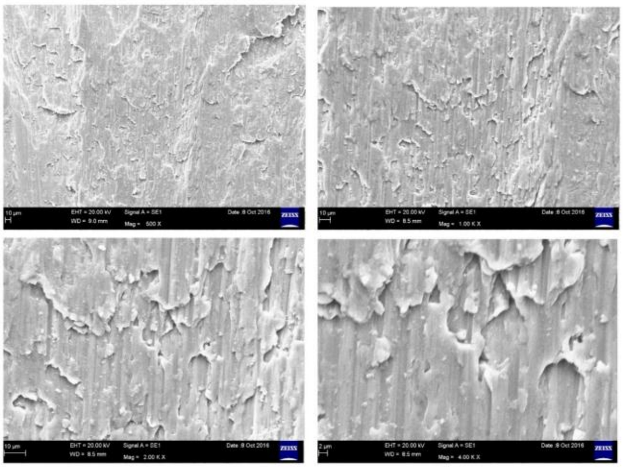

Fig.5.f.Micrographs of Al6351+3% Al_2O_3 at 800rpm stirring speed.

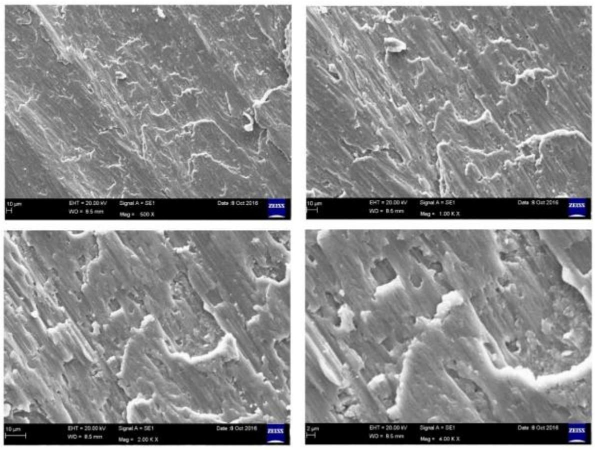

Fig.5.g.Micrographs of Al6351+3% Al_2O_3 at 900rpm stirring speed.

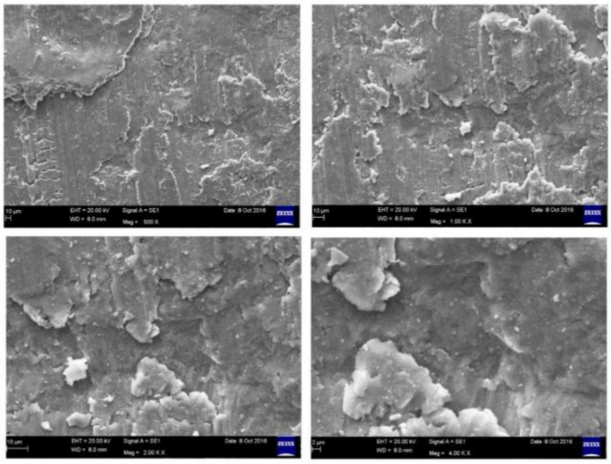

Fig.5.h.Micrographs of Al6351+3% Al_2O_3 at 1000rpm stirring speed.

Density

Theoretical density of the Aluminium Metal Matrix Composite can be calculated by rule of mixture formula:

Theoretical density, $\rho_{tc} = \rho_r \nu_r + \rho_m \nu_m$ (1)

Where,

ρ_r = Density of reinforcement (g/cm^2)

ν_r = Volume fraction of reinforcement

ρ_m = Density of matrix (g/cm^2)

ν_m = Volume fraction of matrix

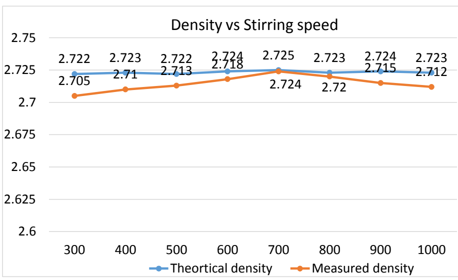

Fig.6.Effect of Stirring Speed on Density

The Figure 6 shows that the theoretical density value of fifth composites matches with the measured density fabricated at 700rpm stirring speed. From the table, it can be concluded that the proper mixing of reinforcement particle was done with the base metal at 700rpm stirring speed. From Figure, it can be observed that the densities of composites are increasing with the increase in stirring speed of the stirrer up to 700rpm, then it falls down.

Hardness

Hardness can be determine by using Brinell hardness testing machine.

The Brinell Hardness Number(BHN) can be determine by

$$BHN = \frac{2P}{\pi D\,(D-\sqrt{(D^2-d^2)})} \quad (2)$$

Where,

P = Applied load in kgf

D = Diameter of indenter in mm

d = Diameter of indention in mm

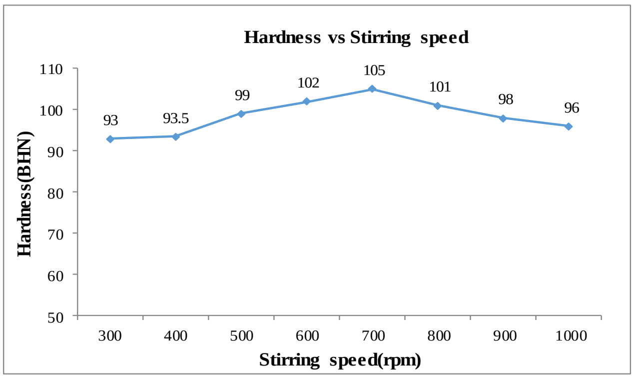

Fig.7.Effect of Stirring Speed on BHN

The Brinell-hardness of Aluminium Metal Matrix Composites fabricated at different stirring speed with 3% by weight of Al_2O_3 are evaluated using carbide indenter at different applied load of 60kg, 100kg and 150kg. From the Figure 7, it can be observed that the hardness of the AMMC is increasing with increase in the stirring speed of the stirrer up to 700rpm during mixing of reinforcement after that with increase in stirring speed, hardness of AMMC decreases.

Tensile Strength

The ultimate tensile evaluated by using Universal Testing Machine (UTM).

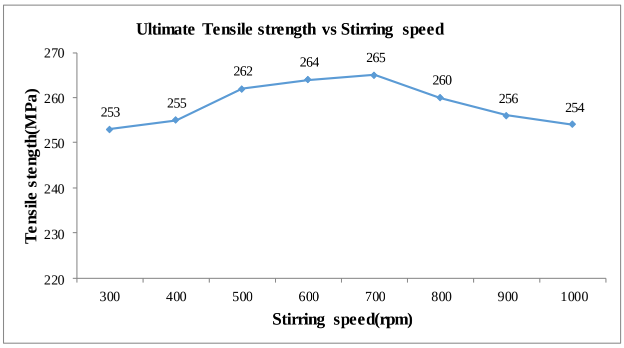

Fig.8.Effect of Stirring Speed on Tensile Strength

The ultimate tensile strength of Aluminium Metal Matrix Composites fabricated at different stirring speed with 3% by weight of Al_2O_3 are evaluated by using UTM machine. From the Figure 8, it can be observed that the tensile strength of the AMMC is increasing with increase in the stirring speed of the stirrer up to 700rpm during mixing of reinforcement after that with increase in stirring speed, tensile strength of AMMC decreases.

Impact Strength

Izod impact strength testing is a method of determining impact strength. A notched sample is generally used to determine impact strength.

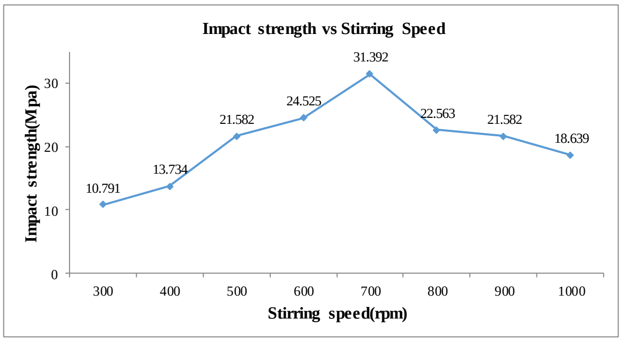

Fig.9.Effect of Stirring Speed on Impact Strength

From Figure 9, it can be observed that the impact strength of the composites is increasing with increase in the stirring speed of the stirrer during mixing of reinforcement up to 700rpm, after that with increase in stirring speed, impact strength of AMMC decreases.

Corrosion Rate

The corrosion rate are determined by using immersion testing. Sample with surface areas of 3-5 cm^2 were cut from the Aluminium Metal Matrix Composites. The weight of the sample specimen were measured. All the surfaces were polished up to 600 grit finished and each sample was separately immersed in 3.5-5% NaCl solution (open to air). After immersion for two months, the weight loss was measured for each sample and calculated the corrosion rates. Formulae used to calculate Corrosion Rate (CR) and Metal Loss (ML) from Weight Loss (WL) are as follows:

$$\text{Corrosion rate (CR)} = (WL \times K)/(\rho \times A \times T) \quad (3)$$

Where,

WL = Weight Loss of AMMC in grams (g)

ρ = AMMC density (g/cm2)

T = Exposure time (hr)

A = Exposed Area (cm2)

K = 3.45 × 1000000 mils/year

Fig.10.Effect of Stirring Speed on Corrosion Rate

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From Figure 10, it can be observed that the corrosion rate of the composites are decreases with the increase of stirring speed of stirrer up to 700rpm there after corrosion rate increases with the increase of stirring speed of stirrer during the fabrication of AMMCs.

Wear Rate

The samples of the AMMCs fabricated at different stirring speeds wear rate are evaluated at different loads of 1kg, 2kg and 3kg by using pin-on-disc apparatus at constant speed of disc of 1500rpm and track diameter of 80mm.

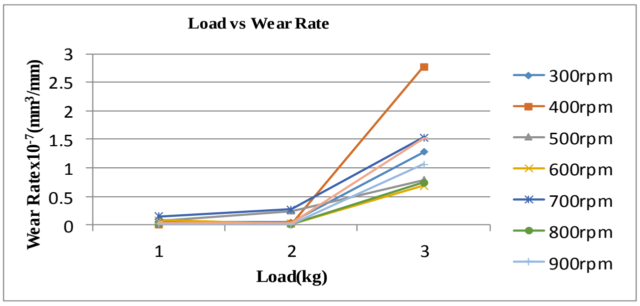

Fig.11.Effect of Load on wear Rate

From Figure 11, it is clear that wear rate of AMMCs fabricated at different stirring speeds increases with increase of load on sample. Because with increase in load on sample, contacting pressure between sample and disc will increases.

V. CONCLUSION

The significant conclusions of the studies on Al6351-Al_2O_3 metal matrix composites are as follows:

- Theoretical density of the composite matches with the measured density at stirring speed of the stirrer at 700 rpm.
- Hardness of the AMMC is highest at stirring speed of the stirrer at 700 rpm.
- Tensile strength of the AMMC is highest at stirring speed of the stirrer at 700 rpm.
- Impact strength of the AMMC is highest at stirring speed of the stirrer at 700 rpm.
- Corrosive resistance of the AMMC is highest at stirring speed of the stirrer at 700 rpm.
- Wear loss of the AMMC is increases with increase of load on sample.
- The optimum stirring speed of stirrer in stir casting is 700 rpm.

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