

# Effect of Solutionising and Age-Hardening on the Tribological Properties of Al7075/Al<sub>2</sub>O<sub>3</sub> Particulate MMC

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**ABSTRACT:** The aim of this work is to evaluate the effect of reinforcement percentage on the wear behaviour and influence of the Solutionising and Age hardening on aluminium based Particulate MMC. Aluminium 7075 based composites reinforced with alumina (Al<sub>2</sub>O<sub>3</sub>) in varying reinforcement weight fractions of 5%, 10%, 15% and 20% were prepared. The stir casting process was chosen as the manufacturing route as it is inexpensive and suitable for mass production. Stirring of the melt was carried out to achieve uniform distribution of the reinforcements. Mechanical test like Hardness test, Microstructure characterization and wear study was conducted on the casted composites to know the effect of weight fraction of reinforcement. Heat treatment was carried out on the developed samples to estimate the effect on the wear resistance. Tribological tests are carried out by pin on disc wear tester. The solutionising is carried out at 500°C for 2 hrs. and then annealing at 250°C for 2 hrs. in a closed chamber to achieve the ageing properties. Hardness was found to increase with increase in weight fraction of the reinforcement. The wear rate and coefficient of friction decreased as the heat treatment and ageing process is applied. Age hardening is contributing to significant increase in hardness and wear resistance of the composite as compared to unreinforced and as cast composites. The wear morphologies at various loads and types of wear were evaluated and categorised by wear track study.

**KEYWORDS:** Age hardening, Al7075, Wear rate, Heat treatment, Wear track, Alumina.

## I. INTRODUCTION

In recent years the concern on the environmental protection has given rise to development of fuel efficient vehicles. The light weight and high strength criteria of the developed composite will be able to fulfil the weight reduction requirement. The weight reduction not only reduces fuel consumption but also meets environmental norms by reducing greenhouse effect. The composite material offers better strength, stiffness, high elastic modulus, low coefficient of thermal expansion, light weight, high wear resistance & many more. The conventional materials and alloy fails to show the enhanced properties as compared with the composite materials. The cost effective and suitability for mass production has given rise to particulate reinforcement for composites. To reduce the cost of the material at the same time without compromising on the performance of the parts the less cost ceramics like fly ash, Sic, Al<sub>2</sub>O<sub>3</sub> are used. The use of Al<sub>2</sub>O<sub>3</sub> as reinforcement has an effect on the composite to respond for age hardening.

The results shows significant increase in hardness of Composite material as compared to Aluminium Alloy. Results clearly indicates that the Wear rate of composite is enhanced by the presence of the Reinforcement and it was observed that composite with 20 % Al<sub>2</sub>O<sub>3</sub> reinforcement produces better results than the other volume fraction for improved wear resistance.

## II. RELATED WORK

The compatibility of the matrix and reinforcement are not valid for all combinations, also not suitable for fabrication process and applications. Wettability, bonding and interface reactions are main issues in the production of the MMC [1]. The mechanical properties to be considered for the development of composite material for automobile application includes density, strength & stiffness, wear resistance, young's modulus. The selected alloy and ceramic has light weight to high strength. The wear resistance of the composite also increases with the given combination of matrix and



reinforcement [2]. The matrix material also decides the cost of production, suitability for the application, compatible for manufacturing process .generally used matrix materials are Al, Cu, Zn, Mg, Ni, Pb, Fe, Ti etc .Most widely researched material is Al alloy [4] because of its unique combination of corrosion resistance ,light weight excellent mechanical properties. It is less expensive as compared to Mg and Ti alloy. The selected aluminium alloy series is 7xxx as it is strongest among most popular 2xxx, 6xxx and 7xxx series alloy. The Al7075 alloy will have good response to heat treatment towards improvement in mechanical properties [5].Melting point of 7xxx alloy is less compared to titanium alloy which reduces the interface reactions in the MMC. The cost and compatibility of Al alloy makes it most suitable for composite system. Increase in hardness and wear resistance was observed up to 16% for Al7075/Al<sub>2</sub>O<sub>3</sub>/SiC composites [6].

III. MATERIALS AND DEVELOPMENT OF COMPOSITE

The aluminium alloy used for the present study was Al7075 supplied by Hindalco Ltd, which contains Zn as major alloying element(6.1%).The matrix material has good response to heat treatment and age hardening. It is light weight and withstands high temperature compared to other series of alloy. The composition and properties of the Al7075 is shown in table 1 and 2.

Table 1. Composition of AL-7075

Element	Si	Fe	Mn	Mg	Cu	Zn	Ti	Cr	Al
Weight %	0.4	0.5	0.3	2.9	2	6.1	0.2	0.28	87.32

Table2. Properties of AL-7075

Hardness –Brinell	150
Ultimate tensile strength	572MPa
Tensile yield strength	503MPa
Elongation at beak	11%
Modulus of Elasticity	71.7GPa
Poisson’s ratio	0.33
Fatigue strength	159MPa
Machinability	70%
Shear modulus	26.9GPa
Shear strength	331Mpa

The reinforcement material selected is Alumina (Al<sub>2</sub>O<sub>3</sub>) supplied by carborundum Universal (India) Ltd, in the form of powder of particle size 50 to 200 microns. The properties of alumina is shown in table 2. The weight fractions of the particulates are 5%,10%,15% and 20% .For one kg melt the reinforcement material for 5% weight fraction was 50gms and matrix material was 950gms.Similarly for the weight fraction of 10%, 15% ,20% the reinforcement of 100gms,150gms ,200gms were used.

Table3. Properties of Alumina

Property	values
Melting Point °C	2072
Hardness(kg/mm2)	1175
Density(g/cm3)	3.69
Coefficient of thermal expansion(micron/m °C)	8.1
Fracture Toughness	3.5
Poisson’s ratio	0.21
Colour	White

The stir-casting Process is adopted to develop the Aluminium MMC with different Percentage s of reinforcements as stated earlier. The Al 7075 available commercially in T6 for is cut into small pieces and Plead in the furnace. The furnace is heated to 700°C and after aluminium melts the slag floating on the surface of the molten metal is removed and Degassing process is performed to remove the air entrapped in the molten alloy. The Reinforcement is separately heated in a heat treatment furnace at a temperature of 500°C for 30 minutes to remove the moisture and to improve the Wettability of the Al<sub>2</sub>O<sub>3</sub>. The reinforcement is added to the molten metal and stirred continuously to have uniform distribution of the Al<sub>2</sub>O<sub>3</sub> in the aluminium matrix. Similar procedure id followed for 5%,10%,15% and 20% reinforcement f Al<sub>2</sub>O<sub>3</sub> reinforced composite.

The Specimens are prepared as per ASTM standards for hardness test, Microstructure analysis and wear test from the as cast composite. The Composite is further subjected to heat treatment process by solutionising and age hardening. The developed composite with 5%, 10%, 15% and 20% reinforcement is taken in the form of bar of 100x50x20 mm and subjected to solutionising by heating in a furnace at 550°C for 2 hrs. Then the specimens are dipped in water at room temperature and then subjected to artificial ageing by heating to 300°C for 1hr 30min in a heat treatment furnace. After the designated time the furnace is switched off and the composite materials are allowed to cool to room temperature by keeping it in open air. The Heat treated composite material are further machined to Hardness teat, Microstructure specimens and wear test specimens.

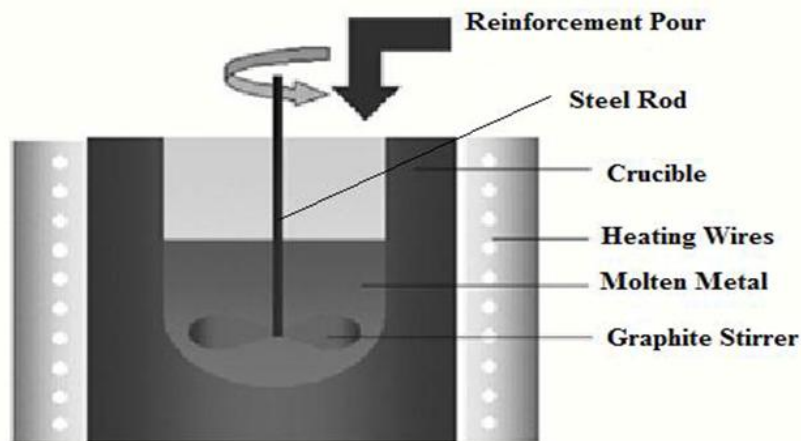


Fig 1. Stir casting process set up.

#### IV. EXPERIMENTAL RESULTS AND DISCUSSION

The objective of the present study is to carry out characterization of Aluminium composite material to evaluate the effect of reinforcement percentage and heat treatment on hardness and wear resistance. Specimen were prepared for various test planed and the specimens of 10x10 mm cross section with length of 30 mm were used for Hardness teat, Wear test and for Heat treatment of MMC.



Fig 2. Composite specimens for Mechanical and wear testing



**Density**

Rule of mixture is applied for calculating the density of the composite based on volume fraction of matrix and reinforcement. Fig.3 indicates that the Density of the composite has increasing trend as the percentage of reinforcement increases and found to be maximum for 20% reinforced MMC at a value of 2.9. This is due to the density of the reinforcement is higher than the aluminium alloy and it adds to weight of composite.

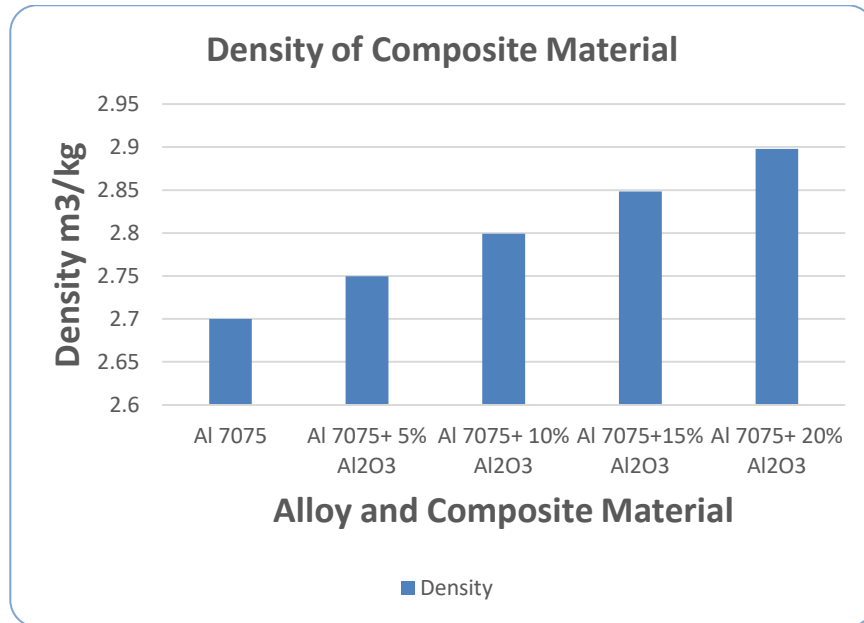


Fig 3. Variation of Density of Composite with various Reinforcement volume fraction

**Hardness**

Vickers hardness test was carried out with load of 20kg and dwell period of 5 minutes for calculating the hard ness of the material. The fig 4 indicates that hardness of the composite is higher than the Alloy due to the presence of hard particles. The hardness has the increasing trend as the increasing in volume fraction of the reinforcement particle to the alloy. The hard reinforcements resists the deformation and gives high hardness to the MMC.

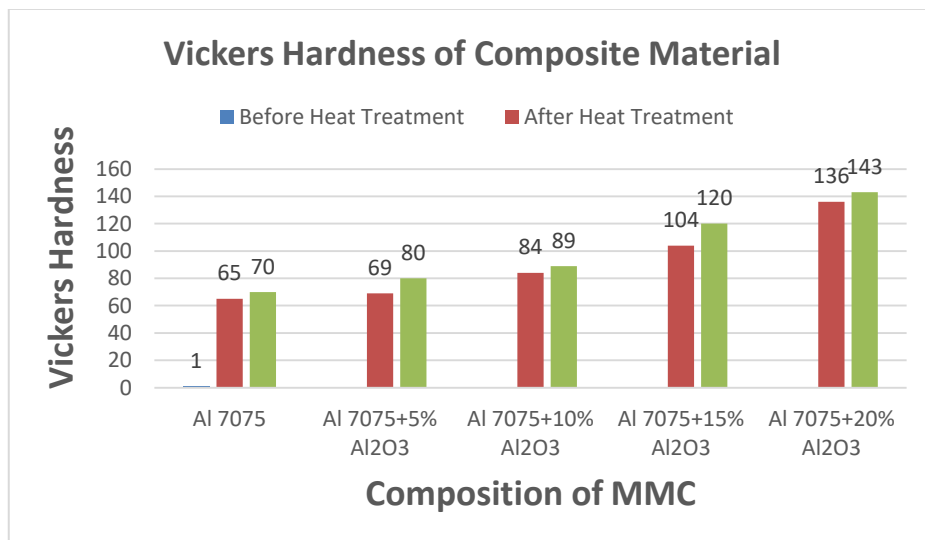
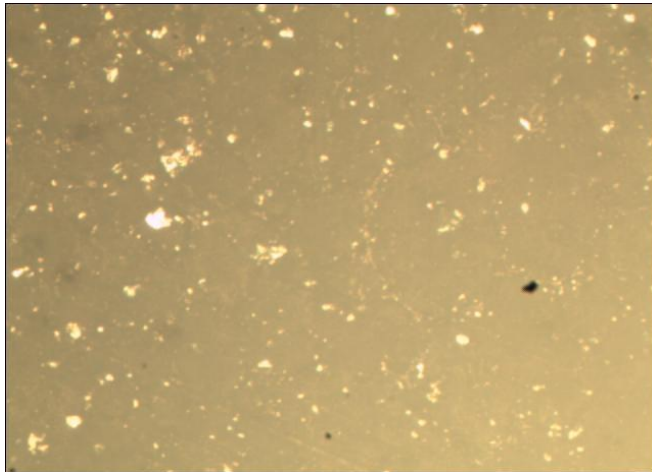


Fig 4. Variation of Hardness of Composite with various Reinforcement volume fraction

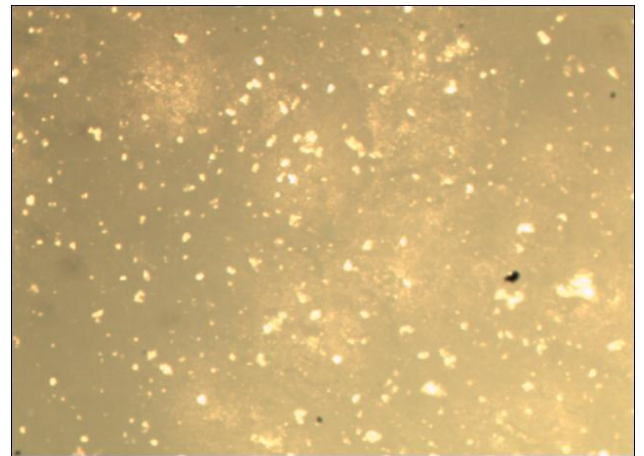


### Microstructure analysis

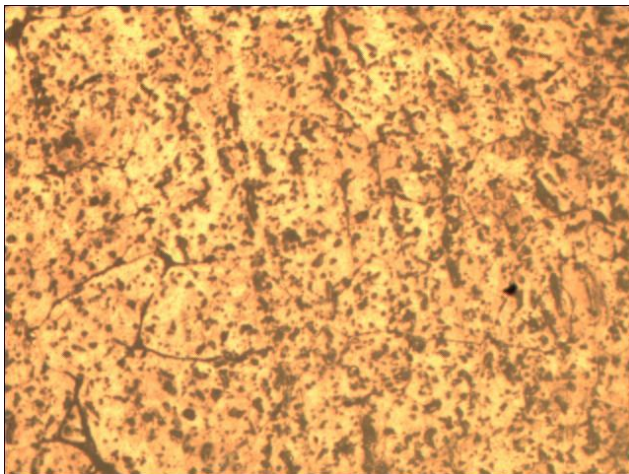
Microstructure analysis was carried out on METZER Metallurgical microscope to identify the distribution of the reinforcements in the matrix and estimate the homogeneity of the dispersion in the matrix. Specimens were cut from the samples and grinded, Polished and etching was carried out as per ASTH standards. The specimens were observed under the microscope at different magnification of 450X, 1000X magnification. The fig 4 indicates the Microstructure of MMC with different volume fraction of reinforcements and it can be observed that more uniform distribution of reinforcements was achieved due to stirring process adopted and also the agglomeration rate was reduced as a result of reinforcement preheating.



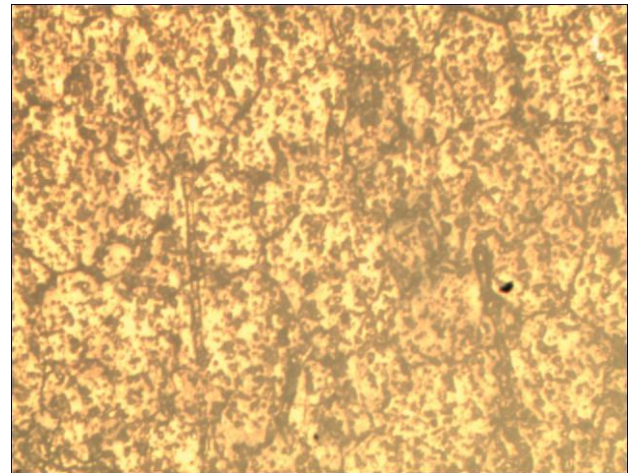
(a)



(b)



(c)



(d)

Fig5. Optical Microstructure of MMC with a) 5% volume fraction  $Al_2O_3$  b) 10% volume fraction  $Al_2O_3$  b) 15% volume fraction  $Al_2O_3$  b) 20 % volume fraction  $Al_2O_3$

### Wear Study

Wear Test were carried out on Pin on Disc wear testing machine as per ASTM standards and Initial weight and final weight of the specimen were measured up to accuracy of 0.001g. The weight loss are converted to volume loss based on the density of composite, The Archard's wear model was employed to estimate the wear rate and specific wear rate. The experiment were carried out for 2kg, 4kg, 6 kg and 8 kg load at 400 rpm speed for 5 minutes duration. The wear track and wear loss recorded for each experiments. This procedure was repeated for all the four composite samples developed including Aluminium 7075 alloy.



**The Plot of Wear Rate**

The wear rate vs load on the specimen indicates that at lower load the wear rate is lower and increases with increasing in the load. More particles are separated from the MMC during increased applied load. The reinforcement has significant role in maintaining the wear rate and controlling the material loss from the composite. The optimum volume fraction of reinforcement was found to be 15% Al<sub>2</sub>O<sub>3</sub> for which it has lowest wear rate as seen from the fig 6.

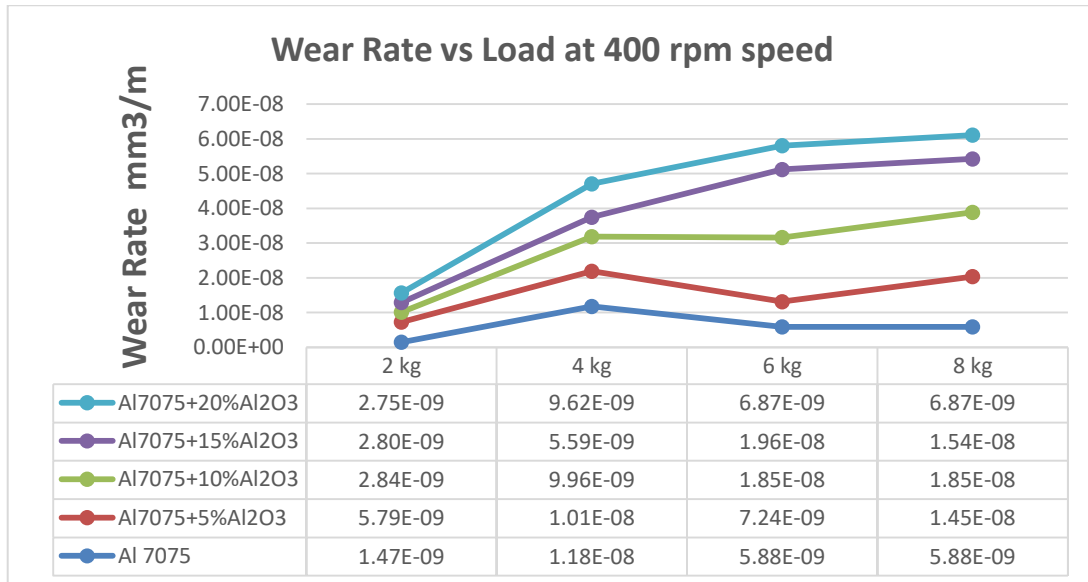


Fig 6. Variation of wear rate vs load for cast composites at 400rpm speed

The fig 7 shows the similar wear rate vs Load variation of all the composite which also has the improved wear resistance of the MMC as compared to as cast composites. At 20% reinforcement it has reduction in wear rate as compared to 15% reinforcement.

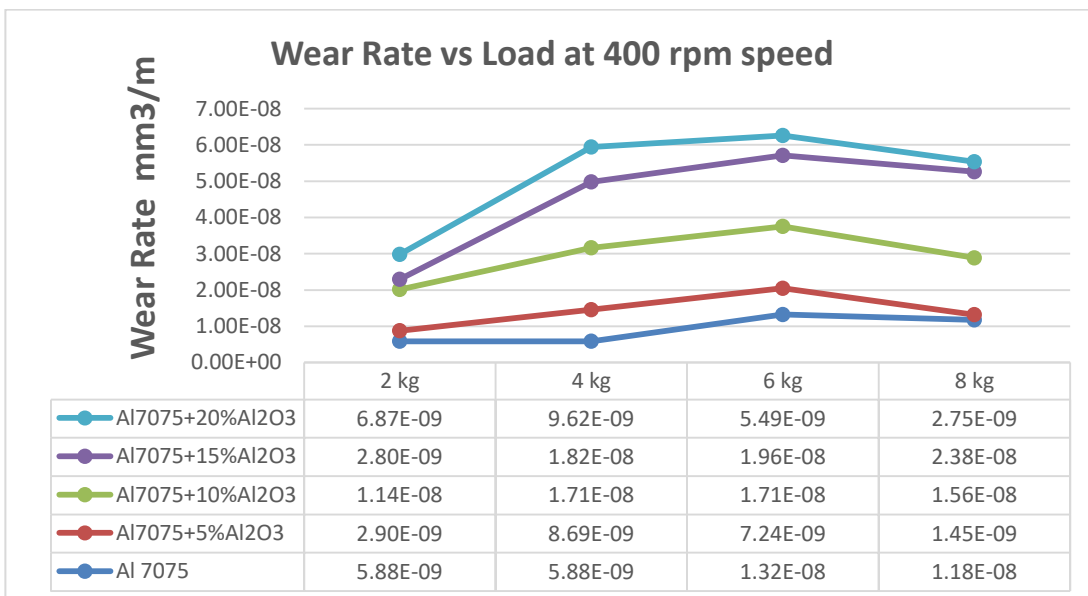


Fig7. Variation of wear rate vs load for Heat treated composites at 400 rpm speed

**Effect of Heat Treatment**

It is observed that the effect of heat treatment on the Composite material performance under dry wear test has shown better resistance as compared to as cast composites. The Influence of Al<sub>2</sub>O<sub>3</sub> reinforcement can have significant effect in

improving the wear resistance. The fig 8 indicates that the wear rate is lower for heat treated composites with maximum wear rate of  $3 \times 10^{-7} \text{ mm}^3/\text{m.s}$  and for the as cast composite it was found to be  $5 \times 10^{-7} \text{ mm}^3/\text{m.s}$ .

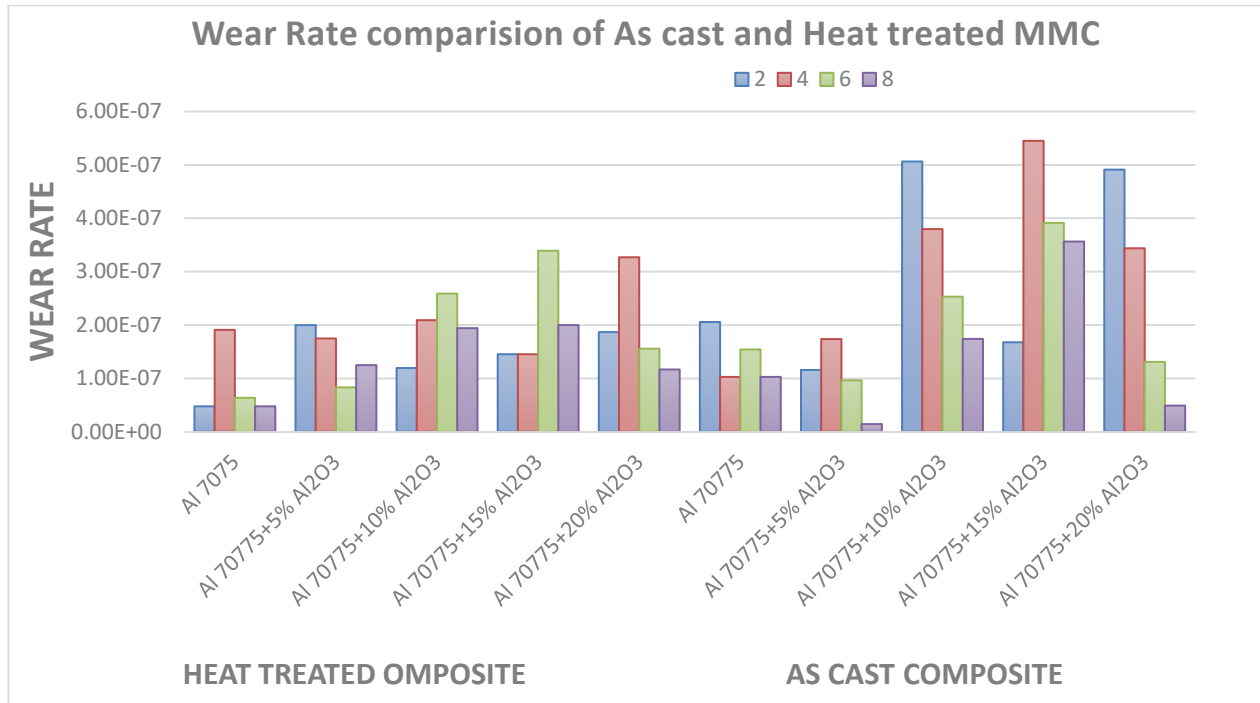


Fig8 Variation of wear rate vs load for Heat treated and as cast composites

### Wear track Study

Wear track of the wear test specimen is shown in fig 9 indicates the types of wear mechanism which are taking place at various loads. Mild wear is characterized by small grooves due to lower load. The mild wear is characterized by larger wide groove due to high load and removal of material from the surface. Severe wear is characterized by high load and material deposition due to thermal softening. The seizer occurs due to high heat at higher load due to this welding of composite material debris on the surface makes depositions.

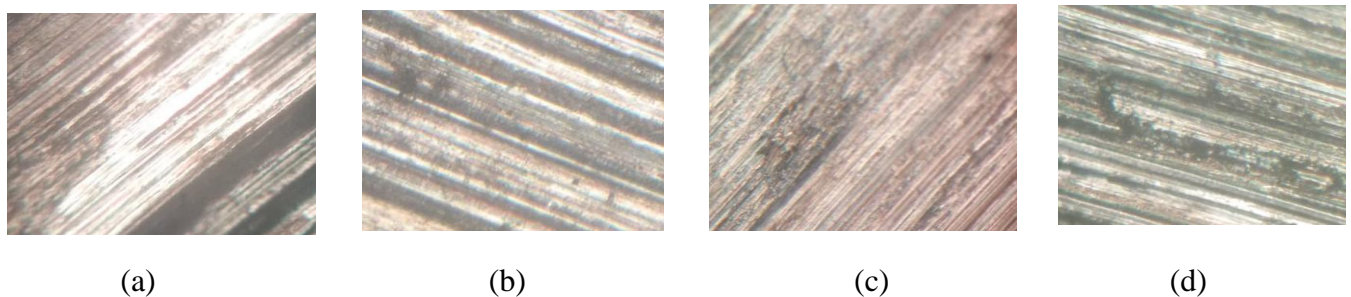


Fig9 wear tracks of MMC at different loading condition indicating the type of wear a) Ultra Mild wear b) Mild wear c) Severe wear d) Seizer

### V. CONCLUSION

1. Stir casting route for the development of particulate composite is suitable and cost effective method. Uniform distribution of the reinforcement is obtained by stirring the melt at 700°C.
2. Enhanced strength, wear resistance and low cost composite can be developed with Alumina (Al<sub>2</sub>O<sub>3</sub>) ceramics material. These materials are fuel efficient and light weight suitable for automobile and aircraft applications.
3. Hardness of the composite increases with the increase in weight fraction up to 20% and further it intensity reduces. ceramic particles increases the hardness at the same time the material becomes brittle. Porosity can be

controlled by stir-casting and preheating the reinforcement. Also with use of metal mould to facilitate rapid solidification.

4. The density of the composite is in between the density of matrix and reinforcement material which is 50% less than the density of steel and cast iron.
5. Wear resistance of Al7075/ Al<sub>2</sub>O<sub>3</sub> particulate composite increases with the weight fraction.
6. The wear rate reduces with speed, but increases with load and sliding distance.
7. Heat treatment of the composite reduces the wear rate as compared to as cast composite by about 30%.
8. The wear surfaces indicates the type of the wear mechanism which depends on the Load and speed.

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