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Wear Analysis of T6 Heat Treated Al 7075/Graphene Composite by Stir Casting Technique

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***Abstract*: The aluminum and aluminum alloys have their insist in industries and research fields with owning several aspects like high strength, light weight, better hardness, corrosion resistance, weldability and good resistance to wear. Aluminum 7075 alloy, with zinc as the main alloying element and it is widely used in aerospace structure. Graphene is the allotrope of carbon with unique set of properties, extracted from graphite by chemical exfoliation process. The methodology contains a grounding of composite by bottom stir casting technique with the variation of 0.5wt% and 1wt% of graphene in aluminum matrix. The samples are heat treated which involves precipitation hardening. The present inquiry focuses hardness and wear manners (pin on disc). Wear loss is decreased around 37.6% in heat treated Al 7075 with 1% wt of graphene. This has the applications in automobile parts, bicycle frame, electrical fittings and marine.**

***Keywords*: Aluminium 7075 alloy, Graphene, Hardness, Heat treatment, Wear.**

1. Introduction

Aluminum is the third abundant material (after oxygen and silicon) and highly abundant metallic element in the earth crust (about 8.3% of mass). Aluminum alloys and their composites are used in a variety of applications in the aerospace, automobile and marine industries, due to their high strength to weight ratio, good wear resistance, low specific gravity, high reflectivity, good electrical conductivity and heat transfer, less gas solubility (except hydrogen gas), corrosion resistance and high stability.

2. Literature Review

Singh et al.[1] The wear resistance was also found to increase significantly with the addition of reinforcements in aluminium. Testing of wear manners was done on pin on disc apparatus at a normal load of 10 N and sliding velocities of 0.8 m/sec and 1 m/sec. The fabricated composites showed enhancement in wear resistance over the aluminum metal.

Behera et al. [2] In the present study, an AlSi10Mg alloy reinforced with 3, 6, and 9 wt% Alumina. Microstructural studies, such as evaluating mechanical properties, such as hardness, strength, and shear strength, were carried out on composites and samples from non-reinforced alloys. The tribological behavior of hybrid composites was studied using a pin on a disk testing machine.

Mahathaninwong N. et al. [3] It reveals that the most favorable solution heat treatment state for the 7075 aluminium alloy. The Al alloy was heat treated for 450^{0}C for 4hr. The ageing was performed at temperatures of 120^{0}C, 145^{0}C, 165^{0}C and 185^{0}C with various durations. The peak ageing at 120^{0}C for 72hr gained good mechanical strength.

Veeravalli et al. [4] In this study the wear resistance of the composites increased with increasing weight percentage of TiC particles, and also the wear and tear rate was particularly less for the material compared to the matrix material. The intense analysis in as-cast condition and T6 condition of the AMMCs was accepted out using SEM so as to seek out the control of TiC particles within the AMMCs formed.

Baba, E. Sai et al. [5] In this study cast samples are heat treated (T6). Wear test conducted on pin-on-disc equipment and tribological behaviour analyzed in terms of wear rate. It was found that, compared to pure alloy the Al-7075 HMMC exhibited improved wear performance due to the incidence of Al2O3 and TiC as reinforcements in HMMC restrict plastic deformation and reduce wear loss. It was observed that during T6 treatment better grain refinement was formed in the Al 7075 HMMC and hence improved wear resistance was exhibited by the treated samples than untreated HMMC.

Viswakarma PR et al. [6] This paper investigates the possibility of growing elite composites with low cast, for different applications like aviation and automobile. The impact of different reinforcements on the AA7075 based composite has been studied. The mechanical properties, have been seen to be either nearly equal or better after heat treatment to the as cast composites. It has been found from the past research that the proximity of the rigid ceramic stage, for example SiC, TiB_2, Al_2O_3 effects through strengthening of the composites.

3. Materials and Method

A. *Aluminium 7075 alloy*

Aluminium 7075 is an aluminium alloy, with zinc as the chief alloying constituent. It is a tough material by strength comparable to many steels, and has good fatigue strength and normal machinability. It has lower resistance to corrosion than other aluminium alloys, but has significantly better corrosion resistance than the 2000 alloys. It is relatively high cost material.

Table 1
Alloying elements of Al 7075

Element	**% by weight**
Aluminium	87.1 to 91.4
Silicon	Max 0.40
Iron	Max 0.50
Zinc	5.1 to 6.1
Copper	0.18 to 0.28
Manganese	Max 0.30
Magnesium	2.1 to 2.9
Titanium	Max 0.20
Others	Max 0.15

B. Graphene

Graphene is theoretically a non-metal but is referred to as a quasi-metal due to its properties. Graphene is an allotrope of carbon that exists as a 2-D planar sheet. Graphene is as a single atomic graphite layer.

Table 2
Properties of Graphene-L

Graphene	**Description**
Purity	99%
Thickness	5 to 10 nm
Number of layers	5 to10
Average lateral dimension(x and y)	10µm
Surface area	60 to 200 m^2/g
Bulk density	0.45 g /cm^3
Chemical formula	C
Physical form	Fluffy, very light powder
Odour	Odourless
Colour	Black powder

C. Stir casting technique

The stir casting is a simple and price effective methodology. The bottom stir casting is successfully utilized to prepare the metal matrix composite. In this study, Al-7075 was used as a metal matrix composite material with various percent graphene. The amount of Al 7075 is 3000 grams and the graphene particles required to obtain composites are 0%, 0.5%, and 1%. The manufacturing process of MMC remains the same, although the composition of MMC is changing. First, the metal matrix composite and graphene are weighed in accordance with our requirements. Graphene is preheated to 400 ° C for each sample. Then, 1000 grams of 7075 aluminum is weighed for each sample and stored in a crucible until it melts. Later chemicals, such as hexachloro ethane and magnesium chips are added to the composition because it reduces the material and increases the wettability. After all chemicals have been added, graphene is added to the aluminum and the composition is mixed, which ensures proper particle distribution. After the mixture of aluminum and graphene is poured into a mouthpiece, which is in a liquid state and waiting 1 hour for cooling, then the sample is removed from the mouthpiece and a sample is obtained.

Fig. 1. Bottom stir casting

Fig. 2. Casted Aluminium

D. Heat treatment

T6 heat treatment has Two-phase method which is applicable to aluminium, copper, and silicon alloy to increase strength up to 30%.

1) Quenching

The MMC is heated to 490 ^{0}C for 4 hours which causes the copper to dissolve in the aluminium and from the single phase alloy confine the reinforcement material in MMC.

2) Ageing

The MMC is heated at 165 ^{0}C for 5hours then cooled by air leads to artificial ageing.

Fig. 3. Muffle furnace

Table 3
Aluminium MMC with heat treatment

Compositions	Al 7075 alloy weight %	Graphene in weight %	Heat treatment
C_1	100	0	NO
C_4	99.5	0.5	NO
C_4	99	1	YES
C_4	99.5	0.5	NO
C_5	99	1	YES

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4. Experimentation

A. Hardness test

The HWMMT-X7-micro VHN tester equipment was used to determine the hardness of the composites. Samples are prepared according to the ASTM E9 standards.

B. Wear test

The pin-on-disc wear test may be a typically used tribological description method to approximation the coefficient of friction and therefore the wear mechanism. Sample dimensions are 10mm diameter and 30 mm height.

Fig. 4. Wear test specimen

C. EDS Evaluation

The energy dispersive X-ray spectroscopy is a special technique to determine or estimate the elements distributed on the surface of the specimen.

5. Result and Discussion

A. Density

The density is the physical property of the material. The aluminium and aluminium alloy are having less density compare to the other metals. Basically Aluminium 7075 density is 2.8 g/cc. The composite densities are determined by Archimedes principle. The matrix with 0.5% wt of graphene has 2.63 g/cc and 1% of graphene has 2.48g/cc.

B. Hardness test

The load applied on the specimen in the experiment was 500grams for 15 to 20 seconds. The experiment shows that micro hardness will improve with the increase in reinforcement and heat treatment. The hardness of 1% graphene reinforced and heat treated specimen improved by 34.88% than cast Al alloy.

Table 4
Hardness values

Compositions	VHN
C_1	84
C_2	112.3
C_3	121
C_4	124
C_5	129

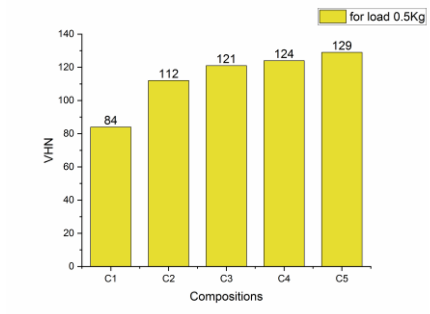

Fig. 5. Micro VHN values

C. EDS Evaluation

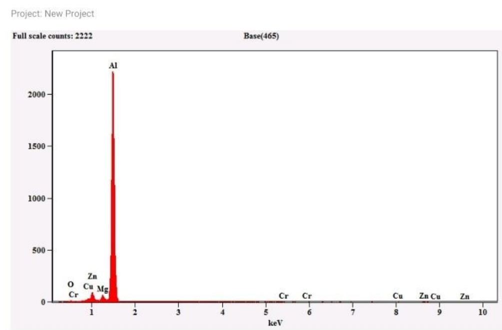

Fig. 6. Aluminium 7075 compositions

The above graph represents the casted aluminium alloy. In this figure we are able to see the maximum percentage of aluminium along with some percentage zinc, so that it confirms that the material taken for this present work is aluminium alloy 7075.

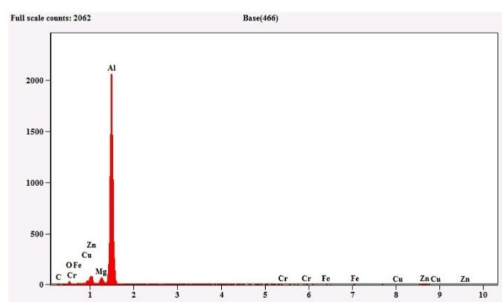

Fig. 7. Al 7075+ 0.5% graphene

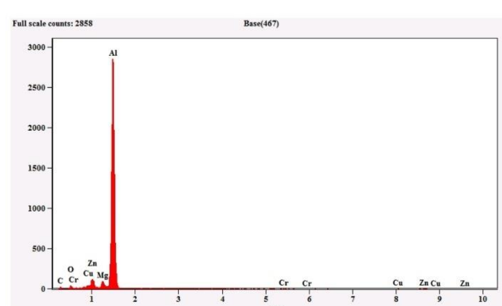

Fig. 8. Al 7075+ 1% graphene

The above graphs represent the Al 7075 reinforced with graphene. The figures show the presence of both carbon and zinc with minute percentage of alloying elements. It confirms that the reinforcement added is present in aluminium alloy.

D. Wear test

Table 5
Wear test

Compositions	Weight loss in grams	Coefficient of friction	Frictional force N
C_1	0.0352474	0.216	2.25
C_2	0.0346623	0.254	2.64
C_3	0.0301443	0.136	1.63
C_4	0.0220675	0.125	1.52
C_5	0.0220174	0.106	1.56

The weight loss is decreased as the increase in the weight percentage of graphene. Further the weight loss and coefficient of friction are decreased with the heat treatment and they are correspondingly low than casted Al 7075 specimen. A maximum weight loss of 37.61% reduction is found in Al 7075 heat treated with 1% wt of graphene compared with Al 7075 base.

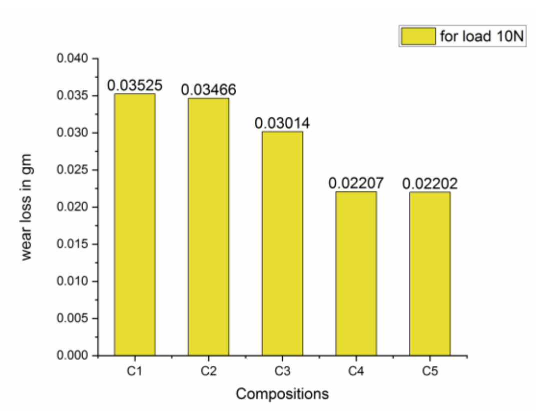

Fig. 9. Wear loss vs. Compositions

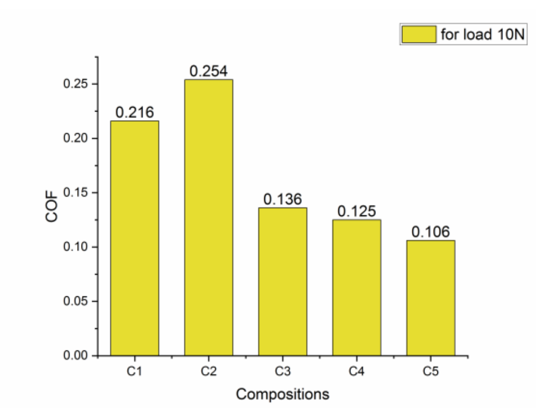

Fig. 10. Coefficient of friction vs. Compositions

The coefficient of friction and frictional force are reduced in heat treated MMC.

Fig. 11. Al 7075

Fig. 12. Al 7075+0.5graphene

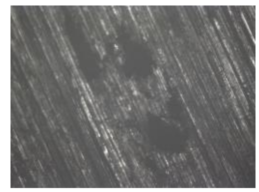

Fig. 13. A l7075+ 1% graphene

Fig. 14. Al 7075+ 0.5% graphene + HT

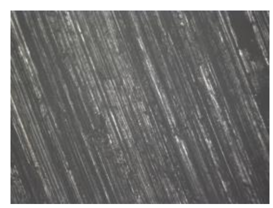

Fig. 15. Al 7075+1% graphene + HT

The above images explain about morphologies of worn surface, direction of wear, wear tracks and wear debris formed in the test samples.

6. Conclusion

The Aluminium 7075/ graphene MMCs are prepared and heat treated successfully by using bottom stir casting technique. The wear properties are investigated for both base and graphene reinforced MMC. The densities of the MMC are reduced with the increase in reinforcement. The hardness found to be increased with the increase in percentage of reinforcement and 1% graphene with heat treated Al specimen improved about 34.88% than cast aluminium alloy. The wear loss and COF are found to be low in 1% graphene reinforced and heat treated Al 7075. The Al 7075/graphene heat treated composite are showing the reduction in wear loss about 37.6%. The microscopic images briefed about the nature wear tracks, debris and direction of wear.

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