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Dry sliding wear behaviour of short Carbon fibre reinforced aluminium matrix composites

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ABSTRACT: In the present research work, the dry sliding wear behavior of nickel coated short carbon fibers (NCSCFs) reinforced aluminummatrix compositewere studied. The composites were fabricated by liquid metallurgy technique by varying with 2, 4, 6 & 8 wt% ofNCSCFs.The wear rateswere evaluated using a pin-on-disc wear-testing machine by varying the loads. The effects of percentageof fiber content, normal load, sliding speed, and wearmechanism were investigated. The results indicated that Al/NCSCFs composite had lower rates than that of Al alloy. The wear rates of the composites decreased with the increase of NCSCFs content.However, wear rates increased with the increase in normal load and rotating speed in both composites and Al alloy. NCSCF develops direct bridge gap between the matrix and counterpart thus, results in improving the better wear resistance in Al/NCSCFs composite.Theworn and fractured surfaces ofboth Al/NCSCFs compositeand Al alloy werecharacterized using SEM

KEYWORDS: Al alloy, NCSCF, sliding wear, wear resistance.

I. INTRODUCTION

Over the decades,metal matrix composites (MMC) has drawn the attention of many investigators to carry the research onaluminiumbased MMC's due to its excellent combination of properties such as higher mechanical strength,young's modulus and good wear resistance [1]. AluminiumMMC's are widely used in automotive industry because of its good strength at high temperature, high weight ratio, high thermal conductivity [2], good dimensional stability and high structural rigidity[3]. AluminiumMMC's are particularly used in automobile like cylinder liners, brake rotors, connecting rods, drive shafts, pistons and reciprocating part, components of brake-system, engine blocks andaerospace industries and defence equipment's [2-3].Although aluminum and its alloy are known for excellent mechanical properties as well as corrosion resistance but in term of wear properties, they are poor. Hence, a strong drives to develop newer material to achieve the better tribological properties [4-5]. Hence, requirements for enhancements in wear resistance and service loads of materials in all these applications has forced researchers to develop and synthesise aluminium based composites.There are many fibres used as reinforcement for aluminium alloy, among that carbon fibre has been used as appealing reinforcements, which enhacethe wear resistance of the part and also reduces the coefficient of friction while maintaining its remarkable properties such as light weight, high specific strength, high thermal and electrical conductivity, high stiffness, specific modulus,low coefficient of thermal expansion and good self-lubricating abilities [6–7].

In spite of many advantages, the applications of carbon reinforced aluminum composite are limited by the industries due to its manufacturing problem [8]. Many researchers have carried out the investigations of fiber reinforced aluminum composites focusing on casting process and uniform distribution of reinforcement, but very limited study is reported about wear and coefficient of friction. Liu Leiet al. [9] studied the friction and wear properties of carbon reinforced aluminum matrix composites the results show that with short carbon fiber content the wear resistance was improved andwear rate was reduced. Daoud et al. [10] investigated CF/2014 Alalloy composites for their wear performance, his finding showed the wear resistance was improved significantly with incorporation of carbon fiber and improvement in seizure resistance.EzhilVannan.Set al. [11] studied the effect of basalt fiber on dry sliding wear behavior of basalt fiber reinforced alumiunium metal matrix composites reported that the wear rate decreased with increase in weight percentage of copper coated fiber basalt fiber. B.Venkataraman et al. [12] investigated the dry sliding wear condition of wear behavior of SiC particulate reinforced aluminiummatrix composites (Al-SiC) suggested that a strong correlation exist between friction and wear transition behavior. Kong et al. [13]studiedcarbon fiber/Al felt composites for their tribological behavior and concluded that wear resistance can be improved with the presence of carbon film. In the case of Al6061 reinforced with TiO_2, it was observed that composites exhibit lower wear coefficient, exhibits better hardness as compared with the matrix alloy [14]. The volumetric wear loss is high because of increased loads and sliding distances, but the coefficient of wear is low in both matrix alloy and its composites. The high strength aluminium alloys Al7010, Al7009 and Al2024 reinforced with SiC particles exhibits significantly better sliding wear characteristics than that of alloys due to the addition of SiC particles [15]. Aluminium matrix composites reinforced with short steel fibres shows decrease in wear rate by increasing the reinforcement fibres decreased the rate of wear and coefficient of friction at different loading conditions [16]. Metal matrix composite of aluminium-7075 with nickel coated carbon fibers in the form of short fibers shows increasing in fatigue strength with increase in reinforcement loading [17]. Surface coating on carbon fibers increase the wettability and it increases the interfacial reaction between matrix and carbon. And it overcomes the arduous of obtaining better interface bonding between fibers matrix. Coating of nickel on surface of carbon fiber exhibits better interface bonding among matrix and fibers and also increases the oxidization resistance, strength of the composites with both metal and polymer matrix [18-19].

In present investigation, Al7075 alloy composite reinforced by NCSCFs were prepared by Liquid metallurgy process. The tribological behavior of Al7075 alloy and NCSCFs/Al7075 were methodically studied using Pin-on-Disc method.The surface, subsurface and the fragments are studied using scanning electron microscopy to analyse the wear mechanisms.

II. Experimental

2.1. Sample preparation

In this study, Al7075 alloy is used as base matrix. The chemical composition of Al7075 is as shown in the table 1. Nickel coated short carbon fiber were used as reinforcement, long polyacrylonitrile (PAN)based carbon fibers were cut into short fiber to length about 1.0-1.5 mm after being dispersed.The properties of polyacrylonitrile(PAN) based fiber are: density is $1.76 g/cm^3$, average diameter of fiber is 7µm. The short fibers were coated with nickel deposition using electroless coatingtechnique; the reason was due to poor wettability between the matrix and reinforcement. The Composites were prepared by reinforcing Al7075 alloy with varying weight percentage of 0, 2, 4, 6 and 8 of carbon fibres coated with nickel using stir casting process.The matrix Al7075 was heated above its melting temperatureupto700^0C; at this temperature around 1% of magnesium metal powder is mixed with the molten metal.

Table 1. The chemical composition of Aluminium alloy (wt. %)

Alloying Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Weight %	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2	Bal

2.2. Wear tests

For wear testing, the specimens had been prepared with the size of Pin-on-Disc specimen measuring 8mm in dia. and 20mm height consistent with the ASTM G99 standard. All the specimens followed a single-track 115mm in diameter, with the tangential force during sliding is monitored by a force transducer continuously which is attached to the specimen holder. The coefficient of friction (µ) is obtained as the ratio of the tangential force to the normal force. The test is performed with a load range of 20N to 50 N at a sliding velocity of 7.35m/s to 31.5m/s and with a sliding distance of 2km. The specific gravity measurements were performed consistent with ASTM C127-88 Standard. For every load, volume losses from the surface of specimens had been determined as a feature of sliding distance, sliding velocity, and applied load. [20].

Fig. 1Pin-on-Disc Test rig

III. Results and discussion

3.1 Wear Behaviour

The effects of reinforcement on wear rate were studied and found that Al/NCSCFs composite has superiortribologicalcharacteristics than Aluminium alloy. It was also observed that the wear resistance of the composite improved significantly with the increase in NCSCFs content. An investigation was carried out to study the effects of reinforcement on both applied load and sliding speed. Fig. 2(a) to 2(d) shows the graphs of sliding velocity vs wear rates of the Al/NCSCFs composites and Al alloy specimens at an applied load of 20, 30 and 40 N, respectively. From the graph, it is evident that the composite with 8 wt. % NCSCFs has the least wear rate for normal loads ranging from 10-40 N with increasing sliding distance at 300 RPM and also similar trends were observed for the same normal loads at 400 RPM and 500 RPM. However, for the initial sliding distance, the wear rate increased, after some duration, it decreased and then remained almost constant for the entire duration of the test.

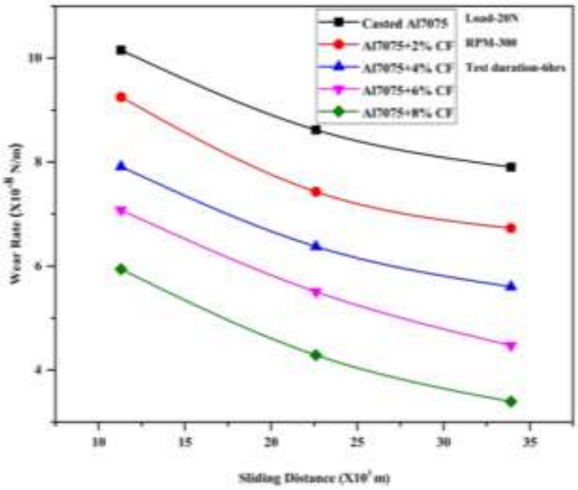


Fig. 2(b) Wear rate at 20N load

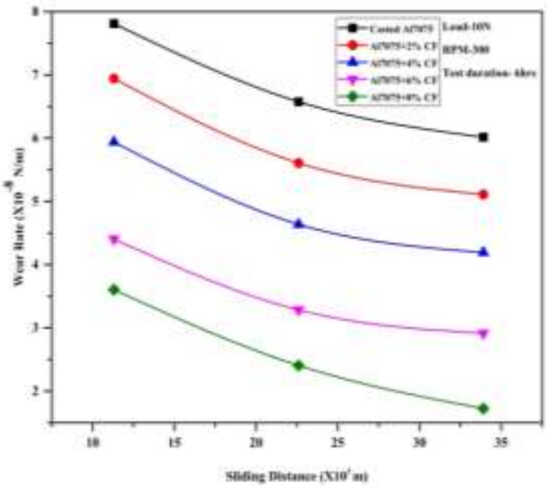
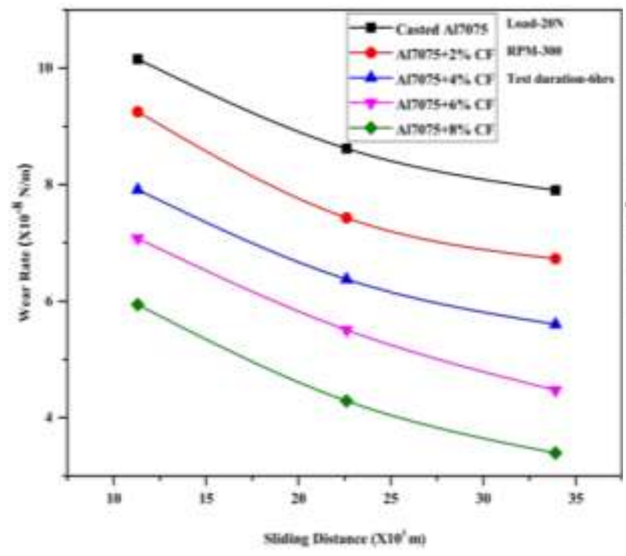


Fig. 2(a)Wear rate at 10N load



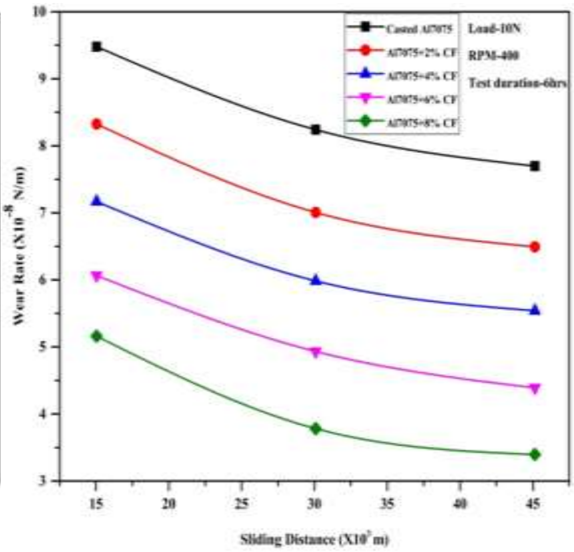
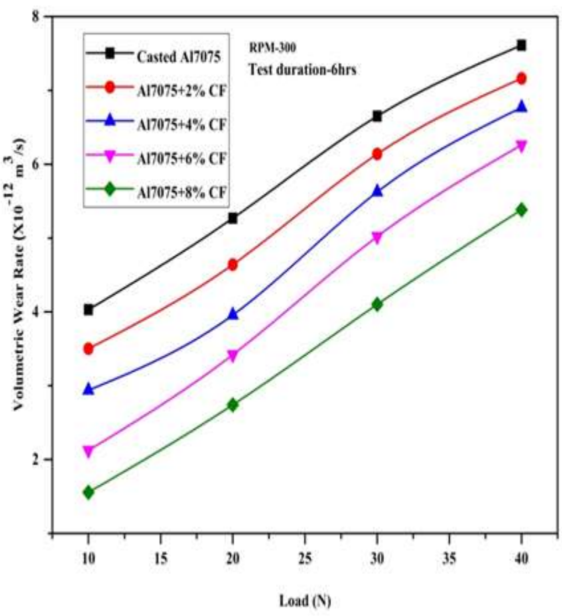


Fig. 2(c)Wear rate at 30N load **Fig. 2(d) Wear rate at 40N load**

Fig. 3shows the result of normal load and rotational speed at 300 rpm on volumetric wear rateofAl/NCSCFs composites. The results indicate that the volumetric wear rate of both Al/NCSCFs compositesand Al alloy increased with the increase in normal load and showed almost linear trend.Owing to the fact that, for significantly greater amounts of normal load, the frictional thrust was observed to have increased and resulted in increased de-bonding and fracture that caused more volumetric wear loss. From the graph it is evident that the composite with 8 wt.% NCSCFshas least volumetric wear ratewhen compared to Al alloy.An additional increase in the load triggered the commencement of delamination which resulted in a higher volumetric wear rate for both, the Al alloy and its composites as observed by several researchers [23-25]. Similar trendswere observed at 400 and 500 rpm.



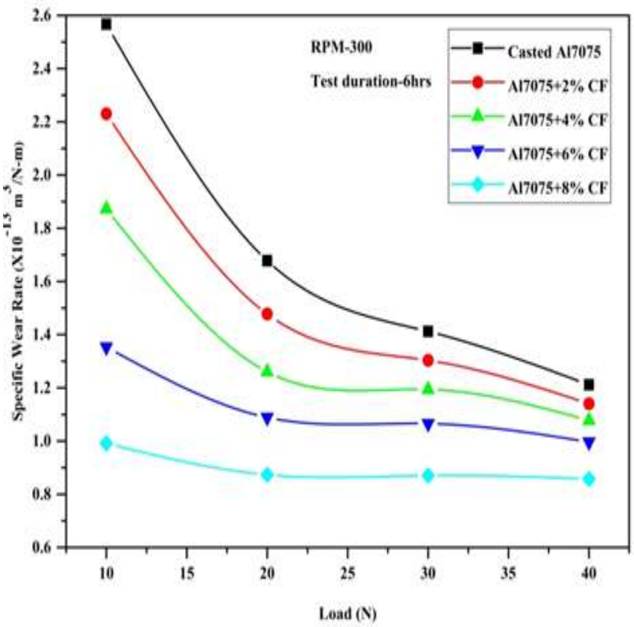


Fig. 3Volumetric Wear rate at normal load and 300rpm

Fig. 4 Specific Wear rate at normal load and 300rpm

Fig. 4shows the result of normal load and rotation speed at 300 rpm on specific wear rate ofAl/NCSCFs composites. The results indicate that the specificwear rate of both Al/NCSCFs compositesand Al alloy decreased with the increase in normal load with speed at 300 rpm. From the graph it is evident that the specific wear rate for Al/NCSCFs composites with 8 wt% NCSCFsshowed a nearly horizontal trend and was found to be much lesser in comparison with Al alloy. The reason being for lower speeds and loads, the difference between the specific wear rate for each specimen was found to be large which decreased with the increase in speed and load. However, for higher speeds of 400RPM and 500 RPM, the rate of specific wear decreases with the increase in normal load values including the 8 wt.% reinforced composite specimen.

3.2 Effect of reinforcement on the wear resistance

The effect of reinforcement on wear resistance is study at different load and speed. It has been observed from the graph that at both 30N and 40 N, the Al alloy seizes as sliding distance is increased, whilethe Al/NCSCFs compositeshad better wear resistance. At highload of 40N, only the 8% carbon fiber reinforced Al composite has better wear resistance, where as the pure Al alloy, 2, 4 and 6 % carbon fiber reinforced composites has high wear rate, which indicates that as reinforcement content is increased than the wear rate of the material is reduced indicating thepositive effect of the reinforcing.

3.3 Wear mechanism

In order to comprehend the wear mechanism of Al alloy and its composite, SEM micrographs observation of the wear surfaces was carried out.A typical worn surface ofthe Al alloy and Al/NCSCFs composites with 4% and 8% carbon fiber is shown in Fig.5.In order to comprehend the wear mechanism of Al alloy and its composite, SEM micrographs observation of the wear

surfaces was carried out. A typical worn surface ofthe Al alloy and Al/NCSCFs composites with 4% and 8% carbon fiber is shown in Fig.5. It is observed that Al alloy shows composition of deep grooves and small debris, indicating the presence of damages occurred due to plastic deformation. Further, some flake shape pieces began to peel off from fracture surface of Al alloy as worn surface becomes soft due increase in surface temperature. The worn surface of Al/NCSCFs composites with 4% and 8% carbon fibershow rough surfaces due to removal of material and also formation of white layers at the top most worn out surface, indicate that the temperature at the surfaces is very high.Moreover, presence of NCSCFs deforms the Al alloy, results a decrease of mass loss. It is observed that as the load increases, the fine scratches on the surface changes into distinct grooves and results in wear loss, which increases with the rise in the sliding speed. From the Fig. 6 it can be clearly seen from the fact that the grooves on the worn surfaces for 500 rpm were more than that of 300 rpm. From the images, it can be seen that extent of grooves in 8 wt% of carbon fibre reinforced composite is much less than 4 wt% carbon fibre reinforced composite and as cast Al7075 alloy in both the cases. Hence it is clear from the figures that adding carbon fibre increases the wear resistance of the composite. At low loads mixed abrasion-plastic deformation mechanism is observed where as in case of high loads it was observed the surface was severely damaged and many facture spots were visible. Resulting in high wear rates and moreover, the protective layer of carbon fibre remains unstable due to ploughing action.

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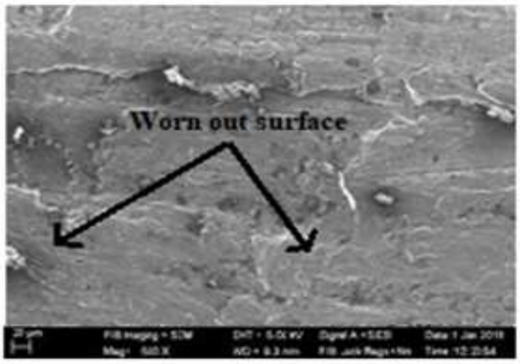
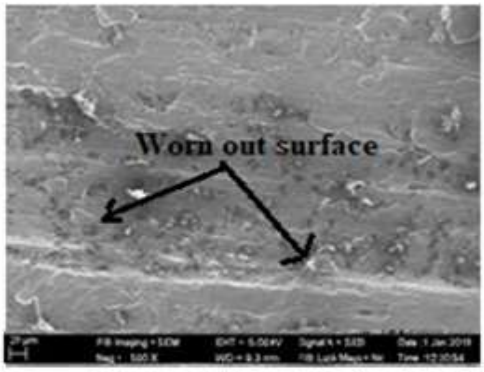
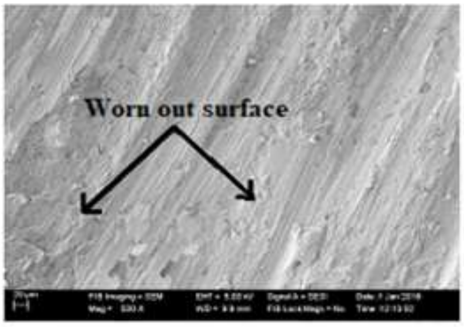
Casted Al7075



Al7075+4% CF



Al7075+8% CF



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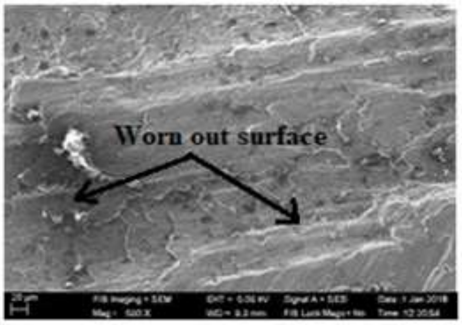
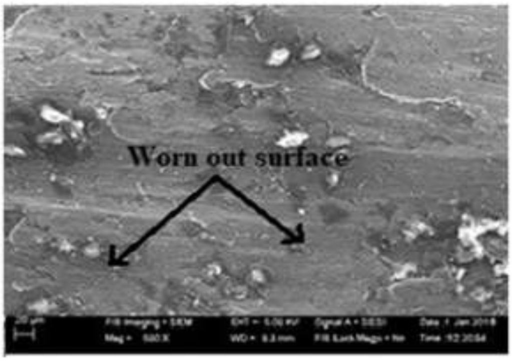


Al7075+4% CF



Al7075+8% CF

Fig. 5 SEM morphology 500rpm

IV. Conclusions

From the investigations of wear behavior the following conclusions are arrived.

1. Addition of NCSCFsin Aluminium alloy showed that wear resistance was improved significantly. With increase inwt% of short carbon fiber content,the wear rate is found to be decreased. The Al alloy and the Al/NCSCFs composites showed that wear rate was increased with increase in applied load.
2. With addition of NCSCFs with matrix,the direct contact between the counterpart and matrix was minimized, results great improvement in wear resistance.
3. At low loads abrasion wear was exhibited by the Al/NCSCFscomposite whereas in case of high loads delamination was observed and found to be superior,who was much evident from SEM micrographs.
4. For different conditions like change in the sliding distance, change in the sliding velocity and change in the applied normal load and at 8 wt% of the short carbon fiber as reinforcement the wear rate was found to be least.

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