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EXPERIMENTAL STUDIES ON WEAR RESPONSE OF A CARBON NANOTUBE REINFORCED ALUMINIUM MATRIX COMPOSITE

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ABSTRACT

Carbon nanotube powder is being used extensively as reinforcement with many of the alloys currently. Specifically, with aluminum 7075 alloy, the properties observed to be better with respect to mechanical behaviour. In the current work the multiwalled carbon nanotube in the powder form was reinforced in aluminum 7075 matrix in stir casting method. The specimens obtained during the process are tested for the microstructure and mechanical characters. Investigation of microstructure under scanning electron microscope images confirmed the extent of bonding between the matrix and the reinforcement. The chemical composition of aluminium and the CNT powder were analysed using XRD procedure. The casted structures were machined to get the samples for mechanical tests. From the experimental results, it was found that 1.25% of CNT reinforcement with the matrix improved the wear resistance of the composite sample produced. The specimens were prepared for the different weight percentage like 0%, 0.5%, 1% and 1.25% CNT by weight. The machined samples were tested for wear behaviour under the ASTM G99 standard and found that addition of CNT as reinforcement with the aluminium material will have enhanced resistance for abrasive wear principle. Thus the aluminium7075 mixed with the graphene based reinforcement like carbon nanotubes possess improved characters.

Keywords: alumnium 7075, MWCNT, stir casting, microstructure, wear test.

1. INTRODUCTION

Aluminum is the most promising and light weight material used in most of the engineering applications. The property of the base aluminum is enhanced using carbon nanotubes as reinforcement in the aluminum alloy and is highly depends on the type of reinforcements inserted into the matrix. Stir casting is one of the commonly used techniques for preparing the metal matrix composites. The process of casting involves the usage of surfactants like sodium dodecyl sulphate in order to enhance the wettability of carbon nanotube powder as the reinforcement material [1]. In order to get uniform distribution of the matrix and reinforcement material during the composite preparation process, it is essential to maintain proper mixing ratio either in terms of weight or by volume fraction. Weight fraction method is followed by most of the researchers as it offers a precise control over the quality of the end product obtained. Particulate composite preparation is the most challenging one and needs efficient use of the facilities [2]. Most engineering applications demands for the light weight structure with a better mechanical property. Aluminium is one such light weight alloy that is widely used at a highly commercial scale in many industries such as sports goods, domestic appliances, automobile and aerospace structures. From the proven results of many research works on aluminium and its alloys as the matrix material, it can be observed that mixing carbon based reinforcements like graphene and CNT; certain characters are enhanced as required by the users in above said industrial applications [3].

Though conventional alloys are stronger but they are heavy and bulk in size. Hence the modern industries started looking for the alternate materials like composites. In specific, alloy based particulate composites like aluminium with alumina, graphite, silicon and so on as the reinforcements. As per the available literature the allotropic form of carbon in tubular form is the promising choice to mix with aluminum alloys for enhancement of mechanical properties [4]. Alumnium reinforced with magnesium and rock dust resulted in less wear for the different percentages at various speeds which were produced by stir casting technique [5]. Dispersoids such as graphene carbides and nitrides when reinforced with alumnium matrix and subjected to dry sliding wear test resulted in increased wear resistance [6]. However, distribution of reinforcement is governed by stirring process parameters. Optimal values of stirring parameters are helpful for development of hybrid composites [7]. Stir casting is one of the widely used technique for the production of particulate metal matrix composite. It is very much essential to create good wettability between particulate reinforcement and the molten alloy matrix in order to have a sound casting done through liquid metallurgy route [8]. This method of producing the composite can also be tried in successive stages known by the method called two step stir casting. The corrosion resistance property got enhanced by following this methods [9]. The LM 6 series of aluminium when combined with copper through vibration casting technique had resulted to highest tensile strength and percentage of elongation [10].

The Rockwell hardness number of alumnium 7075 reinforced with carbon nanotube particles had significantly increased from 58 to 64 during the experimentation conducted on a composite specimen produced through stir casting technique. Also the Brinnel hardness number improved from 90 to 110 when the researchers were testing it for gear making applications [11]. Wear response of alumnium 7075 reinforced with mica and kaolinite under dry sliding using pin on disk

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showed the improvement in the wear resistance with a very less or no agglomerate seen during the microstructure studies [12]. Adding the carbon nanotube particles in the form of billets obtained through hot pressing in order to cast the aluminium composite resulted in agglomeration. Thus the wear behaviour tends to reduce as the weight of the reinforcement is increased [13]. Optimum percentage for mixing the reinforcement with the base aluminium alloy depends on the need of applications for which the composites are functionally graded [14-16].

2. METHODOLOGY

2.1 Materials Used

In the current work Aluminium 7075 alloy is used as the base matrix which finds the applications in aerospace and commercial automotive industries. The chemical composition of the alloy referred from the literature is determined. It is shown in the Table-1.

Table-1. Chemical Composition of Aluminium 7075 base alloy.

Element	Percentage
Zinc(Zn)	5.6 to 6.1 %
Magnesium (Mg)	2.1 to 2.5%
Copper	1.2 to 1.6%
Silicon (Si), Iron (Fe), Manganese (Mn), Titanium (Ti), Chromium(Cr)	< 0.5 %

Along with the base alloy multiwalled carbon nanotube particles of 200-micron mesh size are used as reinforcement. It possesses a unique property which is listed in Table-2.

Table-2. Major Properties of multiwalled carbon nanotubes powder.

Property	Carbon purity	Avg. diameter	Avg. Length	Surface Area	Bulk Density
Unit	%	10^{-9}m	10^{-6}m	m2/g	kg/m3
Value	95	9.5	1.5	250-300	66

2.2 Stir Casting Process

Aluminium 7075 composite cast is obtained using the induction melting furnace. The furnace shown in the Figure-1. It has melting capacity of 3 kg / batch connected with resistance heater with 3 phase and 3 KWh and a stirrer-motor attachment. The mold is preheated at 80° C to avoid thermal shocks. Ingot plate of Aluminum 7075 were placed on the furnace cover for initial preheating and then placed in the graphite crucible. Billets started melting at 450°C and the complete mass turned into molten state at 600°C. A motorized stirrer is then slowly inserted into the furnace and the packets of CNT in a thin aluminum foil were introduced slowly and stirred at a uniform speed of 250rpm.

Figure-1. Molten Aluminium alloy in a graphite crucible.

Figure-2. Casted Ingots in the mould.

This technique of introducing CNT powders wrapped in aluminium sheet will assist to bring down agglomeration and helps in uniform dispersion of reinforcement with the base matrix. A white calcium stearate powder is used as scum during the process in order to separate the impurities like oxides and hydrates. Degasification is done using perchloroethane (C2Cl6) tablets to eliminate blow hole defects in the cast produced. After filtering the slag floating on the surface, the molten pool is then poured into preheated mold box carefully and allowed to cool for 1 hour and then the cast is removed by separating the mould boxes mechanically as shown in Figure-2.

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3. EXPERIMENTAL DETAILS

3.1 Metallographic Observations

The microstructure of the prepared composite is carried out on field emission scanning electron microscope (Fe-SEM). The dispersion of carbon nanotubes in the matrix can be verified with the help of images listed below. In the Figure-3, CNT with the diameter 28.9 nanometer can be observed and the uniform distribution of the reinforcement CNT can be found in the Figure-4. These samples possess better wettability and infiltration with the molten matrix alloy of aluminium. Reinforcement beyond 1.25 % with the matrix will result in the agglomeration which affects the phase of distribution.

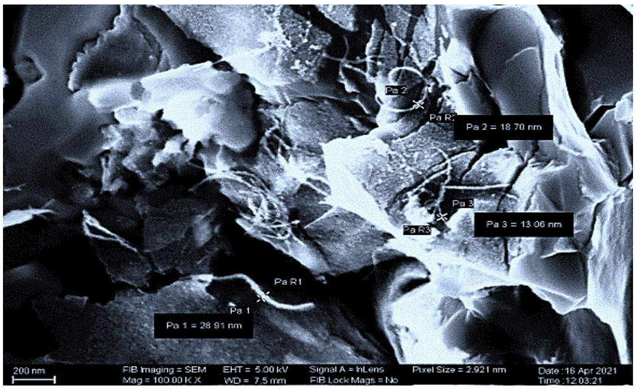

Figure-3. CNT observed at 200nm scale in a 0.75% CNT.

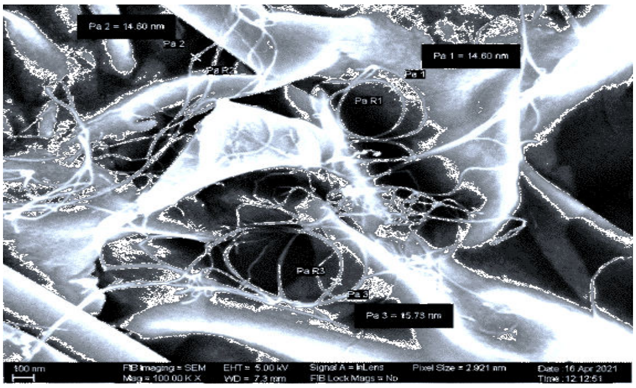

Figure-4. Uniform distribution of CNT in 1.25% CNT.

3.2 Wear Test

Pin on disc sliding wear test procedure is followed as per the ASTM G99 standard to investigate the tribological response of the current composite with Alumnium 7075 as the matrix and Multiwalled carbon nanotubes as the reinforcements. The experimental setup is shown in the Figure-5.

Figure-5. Pin on disc wear testing apparatus.

Wear test is done for 10N,20N and 30N load for all the four combinations of reinforcement with the varying sliding distances and speed. The values of coefficent of friction with respect to the time duration at a speed of 400 rpm for all the four combinations of CNT. The corresponding values of friction force and the wear rate are tabulated in the Table-3.

4. RESULTS AND DISCUSSIONS

Figure-6 shows the effect of CNT on different composition by weight. From the graph it is found that the wear loss is more with the specimen without CNT content. As the CNT percentage increased the wear loss tends to decrease whereas the frictional force is increasing.

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Table-3. Results of wear and frictional force.

Composition (%)	Time in min.	Load in 'N'	Frictional Force 'N'	Wear in 'µm'
Aluminium + 0% CNT	3	30 N	0.3	21
	6		0.2	20
	9		0.3	19
	12		0.4	18
Aluminium +0.5% CNT	3	30 N	0.5	20
	6		0.4	19
	9		0.6	20
	12		0.7	19
Aluminium +0.75% CNT	3	30 N	0.7	17
	6		0.8	19
	9		0.8	16
	12		1.1	18
Aluminium +1.25% CNT	3	30N	1.2	16
	6		1.4	14
	9		1.6	11
	12		1.8	10

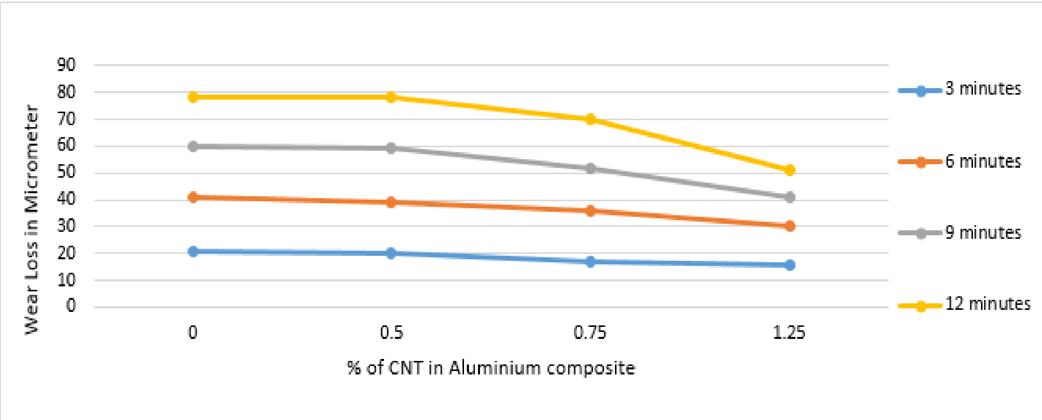

Figure-6. Wear loss v/s time of wear.

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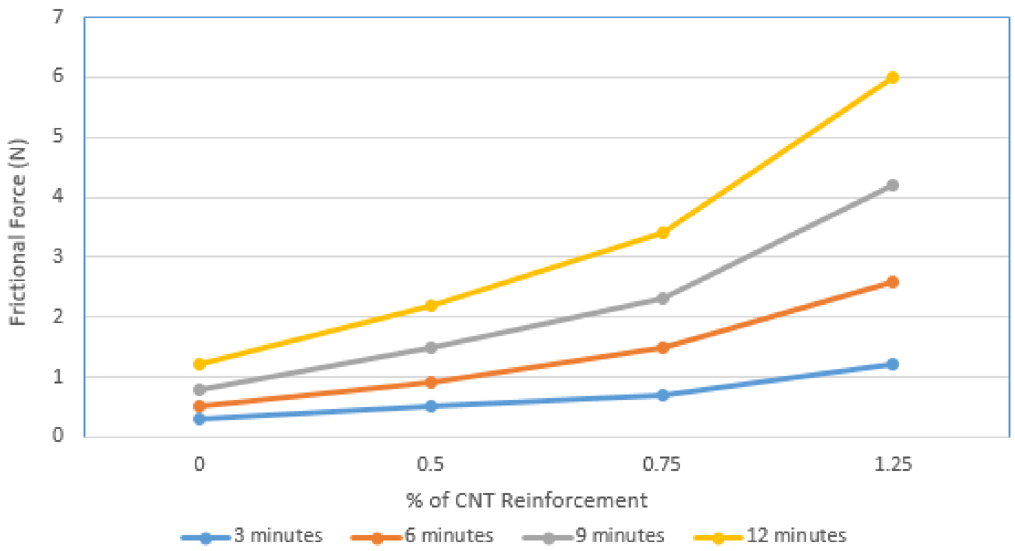

Figure-7. Frictional force v/s time of wear.

5. CONCLUSIONS

Aluminium 7075 composite reinforced with multiwalled carbon nanotube particles is prepared successfully through stir casting technique. There is no porosity or agglomeration formed during the process as per the microstructure carried out on scanning electron microscope. Prepared specimens are machined into to check for wear response as per the ASTM G99 standard. The reinforcement was mixed with the base alloy at a varied percentage of 0.5 %, 0.75% and 1.25% by weight. Wear response observed during the experiments on pin on disc apparatus shows that addition of carbon in the nanoscale to the aluminium matrix enhanced the wear resistance considerably. Though the wear loss seems to more during the testing trials with less time durations of 3 minutes and 6 minutes, in the later trials of 9 minute and 12 minutes it tends to decrease drastically. For the CNT content of 1.25 % with a highest frictional force of 1.8 N, the wear loss of 10 micrometer is observed. Hence addition of the CNT as the reinforcement enhanced the wear resistance to the considerable extent.

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