Study of Wear and Hardness Tests On Heat Treated Aluminium Alloy

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Abstract: Heat treatment is a process in which a material is heated to a specific temperature and then cooled in a controlled manner. This process can be used to alter the properties of the material, including its strength and wear resistance. The present work is to study the effect of heat treatment on the wear properties of aluminium hybrid composites. Material chosen for the study is Aluminium 6061 as a matrix, Silicon Carbide is the reinforcement. Hybrid metal matrix composite is produced by making use of the stir casting route of silicon carbide. The wear test is conducted on the heat treated metal matrix aluminium composite at room temperature for both the as-cast and age hardening conditions. Micro structural characterization of hybrid aluminium metal matrix composite is analysed.

Keywords: Heat treatment, Wear Test, Hardness test, Aluminium composite

I. INTRODUCTION

Aluminium hybrid composites are materials that are made by combining aluminium with other materials such as ceramic particles, carbon fibres or other metals. These composites have a unique combination of properties such as high strength, good wear resistance and low density.

Wang et al. [1] have studied a novel hybrid composite PCM and it was manufactured by adsorbing octadecane into the porous supporting material based on the aluminum nitride (AlN) material, which owned high thermal conductivity. Meanwhile, a layer of nano capsule PCM was coated on its surface for increasing the latent heat and achieving the PCM encapsulation. The results showed that the AlN efficiently enhanced the thermal conductivity of the composite PCM, and the addition of nano capsule PCM further improved the stability and latent heat of the composite PCM. Senthil et al. [2] have studied composite materials and their superior physical and mechanical properties to enhance modern engineering applications and industrial needs. These needs can be archived by metal matrix Composites. This also satisfies the consumers' demands for a light-weight material, low cost-effective, less production cost, higher flexibility with major strength.

Khan et al. [3] have studied the mechanical properties of Al6061 metal matrix with GNPs and B_4C composite. Effects of SPS processing and the resulting microstructures are correlated with the mechanical performance of the composites and other relevant studies. The results encouraged the potential use of Al-GNPs, Al–B_4C and Al-GNPs-B_4C composites for the futuristic design of low weight and high strength applications of the automobile and aerospace industry. Radhika et al. [4] studied abrasive wear behaviour of cast aluminium-SiC composite with nickel coating. For the study of wear behaviour, they utilized taguchi design of experiments and analysis of variance.

Doddamani et al. [5] have done experimentation investigation on wear behaviour of aluminium-graphite MMC and they found that the adding of particles of graphite has increased the resistance to wear of the MMC. Bandil et al. [6] investigated the effect of Si and SiC addition on the microstructure, mechanical, and corrosion properties of Al matrix-based composites. Maximum hardness is found for composites having 15 % weight reinforcement content. Pin-on-disc wear test reveals that SiC particles increase the wear resistance of composites. Corrosion test reveals that composites reinforced with 20% reinforcement content show the minimum i corr among all the compositions, attributed to the maximum corrosion resistance.

Garg et al. [7] have reviewed aluminium matrix composites and their properties are widely used in engineering applications. Overviews of synthesis routes, mechanical behaviour and applications of aluminium matrix composites are reported. Special focus is given to primary processing techniques for manufacturing of aluminium matrix composites. Commercialization challenges, industrial aspects and future research directions are also briefed.

Hossain et al. [8] have studied the aluminium-based, hybrid metal matrix composite developed by a stir casting method. Al_2O_3 content is fixed as 1 % weight and SiC content is varied from (0, 2, 4, 6, and 8) % weight as

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reinforcement material. Microstructure, mechanical properties and wear behaviour of prepared samples have been investigated. The result indicates that incorporation of Al_2O_3 and SiC reinforcements in the aluminium Al-6103 grade matrix improved hardness and wear resistance of the material. Kumar et al. [9] have developed aluminium reinforced SiC-TiC hybrid metal matrix composites by liquid stir casting process. Also they investigated the effect of hybrid ceramic reinforcements on the micro structural, mechanical and tribological behaviour of composites. It is found that increase in the reinforcement content of SiC-TiC particles increases the hardness and decreases the density of composites and improvement in wear resistance at higher reinforcement content.

Rajesh et al. [10] have conducted wear tests on a pin on disc device at room temperature for both the age hardening and without age hardening conditions. Al7075 was chosen as the matrix material. HMMCs are produced utilizing a stir casting route to enhance the wear behaviour and hardness number. The reinforcement used is silicon carbide with 5%, 10% and 15% weight percentage and Al_2O_3 as the reinforcement at 5%, 10% and 15% weight percentage. As an increase in weight fraction, there is a decrement in the rate of wear of composites.

Problem identification: While considering conventional wheel rims, the following problems were identified

1. The weight of the conventional wheel rim is relatively high.
2. Manufacturing of the rims involves high consumption of time and requires more manpower.
3. The machining process of conventional rims is complicated and requires high-skilled workers to do the operation.
4. Metals are highly prone to temperature changes as they expand in hot conditions and shrink in cold conditions.
5. It is difficult to identify the small deformation in the conventional rim caused due to sudden impact.
6. Costs of the metal rims are comparatively high.

II. OBJECTIVES

1. To investigate the effect of heat treatment on the microstructure and mechanical properties of aluminium hybrid composites.
2. To study the wear properties of aluminium hybrid composites under different wear conditions.
3. To determine the effect of heat treatment on the wear properties of aluminium hybrid composites.
4. To evaluate the effect of type and volume fraction of reinforcing particles on the wear properties of aluminium hybrid composites.
5. To optimize the heat treatment parameters for improving the wear resistance of aluminium hybrid composites
6. To develop a fundamental understanding of the relationship between micro structure, heat treatment, and wear properties of aluminium hybrid composites.

In this study Aluminium 6061 is chosen as matrix material and the reinforcement used is silicon carbide with 5%, and 10% weight percentage. Stir casting method is used to prepare the samples and finished using wire cut EDM.

Figure 1 shows the photographic view of the prepared sample. The samples are tested using "Pin on Disc" test rig.

Figure 1 photographic view of the sample

III. METHODOLOGY

Figure 2 shows the methodology followed in the present work represented in the form of flow chart.

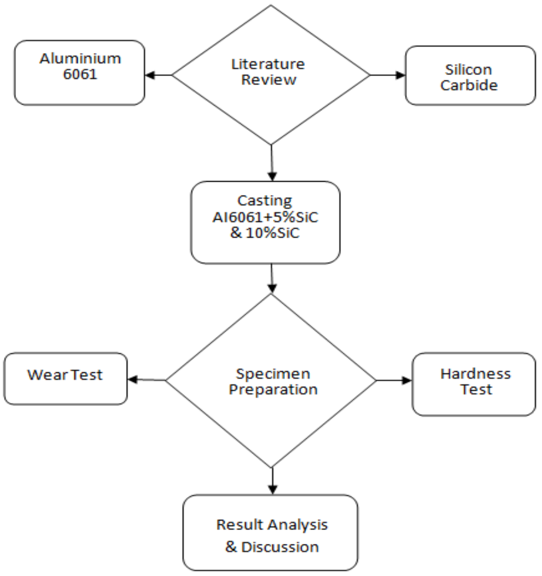

Figure 2 Methodology

Sample size and Pin on Disc test parameters

- Specimen: Pin size 2 mm diameter & 32 mm long

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- Wear Disc Size: Standard Disc: ø 165 x 8mm thick: Material En31 Hardened to 60 HRc ground to1.6 Ra Surface roughness
- Square Disc: 20mm×20mm-100mm×100mm
- Wear disc Holder: Standard disc holder: ø170 x 35mm thick. Universal
- Holder: For square and cylindrical disc up to ø100 x8mm
- Wear Track Dia: 10-160 mm in steps of 2 mm
- Disc Rotation: 20-2000 rpm in steps of 1 rpm.
- Normal load: 0.5 Kg-20 kg in steps of 0.5 kg by dead weights
- Frictional force: Max-200N least count 0.1N
- Wear: 0-200 µm
- Temperature: 400°C– Pin Heating, 400°C– Chamber Heating

Aluminium alloy with silicon carbide is applicable where hardness and toughness are the requirements. Metal matrix composites are designed in order to have the combined properties of both metals and ceramics.

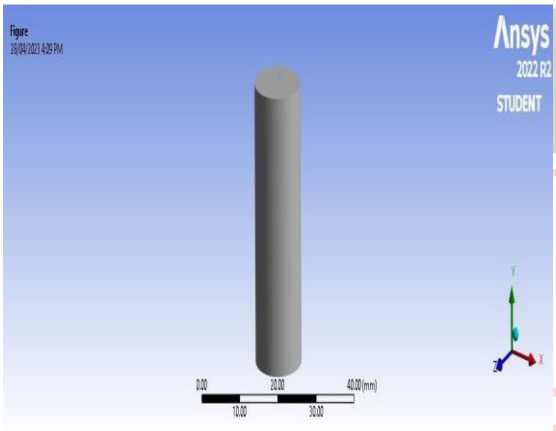

Figure 3 Model

Figure 3 shows the model of the specimen to be tested using ANSYS software.

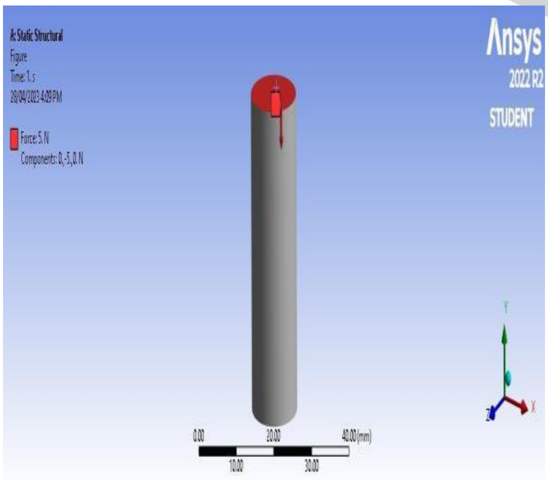

Figure 4 Load application

Figure 4 shows the load application on the designed model on which testing has to be done. The load applied is about 50N vertically.

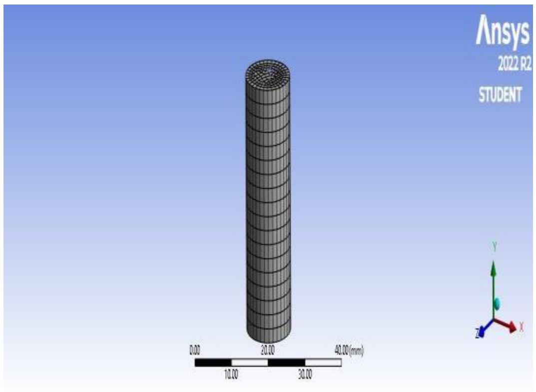

Figure 5 Mesh view

The Figure 5 shows the mesh view of the imported model on the ANSYS work bench.

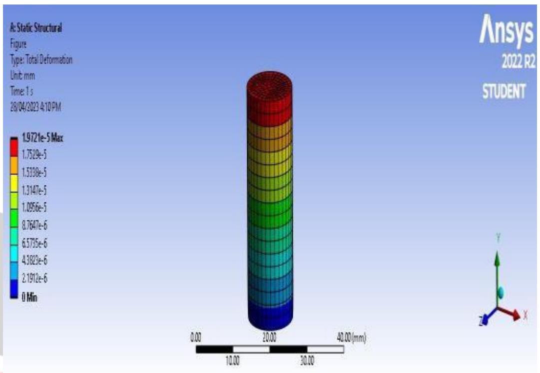

Figure 6 Total Deformation

The Figure 6 shows the total deformation of the work piece after application of the load. It is seen from the Figure 6 that the deformation increased from bottom end to upper end obtained at the top end.

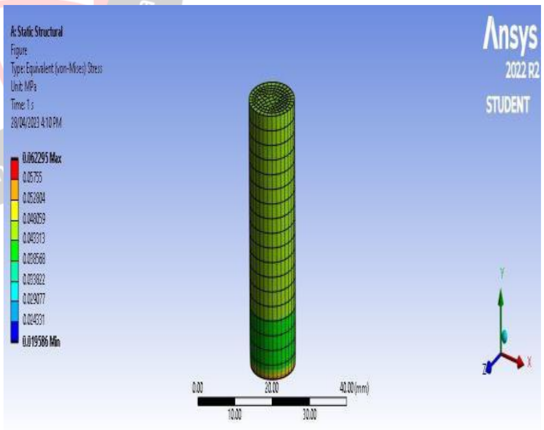

Figure 7 Stress analysis

Figure 7 shows that the stress developed on the model after applying load. The maximum stress obtained at bottom of the model.

2. WEAR TEST

Sliding wear is a type of wear that occurs between two surfaces that slide against each other under load. It can be caused by various factors, including friction, adhesion, abrasion, and corrosion. Pin-on-disc testing is a type of wear testing method used to evaluate the friction and wear

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behaviour of materials. It involves sliding a pin-shaped sample against a rotating disc under controlled conditions, such as load, sliding speed, and duration of testing. During the test the pin is placed vertically against the disc and is pressed down with a specified load. The disc is then rotated, causing the pin to slide along the surface of the disc. The frictional force between the pin and disc and the wear on the pin are continuously measured and monitored during the test.

Table 1 shows the wear rate of the samples with variations in load and speed on the specimen. It is observed from the table that the wear rate increases with an increase of sliding speed and sliding distance. But the signal to noise ratio is decreases with the increase of sliding speed. The signal to noise ratio is maximum at 1000 m sliding distance. It is also seen from the table that the enhanced in wear resistance is due to the increment weight fraction of reinforcement.

Table 1 Wear test results

S.No	Sliding Speed (m/s)	Sliding Distance (m)	Load (N)	Wear Rate (m^3/Nm)		Signal to Noise Ratio	
	S	D	L	AI6062+ 5% SiC	AI6062+ 10%SiC	AI6062+ 5%SiC	AI6062+ 10%SiC
1	1.0	500	15	0.0072	0.0061	42.85	44.29
2	1.0	1000	30	0.0066	0.0056	43.61	45.04
3	1.0	1500	45	0.0086	0.0083	41.31	41.62
4	1.5	500	15	0.0068	0.0058	43.35	44.73
5	1.5	1000	30	0.0091	0.0086	40.82	41.31
6	1.5	1500	45	0.0097	0.0098	40.26	40.18
7	2.0	500	15	0.0163	0.0148	35.76	36.59
8	2.0	1000	30	0.0094	0.0084	40.54	41.51
9	2.0	1500	45	0.0099	0.0091	40.09	40.82

The Figure 8 shows the S/N curve with respect to sliding speed, sliding distance and load for minimal wear rate for aluminium (Al6061), aluminium alloy Al6061 with 5%SiC Composites. From this graph, it is found that the optimum parametric combinations are sliding speed 1m/s, sliding distance 1000 m and applied Load 30N. In other words, in the above-said parameters, the combination gives the better wear resistance for the composite material.

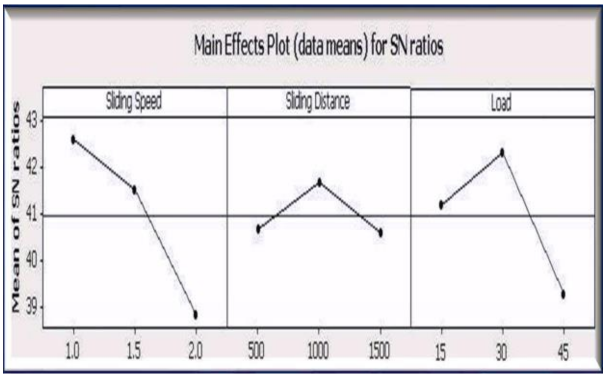

Figure 8 S/N curve for Al (6061)+ 5% SiC Composites

IV. HEAT TREATMENT

Heat treatment is a process in which a material is heated to a specific temperature and then cooled in a controlled manner. The purpose of heat treatment is to change the properties of the material in order to improve its performance or suitability for a particular application. In this process the heat treatment is done at a temperature of 400°C.

The results are obtained by heat treatment of material after 4 hours, 6 hours and 8 hours time periods. The changes in microstructure are obtained during the heat treatment process and the results are analyzed by means of SEM analysis. Figures 9-12 show the microstructure before heat treatment and changes in microstructure after 4 hours, 6 hours and 8 hours of heat treatment.

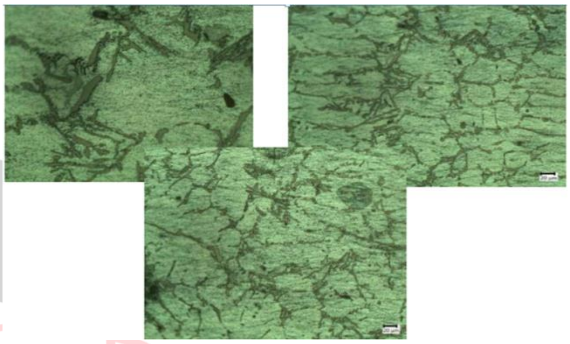

Figure 9 Microstructure of the specimens before conducting heat treatment

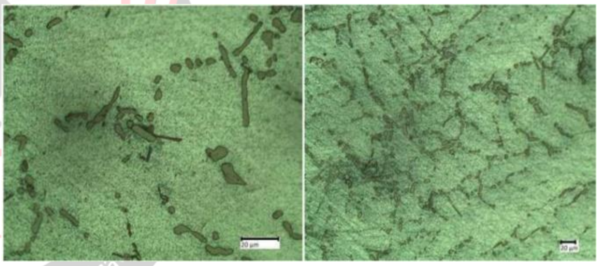

Figure 10 Change in microstructure of the specimens by heat treatment after 4 hours

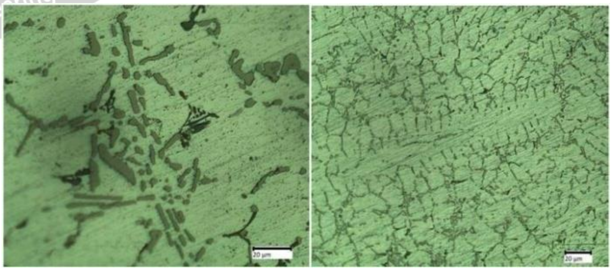

Figure 11 Change in microstructure by heat treatment after 6 hours

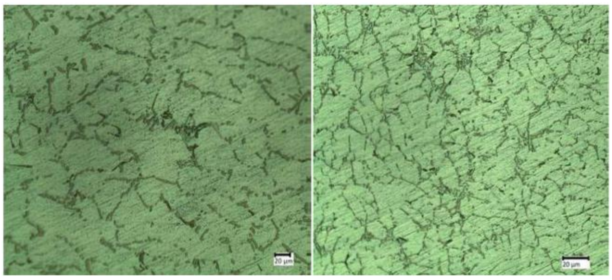

Figure 12 Change in microstructure by heat treatment after 8 hours

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It is construed that from the above figures that the grain structures changes with an increase in duration of heat treatment process. The hardness of the aluminium alloy material is increased with an increase in duration of heat treatment process.

V. HARDNESS TEST

The hardness of a material is a key factor in determining its suitability for various applications, as it can affect the material's strength, durability, and wear resistance. Hardness testing is a non-destructive testing method used to measure the ability of a material to resist plastic deformation, indentation, or penetration under an applied load. The Brinell test involves applying a load to the surface of the material using a hardened steel ball and measuring the diameter of the resulting indentation. The sample1, sample 2 and sample 3 are heat treated for a period of 4 hours, 6 hours and 8 hours time periods respectively.

The variation of hardness with an increase in the ageing hours is shown in Table 2. It is observed from the table that with an increase in the ageing duration, there is a significant improvement in the hardness of the aluminium alloy.

Table 2 Variation of Brinell hardness number for three samples with respect to load and hardness

	Load in kN	Brinell Hardness Number
Sample 1	0.334	83.1
	0.336	82.1
	0.339	80.7
Sample 2	0.296	106
	0.291	110
	0.292	109
Sample 3	0.289	111
	0.285	114
	0.288	112

VI. CONCLUSION

The hardness of the aluminium alloy material is improved by heat treatment process and the hardness of the material is increased with an increase in time duration of heat treatment process. This investigation reveals that the enhanced in wear resistance is due to the increment weight fraction of SiC reinforcement. There is a reduction in the rate of wear with an increase in sliding distance. The wear resistance of the composites can be improved by heat treatment process. Overall, the study suggests that aluminium hybrid composites have great potential as a material for wear resistant applications, and the wear properties can be further optimized through proper heat treatment.

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