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Research paper



Fretting Analysis of Aluminium 6061 Reinforced With Graphene

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Abstract

The application of Aluminium alloys becomes significant and most wide in the field of aviation industry. Aluminium 6061, because of its pro mechanical characteristics. Graphene is one of the allotropic forms of Carbon which is abundantly available in nature. The high tensile strength and low density of graphene is the added advantage as it is used as a reinforced material with Aluminium 6061. Graphene was found to be a more suitable reinforcing material that improves tribological properties of metal. Composite materials are mixtures of various parent materials resulting in the formation of materials having a mix of varied desired properties like low weight, larger stiffness, higher specific strength etc. The composite materials so obtained invariably have superior properties to their parental ones. So these materials become a really enticing notice for higher strengthened material for industrial sector. This paper primarily focuses on distinctive effects of utilizing Graphene as reinforcement for Al-6061in the view of tribological characteristics. Graphene has outstanding mechanical and physical properties, creating it a perfect reinforcement material for lightweight weight and high strength metal matrix composites (MMC) like Al-6061. Fabrication, being a important step, because it controls the microstructure, that successively determines the properties of the material, was conducted by stir casting. Stir casting additionally helped within the dispersion of Graphene uniformly within the metal matrix composite. To analyze the effect of tribological parameters damage resistance of the metal matrix composite, linear reciprocating tribometer was used.

Keywords: *Fretting, Tribometer, Co-efficient of Friction, weight loss, frictional force.*

1. Introduction

Aluminium

Aluminum is a synthetic component with symbol “Al” and atomic number 13. It is a gleaming white, delicate, nonmagnetic, malleable metal in the boron gathering. By mass, aluminum makes up around 8% of the Earth's outside layer; it is the third most plenteous component after oxygen and silicon and the most inexhaustible metal in the covering, however it is less basic in the mantle beneath. The main metal of aluminum is bauxite. Aluminum metal is so synthetically responsive that local examples are uncommon and restricted to extraordinary lessening conditions. Rather, it is discovered consolidated in more than 270 unique minerals. Aluminum is astounding for its low thickness and its capacity to oppose consumption through the marvel of passivation. Aluminum and its amalgams are essential to the avionic business and vital in transportation and building ventures, for example, building exteriors and window outlines. The oxides and sulfates are the most valuable mixes of aluminum.

Graphene

Graphene is an allotropic type of carbon comprising of a solitary layer of carbon atoms orchestrated in a hexagonal grid. It is the essential basic component of numerous different allotropes of carbon, for example, graphite, charcoal and fullerenes. It can be considered as an inconclusively extensive fragrant molecule, a definitive instance of the group of level polycyclic sweet-smelling hydrocarbons. Graphene has numerous bizarre properties. It is the strongest material ever tested, effectively leads warmth and power and is almost transparent. Graphene demonstrates a substantial and nonlinear diamagnetism, which is more prominent than that of graphite.

Metal Matrix Composites

Metal Matrix Composites (MMCs) have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. Reinforcement to the aluminium alloys with graphene enhances the mechanical properties like strength, hardness, and thermal conductivity of the aluminium composite material. In the present project, the main aim is to improve the dynamic properties of the composite material. Aluminum is reinforced with Graphene to improve its mechanical properties.

Graphene, one of the allotropes (carbon nanotube, fullerene, diamond) of elemental carbon, is a planar monolayer of carbon atoms arranged into a two-dimensional (2D) honeycomb lattice with a carbon–carbon bond length of 0.142 nm.**[2]**

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Jun Wang et. al[1] explained that fretting is induced by vibrations or the application of bulk fatigue stresses to one or both of the contacting parts. It widely occurs at the interface of the contact between two parts when there is small amplitude oscillatory relative movement at typically 5–50(μms) micrometers, such as cables in overhead conductors and mine hoists, riveted joints, prostheses, dovetail roots of compressor blades in aircraft engines, etc. Various studies have shown that the combined actions of fatigue and fretting had a significant effect on the fatigue limit of metallic materials, including aluminum alloys. Fretting results in an enormous reduction of the endurance limit of a component by half or more, in comparison to the normal fatigue conditions.

K. Pereira et. al [2] investigated that fretting fatigue is a complex phenomenon that affects many mechanical assemblies leading to their premature failure. The fatigue limit of a material may well be reduced by 50% under fretting conditions. Thus, the proper prediction of fretting fatigue lives is of great interest in engineering field

Pulkit Garg et. al [3], in "Structural and Mechanical Properties of graphene reinforced Aluminum Matrix composites" investigated the effect of sintering temperature on structural and mechanical properties of graphene reinforced aluminum matrix composites.

2. Material Preparation

The specimen specimen is prepared by varying the percentage of graphene with aluminium 6061., viz 0%, 0.25%, 0.5%,0.75% and 1% of weight of Aluminium. Stir cast process is used to cast the specimen. The specimen is machined to flat plate for the dimension of 40mm x 40mm x 6mm and the pin is machined to dia8 x15mm length. The specimen and pin is grinded to achieve smooth surface and polished to achieve a Ra value less than 500 μm.

Scanning Electron Microscope (SEM) , EDAX and X-Ray Diffraction (XRD) results witness the equal distribution of graphene with Aluminium material.

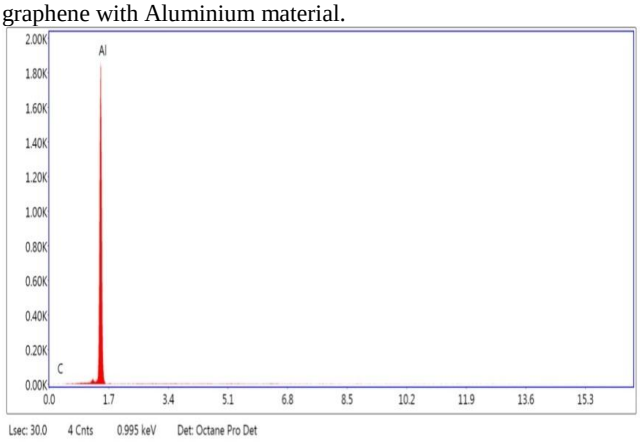
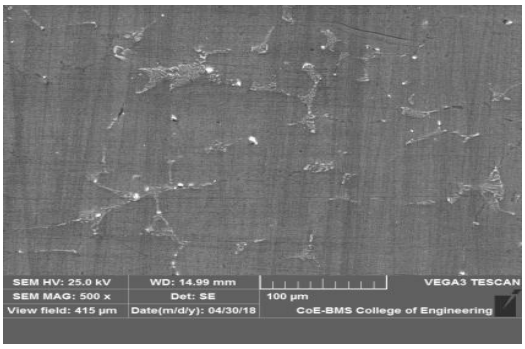
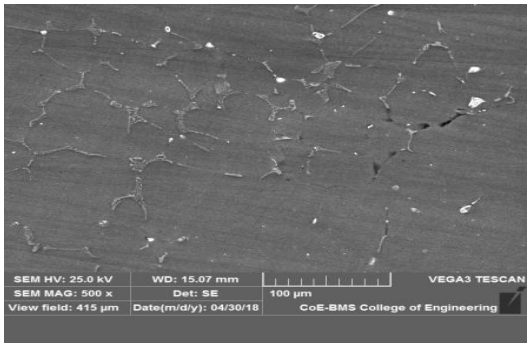


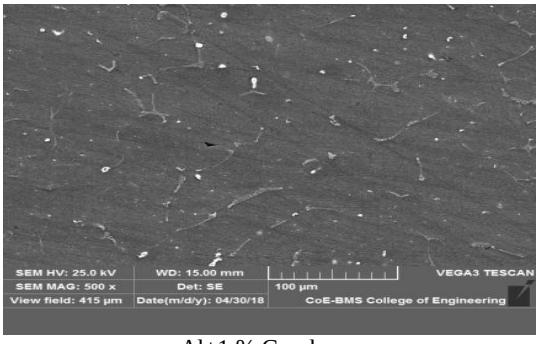
Fig. 1: SEM, XRD and EDAX of aluminium 6061 reinforced with graphene



Al+ 0% Graphene



Al+0.5 % Graphene



Al+1 % Graphene

3. Experimentation

The Linear Reciprocating Tribometer (LRT) equipment which is used to measure the tribological parameters. It determines the co-efficient of friction and frictional force to evaluate the wear

characteristics of a given material. The principle is to vibrate the pin/ball indenter against a flat specimen under dry, lubricated or in heated condition. The specimen placed above moves in a linear reciprocating motion under different conditions of load, frequency, stroke length and temperature.

The load is applied by the upper specimen pressing the horizontally mounted flat bottom specimen. The input parameters are load, frequency, stroke length, temperature and test duration

Element	Weight %	Atomic %
C K	0.10	1.72
AlK	99.22	98.28

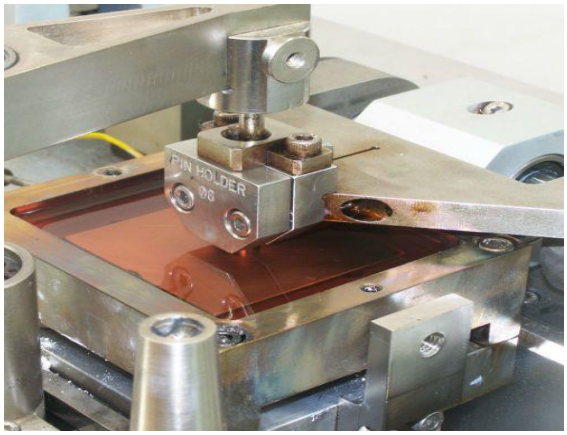
while the output parameters are co-efficient of friction and frictional force. The LRT instrument which is employed for experimentation is operated by 'WINDUCOM 2010' software

Specifications of Linear Reciprocating Tribometer

Table 1: Specifications of LRT equipment

Cylindrical pin indenter	8mm dia x 15 mm long
Spherical ball indenter	8 mm dia
Flat specimen	40 x 40 x 5 mm
Normal load	20-200 N
Frequency	5-50 Hz
Stroke length	1-20 mm

Frictional force	Max 200 N
Temperature	Ambient to 300˚C
Equipment size	600 x 520 x 920 mm



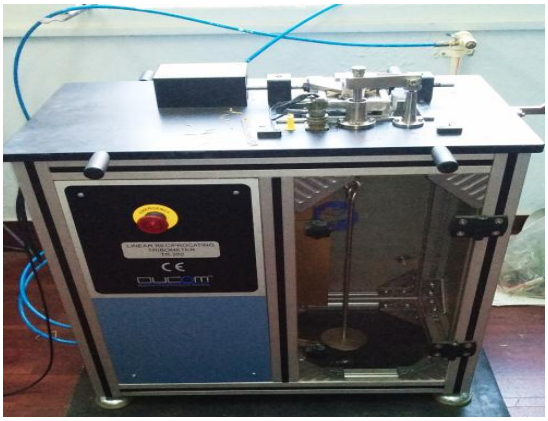


Fig. 2: Linear Reciprocating Tribometer set-up

The experiment is conducted selecting the loads of 20N, 30N, 40N and stroke length of 2mm with a frequency of 40Hz. The experiment is conducted for a running length of 200 meters (42 Minutes).

4. Results and Analysis

The experiments are conducted for dry condition with ambient temperature for ball indenter and the results are obtained as follows.

Table 2: Consolidated Table of Wt Loss, COF, FF

Sl No	PERCENTAGE	LOAD	WT LOSS	COF	FF
9	0.5	40	0.146	0.031	1.25
10	0.75	20	0.048	0.008	0.15
11	0.75	30	0.093	0.028	0.84
12	0.75	40	0.130	0.030	1.17
13	1	20	0.064	-0.001	-0.04
14	1	30	0.074	0.030	0.89
15	1	40	0.035	0.026	1.06

Sl No	PERCENTAGE	LOAD	WT LOSS	COF	FF
1	0	20	0.072	0.023	0.46
2	0	30	0.124	0.018	0.54
3	0	40	0.162	0.038	1.51
4	0.25	20	0.059	0.017	0.34
5	0.25	30	0.126	0.028	0.83
6	0.25	40	0.151	0.032	1.29
7	0.5	20	0.055	0.003	0.07
8	0.5	30	0.108	0.015	0.46

The results are analyzed for weight loss, co-efficient of friction and frictional force. The observations are shwn graphically as follows.
Graphical representations:

Weight Loss

Table 3: Weight loss for varying percentage of graphene and different loads

Percentage of Graphene	20 N	30N	40N
0%	0.072	0.124	0.162
0.25%	0.059	0.126	0.151
0.50%	0.055	0.108	0.146
0.75%	0.048	0.093	0.13
1%	0.044	0.074	0.135

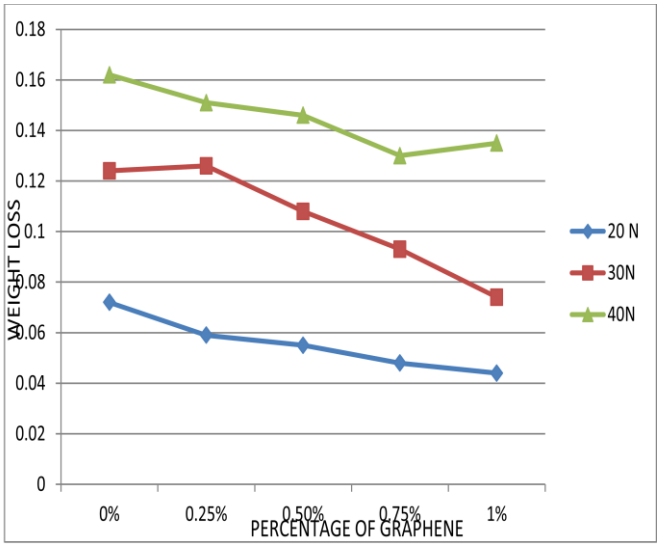


Fig. 3: Graphical representation of percentage of graphene versus weight loss

The graphical representation shows that the material removal reduces as the percentage of graphene increases. The results also revealed that as the load increases the specific weight of the material also increases.

Co-efficient of Friction

A coefficient of friction is a value that shows the relationship between the force of friction between two objects and the normal reaction between the objects that are involved. It is a value that is sometimes used in physics to find an object's normal force or frictional force when other methods are unavailable. The force of friction between two objects and the normal reaction between the objects that are involved. It is a value that is sometimes used in physics to find an object's normal force or frictional force when other methods are unavailable. Table 4 shows the results between percentage of graphene and co efficient of friction

Table 4: Co-efficient of friction for varying percentage of graphene and different loads

% OF GRAPHENE	20 N	30N	40N
0%	0.0232	0.0296	0.0379
0.25%	0.0169	0.022	0.0324
0.50%	0.0085	0.0152	0.0312
0.75%	0.0076	0.0148	0.0292
1%	-0.002	0.01296	0.0263

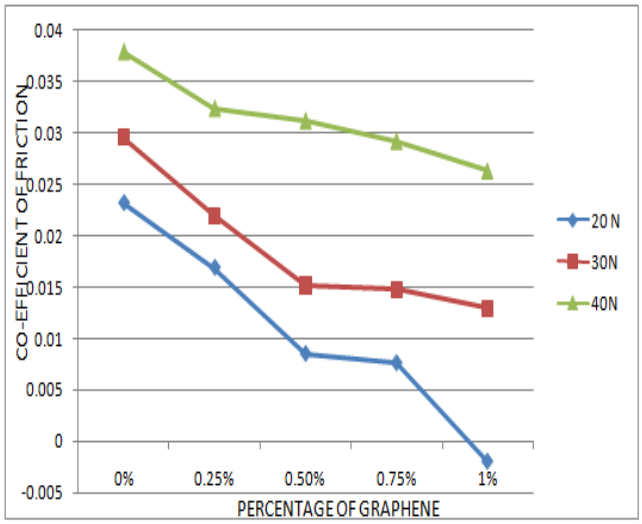


Fig. 4: Graphical representation of percentage of graphene versus COF

The graph reveals that the co-efficient of friction reduces as the percentage of graphene increases significantly.

Frictional Force

This force is static friction force, which is the force exerted on the surface by another when there is no motion between the two surfaces. Static friction force acts in response to a force trying to cause a stationary object to start moving.

Table 5: Frictional force for varying percentage of graphene and different loads

% OF GRAPHENE	20 N	30N	40N
0%	0.46	0.94	1.51
0.25%	0.34	0.83	1.29
0.50%	0.07	0.86	1.25
0.75%	0.15	0.84	1.17
1%	-0.04	0.89	1.06

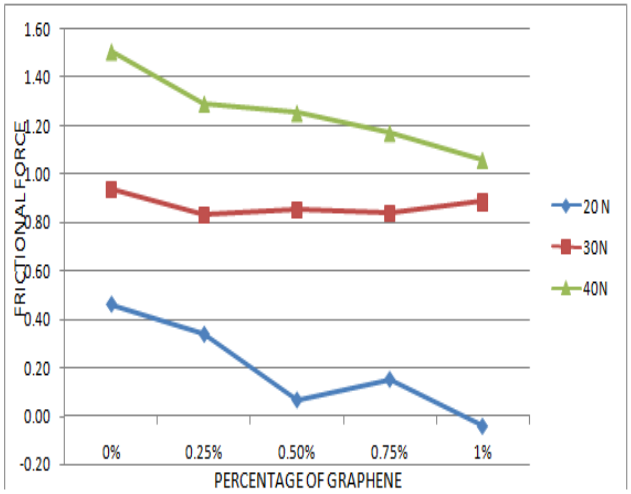


Fig. 5: Graphical representation of percentage of graphene versus frictional force

From the above graph, it can be interpret that that the weight loss, COF and Frictional Force decreases with the increase in the percentage of graphene.

5. Conclusion

The results reveal that as the percentage of graphene increases from 0% to 1.0% weight percent of Graphene which is reinforced with aluminum-6061 reduces the wear of the material significantly. Reinforcing 1% of Graphene reduces the weight loss of the material by 60% which in turn reduces the fretting of Aluminium6061 in service conditions. The frictional force also reduces by 50% to 60% for every 1% reinforcement of Graphene. So reinforcement of Graphene reduces the fretting in aluminium material which is significantly used for aviation industries. This reduces the fretting near permanent joints like riveted joints where specific loads are acting at a definite frequency.

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