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EFFECT OF MECHANICAL AND WEAR BEHAVIOR ON AL7075/AL2O3/SICP REINFORCED ALUMINUM MATRIX COMPOSITES (AMC)

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ABSTRACT

A composite is a material system collected of a combination of two or more micro or macro elements that differ in chemical composition and that are basically insoluble in each other. In this investigation Metal Matrix Composite (MMCs) have been produced using stir casting process for improving the mechanical and wear behavior of Al alloy composites containing 6 wt% SiC, 160°C heat treatment (HT) constant and various Al_2O_3 compositions namely 2%, 4% and 6% by weight were fabricated and tested, and their properties were compared with Al alloy composites containing 4 wt% Al_2O_3, 160°C heat treatment constant and various SiC compositions namely 3%, 6% and 9% by weight. These tests reveal that the tensile strength has been increases with the increase in the reinforcement weight fraction. It has been noted that when percentage of reinforcements increases, there is a sudden decrease in hardness value due to the cluster formation. The wear rate decreases with the increase in the reinforcement weight fraction.

Keywords: Metal matrix composites; Stir casting; Tensile strength; Hardness; Wear

INTRODUCTION

Metal matrix composites (MMCs) are the combinations of two or more dissimilar metals or intermetallic compounds phases in which distributed phases are surrounded inside the metal matrix. The Great interest of this collection of the materials is due to because of their good properties, such as stiffness, specific strength, high specific modulus, low thermal expansion coefficient, light weight, high thermal conductivity and better wear resistance. The main advantages of producing MMCs are usually relatively better fabrication and also in reinforcement materials. MMCs lean towards to collection about two extreme types. One is very high performance of composites reinforced with high-cost continuous fibers and needing expensive manufacturing methods. The other one is relatively low-cost and low-performance composites reinforced with inexpensive particulate. However, MMCs also having some major disadvantages like, for high-performance MMCs the cost of fabrication is high and lower ductility and toughness. MMCs are gradually becoming better materials for turbines, advanced aerospace, automobiles etc applications and their mechanical properties can be improved through the adding of particular reinforcements. It's very important to maintain the cost effective method for the Manufacturing composites in terms of expanding their applications. MMCs can be produced by liquid state process (stir casting, squeeze casting etc.), semisolid process and powder metallurgical process. Generally the ceramic particles and non-metallic like alumina (Al_2O_3),silicon carbide (SiC), graphite, boron carbide (B4C), etc. are been used as reinforcements in MMCs. Stir casting technique can be effectively used to fabrication of MMCs with preferred properties. When the ceramics particles are reinforced with Aluminum and its alloys, it has seen the significant increase in mechanical properties. Addition of Al_2O_3, SiC etc. particles in aluminum, there will be an improvement in tensile strength, yield strength and hardness, while ductility is decreased [1]. Md. Habibur Rahman and Mamun Al Rashed H. M [2] in this study, the MMCs of varying SiC content (0, 5, 10 and 20 wt. %) were used to prepare the stir casting technique. Here tensile strength, hardness, wear and Microstructure of composites were studied. Addition of SiC in Al matrix increased tensile strength and hardness of composites when compared with unreinforced Al.20 wt. % SiC content shows the maximum tensile strength and hardness. 20wt. % SiC reinforced MMCs shows the maximum wear resistance. Mahalinge gowda H.B, Mahesh B.S [3] in this investigation, MMCs contains Al_2O_3 compositions i.e. 3%, 6% and 9% by weight containing 2% of Graphite constant. The hardness and compressive strength of composites was increased by adding Al_2O_3 to Al6061 and Tensile strength also increased by adding only Al_2O_3 when it is compared to AL6061- Al_2O_3-GR hybrid composites. As a reinforcement of alumina and graphite will improves the wear behavior of MMCs. Poovazhagan. L et al. [4] in this investigation Al 6061 reinforced by 0.5, 1.0 and 1.5 vol. % of SiC nanoparticles and 0.5 vol. % of B_4C nanoparticles constant. Here SEM analysis indicates that, the nanoparticles were consistently dispersed in the matrix for up to 1.0 vol. % SiC and 0.5 vol. % B_4C. Whereas agglomeration tendency increases was observed at the ratio of 1.5 vol. % SiC and 0.5 vol. % B_4C. The hardness of composites increases by the hybrid ratio increases. The higher tensile strength was found at the ratio of 1.0 vol. % of SiC and 0.5 vol. % B_4C.Deshmanya I. B and Purohit G k [5] in this investigation it is shown that the central composite rotatable design (stir casting) can be used to systematically to find the micro-hardness of MMCs with reinforcement of Al_2O_3. The size and % weight of reinforcement are the two most important factors affecting hardness of the MMCs produced by stir-casting method. 72% of hardness was increased in Al-7075 matrix containing 15% of 36 µ Al_2O_3 particulates. Padmavathi K.R and Ramakrishnan. R [6] in this study, the stir casting process is found to be appropriate to produce the hybrid Aluminium-SiC-MWCNT reinforced Nano composites. Where Aluminium reinforced with SiC and MWCNT gives better wear resistance. As the hybrid ratio increases the Hardness of the composites will be increased. Raghavendra. N and Ramamurthy V. S. [7] in this study, Al-7075 has been considered as the matrix material, silicon carbide (SiC) with 3% weight fraction and Alumina (Al_2O_3) with 3%, 6%, 9% &12% weight fraction are been used as reinforcements. Due to the stir casting process the Particulate MMCs can be developed effectively and porosity can be reduced by constant stirring. The amount of wear rate is reduces at greater speed than at lesser speed of the disc. The addition of SiC has reduces the coefficient of friction and there will be a reduction in the noise and vibration during the sliding motion. Sozhamannan G. G. et al. [8] in this study the viscosity of MMCs decreases with increased in processing temperatures. The interrupting liquid viscosity of Al-SiCp is highly higher by 38% than the Almatrix without reinforcement. The tensile strength of MMCs decreases with increasing in holding time. It is exposed that holding time affects the viscosity of molten metal , particles dispersion and also chemical reaction between matrix and reinforcement will takes place. Due to increasing the processing temperature from 750℃ to 800℃ at 20 minutes holding time then hardness values increases more or less linearly. Chin- Chun Chang et al. [9] in this investigation, the heat treatment process of the aluminum 7050, the optimum conditions for better strength are: pre-aging temperature 120℃ / pre-aging time 12 hours and re-aging temperature140℃ / re-aging time 8 hours, respectively. Shanmugha sundaram. P [10] in this study, it is observed that the heat treated (T6 aged for 6 hours) AA 7075 –SiC composites shows higher wear resistance compared to the heat treated (T6 aged for 2 hours) and as-cast composite specimens.

METHODOLOGY

The main objective of the work is to study the mechanical property and ware rate of aluminium matrix composites (AMC) produced by stir casting method. The material combination of this investigation will be studied in detail contains of Al7075/Al_2O_3/ SiC. The stir casting mostly used to produce the Processing Parameters on Metal Matrix Composites (PRMMCs) because it revealed to be a very capable for the manufacture of near net nature composites in an easiest and cost effective manner [8]. Al 7075 was used as a base material which is a precipitation hardening aluminum alloy, containing major alloying elements like magnesium and silicon. The major applications of these materials are marine, aircraft and automobile industries. The mixture of Al_2O_3 and SiC particles were used as the reinforcement material. The experiments was done in two attempts i.e., varying volume percentage of Al_2O_3 (2%, 4% and 6%) with maintaining constant of 6% of SiC and 160℃ of heat treatment for 4 hours. Whereas in second attempt varying volume percentage of SiC (3%, 6% and 9%) with maintaining constant of 4% of SiC and 160℃ of heat treatment for 4 hours.

EXPERIMENTAL PROCEDURE

In the view of saving time and material cost involved in work, the lesser number of experiment trials were chosen. Al 7075, alumina oxide (Al_2O_3) of 100 mesh size having ph value of 6.5 – 7.5 and silicon carbide (SiC) of 220 mesh size as shown in the Fig. 1and 2. Al 7075 alloy, which was in the form of bright extruded rod, was cut into small pieces to which can be placed in the crucible. Coke fired furnaces was used in this investigation. Once the molten metal is ready, the pre-heated reinforcements were added in to the graphite crucible according to weight % and stirring process was done to get exact mixture of base metal and reinforcements. Then the pre-

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heated metal die was been equipped with die releaser spray, finally the molten metal was poured in to the die continuously and defect less castings was obtained. Based on ASTM standards the casted parts were machined by CNC to prepare the specimens as shown in Fig. 3 to 5. Heat treatment (HT) was done at 160℃ up to 4 hours continuously.

Fig.1: Alluminium 7075.

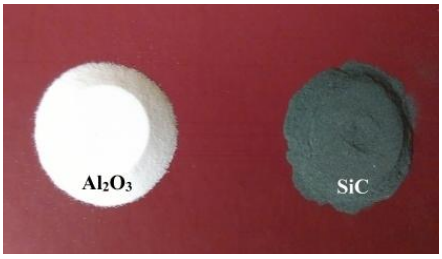

Fig.2: Reinforcements.

Fig. 3: Tensile test specimen.

Fig. 4: Hardness test specimen.

Fig. 5: Wear test specimen.

Tensile test was performed for measuring the strength for Al- Al_2O_3-SiC metal matrix composites as shown in the Fig. 6. A pin-on-disc wear testing machine was used to evaluate the sliding wear behavior of the composites. The hardness test is carried out in Vicker's micro hardness tester as shown in the Fig. 7. Sliding wear tests were conducted in pin-on-disc wear testing apparatus (model: TR20-LE, Wear and Friction Monitor, Ducom Make, Bangalore, India) under the load of 30N at a fixed sliding speed of 1.66 m/s against EN32 steel disc as shown in the Fig. 8.

Fig. 6: Universal Testing machine.

Fig. 7: Micro Hardness Testing machine.

Fig. 8: Wear Testing machine.

RESULTS AND DISCUSSION

Tensile test
Tensile test was performed by using Universal Testing Machine (UTM) to obtain the ultimate tensile strength, yield stress and % elongation. The results of the Tensile strength are shown in Table 1 and 2. The comparison of

Tensile strength values of various percentages of MMCs are depicted in Figure 9 and 10. Tensile strength was found to increase with increase in weight percentage of reinforcement.

Table 1. Experimental results of Tensile test for varying Al_2O_3.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Ultimate Tensile Strength (MPa)
1	2 %	6 %	160	140.894
2	4 %	6 %	160	162.986
3	6 %	6 %	160	186.984

Table 2. Experimental results of Tensile test for varying SiC.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Ultimate Tensile Strength (MPa)
1	4 %	3 %	160	155.854
2	4 %	6 %	160	162.986
3	4 %	9 %	160	175.522

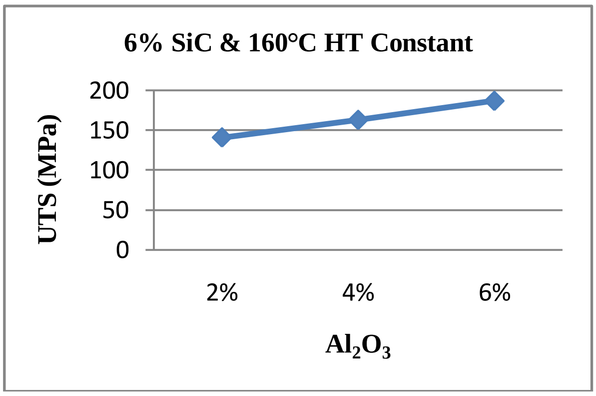

Fig.9. Comparison of Ultimate Tensile Strength values varying Al_2O_3.

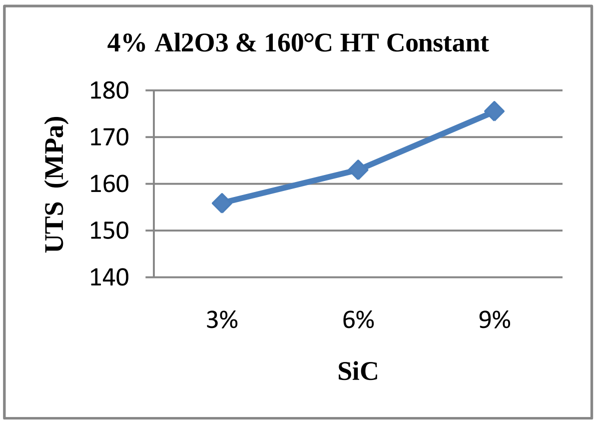

Fig.10. Comparison of Ultimate Tensile Strength values varying SiC.

Hardness test

Hardness test was conducted for determining the hardness of the twin reinforced aluminium metal matrix composite. The load of 0.5 kg for a period of 10 seconds is applied on specimens. The hardness results were measured in three locations/positions over the sample and the average values are been tabulated in the Table 3 and 4. The comparison of hardness values of various percentages of MMCs is depicted in Figure 11 and 12.

Table 3: Experimental results of Hardness for varying Al_2O_3.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Hardness
1	2 %	6 %	160	116
2	4 %	6 %	160	130
3	6 %	6 %	160	129

Table 4: Experimental results of Hardness for varying SiC.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Hardness
1	4 %	3%	160	129
2	4 %	6 %	160	130
3	4 %	9 %	160	123

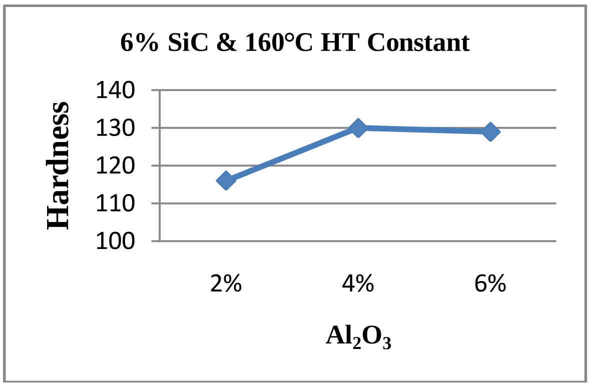

Fig.11. Comparison of Hardness values varying Al_2O_3.

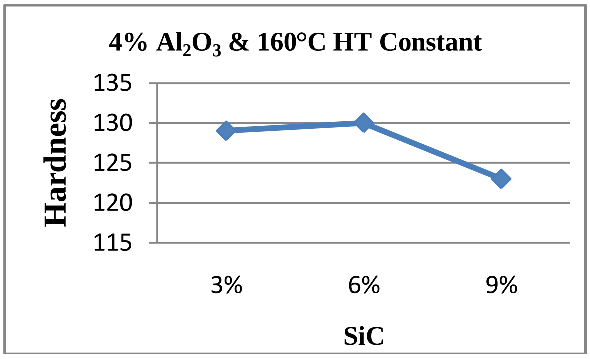

Fig.12. Comparison of Hardness values varying SiC.

Wear loss

During the wear test, the pin was forced against the counterpart rotating disc (EN32 steel disc) against an AISI-O1 Cast Iron disc by applying the load. Friction sensing arm coupled to a strain gauge and the pin (specimen) loaded vertically into the rotating tool steel disc as shown in the Figure 5. Initial weight pin was checked, after running through a fixed sliding period, the pin were removed, cleaned with acetone liquid, dried out and final weight was checked to conclude the weight loss due to wear. The values of wear loss are shown in Table 5 and 6. The comparison of ware rate values of various percentages of MMCs is depicted in Figure 13 and 14. The wear loss was reduced by increase in weight percentage of reinforcement.

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Table 5: Experimental results of Wear loss for varying Al_2O_3.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Wear loss
1	2 %	6 %	160	0.075
2	4 %	6 %	160	0.053
3	6 %	6 %	160	0.031

Table 6: Experimental results of Wear loss for varying SiC.

Trial	Al_2O_3	SiC	Heat Treatment (°C)	Wear loss
1	4 %	3 %	160	0.060
2	4 %	6 %	160	0.053
3	4 %	9 %	160	0.052

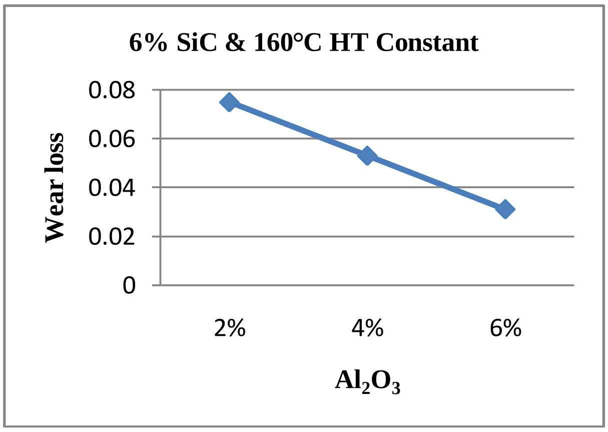

Fig. 13. Comparison of Wear loss for varying Al_2O_3.

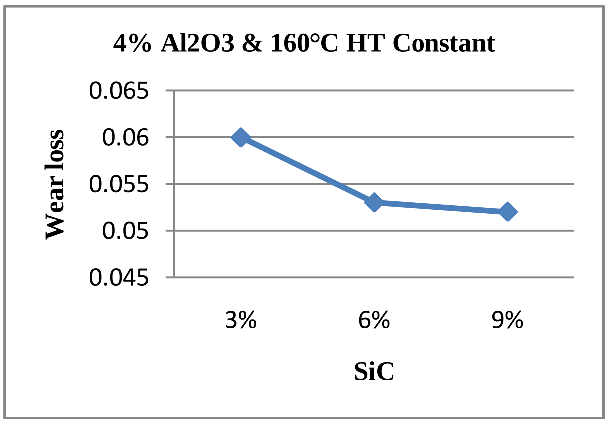

Fig. 14. Comparison of Wear loss for varying SiC.

CONCLUSION

A fabricating of aluminum matrix composite by using stir casting method is proved to be successful. The succeeding conclusions are attained based on the experimental study on the distribution of Al_2O_3 and SiC in the stir casting with heat treatment and its effect on mechanical properties of MMCs at different weight percentage of Al_2O_3 and SiCp:

- The Tensile strength was increased in both the condition, varying Al_2O_3 and Varying of SiCp.
- The ware rate is reduced in increasing of both Al_2O_3 and SiCp, when one in both was kept constant.
- The hardness value was increased by addition of Al_2O_3 and SiCp, when one in both was kept constant in aluminium matrix. It has been also noted that when percentage of reinforcements increases, there is a sudden decrease in hardness value due to the cluster formation.

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- The optimal heat treatment process for increasing the UTS of the Al 7075 alloy are a solution temperature of 160°C for 4 hours. By heat treatment under these optimum conditions, the obtained tensile strength and ware rate was satisfied with in the trials.
- This investigation is a preliminary study. The complete investigation is required in terms of Taguchi method to evaluate the influence of Al_2O_3, SiCp and heat treatment on the properties of the hybrid MMC

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