Effect Of Nano-Zirconia Addition On The Tribological Behavior Of Al-7075 Nano Composites

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Abstract: Metal matrix nano composites are widely used in aerospace, automotive, marine, and many other applications due to their high rigidity, enhanced mechanical properties and extremely resistant to wear. In the present study, wear behavior of Al-7075 reinforced by 5 wt.% of nano-boron carbide B_4C + 10 wt.% of aluminum oxide Al_2O_3 and improved by 2,4,6 and 8wt.% of ZrO_2 nanoparticles was studied. Samples were prepared using stir casting method. The dry wear test was conducted using a computerized pin-on-disc apparatus to examine the tribological behavior of different aluminum nanocomposites. The effect of sliding speed and applied load was studied. The experimental results show that the resistance to wear is increased as weight fraction of ZrO_2 increases within AL-7075 hybrid nanocomposites.

Keywords: Stir casting; ZrO_2; B_4C; Al-7075; Al_2O_3; Ceramic nano particles; Tribological behavior; COF.

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1 INTRODUCTION

Aluminum alloys are widely used in many engineering applications Owing to its fascinating properties, the reason for its spread over other non-ferrous materials due to easy availability, low-cost, high strength to weight ratio, Fine ductility and high resistance to corrosion [1-3]. Ceramic particles such as ZrO2, TiO2, SiC, Zr, Al_2O_3, TiC, MgO, B4C, Si3N4, TiB2, BN and AIN in particulate or whisker shape [4-9]. Hybrid metal matrix composites HMMCs are characteristic for high specific modulus, high wear resistance, strong abrasion resistance [10-11]. HMMCs can be produced by various casting processes for example stir casting, spray atomization casting, squeeze casting, compo casting, powder metallurgy process and plasma spraying [12-18]. Liquid processing methods like stir and squeeze casting are preferred above others because of their reduced cost [19-20]. Large-scale studies have been conducted for MMCs for the last twenty years and here are still many studies being conducted in this field [21-22].
Daoud et al. [23] added Al_2O_3 to Al 7075 alloy and studied its effect on the wear rate they found that Al_2O_3 they found that the reinforced composites give greater wear resistance than other un- reinforced aluminum composites. The dry sliding wear of HMMC's was investigated by Basvarajappa et al. [24] they noted that adding graphite increased the wear resistance by making a graphite layer with the pin and the disk. Manish roy et al. [25] examined the wear rate of aluminum metal matrix composites reinforced by ceramic particles they found that the wear rate reduced due to the presence of these particles. The effect of zirconia on the wear properties of aluminum HMMC's was introduced by Pandiyarajan et al. [26] they concluded that wear characteristics enhanced affectively. Rao et al. [27] added SiC powder to Al 7009 reinforced by Zn and Mg. They studied the influence of heat treatment on the applied load, sliding velocity and wear rate they observed that silicon carbide is well dispersed in all aluminum nano composites this leads to enhance the wear rate even at high load and high sliding speed. Kumar et al. [28] examined wear characteristics of Al 7075 / SiC. The alloy was fabricated using powder metallurgy it is noted that wear resistance enhanced due to Sic reinforcement. Uyyurua et al. [29] used the method of stir casting to fabricate aluminum reinforced by SiC. Silicon carbide was added by weight ratio of 15 to 20%. Wear rate and friction coefficient vs sliding speed and applied load were investigated. They found that with the variation of sliding speed coefficient of friction is decreased. The mechanical and tribological properties of Al6061 improved by Sic and manufactured using stir casting process were investigated by Kumar et al. [30]. Tensile strength, hardness and wear properties were improved by the addition of nano filler compared to base metal. Martin et al [31] investigated the wear mechanisms of Al 6061-Al_2O_3 also Straffelini et al. [32] performed similar types of researches results showed that there is a direct relation between hardness of matrix material and wear rate. Suresh [33] performed wear test of aluminum reinforced by B4C, TiC, SiC and TiB_2. He observed that wear characteristics is not affectively affected by type and size of different nanofillers but wear rate highly affected by changing volume fraction of nano fillers. Tribological behavior of aluminum base metal reinforced by Al_2O_3 and graphite was examined by Radhika et al. [34]. They concluded that sliding speed and applied load highly affected wear rate. Kok and Ozdin [35] conducted wear test on Al 2024/ Al_2O_3 to study the influence of Al_2O_3 presence on the wear behavior. The wear experiments on Al 7075/ TiC were carried out by Venkataraman and Sundararajan [36] they identified a connection between composite wearing behavior, TiC material and applied load. In the present study aluminum nanocomposites were produced using stir casting process. This method is used as it is one of the cheapest methods chosen for liquid metallurgy [37]. The aim of the present research is to investigate the ability of both nano Al_2O_3 and nano B4C with Al-7075 to develop lightweight hybrid nanocomposites in superior condition. A pin on disk apparatus was used to investigate the tribological behavior of aluminum hybrid composites under different loads and sliding speeds.

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2 MATERIALS AND METHODS

2.1 materials

The aluminum base matrix chosen for this analysis is Al-7075. Due to the nature of its chemical composition, it has high erosion resistance and a high strength. The chemical composition of aluminium-7075 is exhibited in Table 1. A fixed proportion of 10 weight percent of nano Al_2O_3 (25 nm) and 5 weight percent of nano B4C (50 nm) are used to reinforce Al-7075 base metal for all samples. Nano Zirconia (ZrO_2) is applied to composite by means of a varying percentage of weight (2,4, 6 and 8 wt%). The surface area of nano powder ZrO_2 is 10±2 m2 / g with an average grain size of 35 nm and its purity is 99.9%. Sigma-Aldrich produced nano particles. Wear tests are conducted using pin on disk apparatus.

2.2 samples preparation

In the present study nano $ZrO_2$with varying percentage of weight (2,4,6 and 8 wt%) was introduced to Al-7075 reinforced by both 10wt% of Al_2O_3 and 5wt% of B4C as a fixed ratio by using of stir casting method as shown in Fig. 1. The composite aluminum nano composite was slowly heated to 350 ° C and melted to around 800 ° C. The molten was stirred 8 min by a motor at 1200 rpm. To get rid of moisture ZrO_2 is pre-heated at a temperature of about 350 ° C and then applied to the molten mix. and then it stirred again for 8 mins. At 800°C the temperature is continuously preserved. The blend is moved to previously heated steel molds. The specimen produced is 50 mm in diameter and 280 mm in length. The final casting is then machined to be used in wear test the size of the pin in Fig.2. Table 2 lists process details and parameters for casting composites. composition of the fabricate specimens are given in the Table 3.

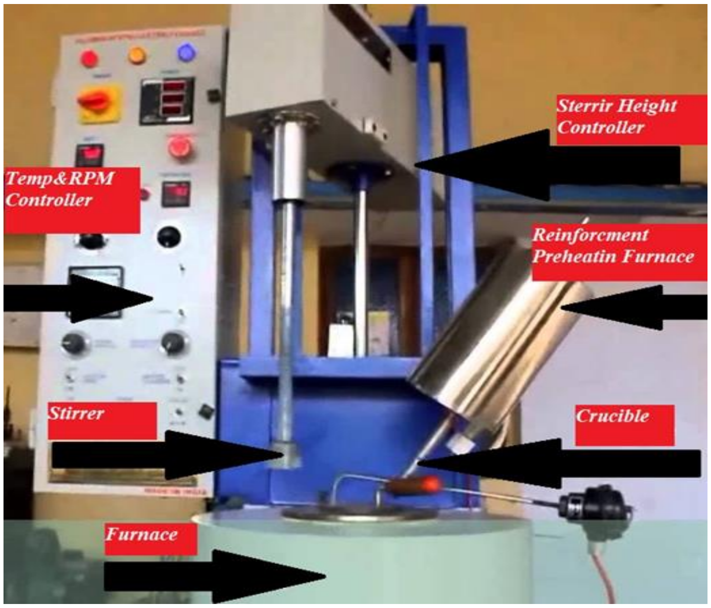

Fig.*1 stir casting setup*

Fig.*2 Wear test samples*

TABLE 1

AL-7075 CHEMICAL COMPOSITION.

Aluminum 7075	Mg	Fe	Zn	Cu	Cr	Ti	Si	Mn	Others
% Composition	2.1	0.2	5.9	1.4	0.19	0.047	0.052	0.05	0.025

TABLE 2

STIR CASTING DATA.

Furnace capacity	4-5 Kg
Furnace Operating Voltage	430 Volts, 3 Phase
Furnace Operating Temperature	100-1500 °C
ZrO_2 Preheat temperature	350 °C
Speed of Stirring	1200 rpm
Temperature of stirring	800 °C
Time of stirring	8 mins

TABLE 3

ALUMINUM HYBRID MMC'S COMPOSITION IN WT.%

	Composition in wt.%			
Sample code.	Al-7075	Al_2O_3	B_4C	ZrO_2
S1	85	10	5	0
S2	83	10	5	2
S3	81	10	5	4
S4	79	10	5	6
S5	77	10	5	8

2.3 Experimental procedure

The wear behavior of Al-7075 based hybrid composites nanocomposites was studied using A pin-on disc wear tester model (DUCOM, TR 20LE) as per ASTM G99 standards as shown in Fig. 3. The pin was mounted to a wear path diameter of 100 mm on the rotating disk, balanced by means of a loading device for weight. The rotating counterface is made of 60 HRC hardened steel, under dry sliding conditions all the experiments were done. For loads of 10, 20 and 30N with rotational speeds of 1.8, 3.5,5 and 6.5 m/s, as shown in Table 4 all samples subjected to wear and friction test. Using acetone and ethanol, the various samples were finely polished. Due to the selected speed, the machine runtime was set. Wear and friction coefficient were calculated for the five various samples. The pin weight was measured to calculate the weight loss for the composite before and after each test. For further calculations the wear and friction force on the monitor was noted.

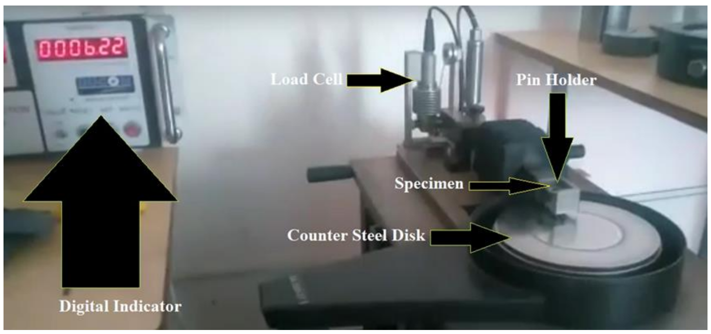

***Fig.**3 Pin-on disc wear apparatus*

TABLE 4
PARAMETERS OF WEAR TEST

Parameters	Values
Disk Diameter, mm	100
Time, min	10
Applied Load, N	10, 20, 30, 40
Sliding Speed, m/s	1.8, 3.5, 5, 6.5

3 RESULT AND DISCUSSION

3.1 Applied load and nano-fillers effect on wear rate

Figs. 4-7 indicates a variation in the wear rate of dry sliding from 1.8 m/s to 6.5 m/s sliding speed at varied load of 10, 20, 30 and 40 N. From these figures it can be seen that with increased loads, the wear rates of Al 7075 alloy and its hybrid nano composites increase linearly. The increased loads lead to an increase in plastic deformation zone of samples surface. Wear is a consequence of wear losses caused by delamination when loads are increased. Hardness of counterface, increased loads and sliding speeds during wear test are the reasons of creating fracture between reinforcement materials and base metal and that leads to the increase in wear rate. The wear rate is reduced for (Al-7075+5 %B4C+ 8% ZrO_2) compared to other aluminum nano-composites. The improvement in wear rate resistance by zirconia addition can be seen at all load variation.

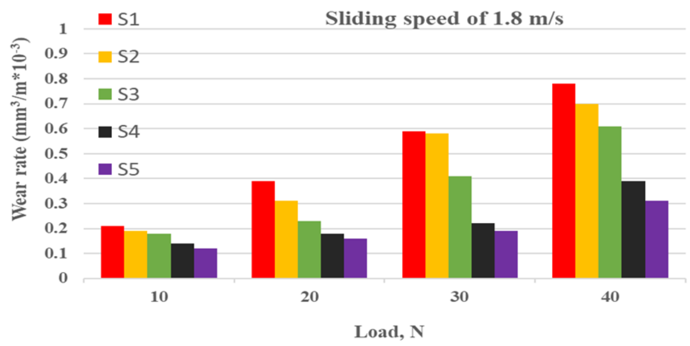

***Fig.4** variation in the wear rate vs load of at sliding speed of 1.8 m/s*

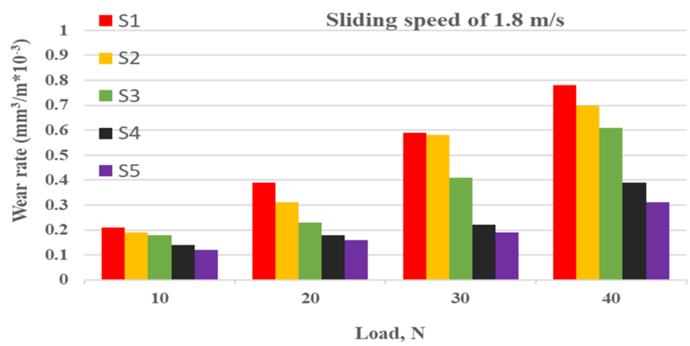

***Fig.5** variation in the wear rate vs load of at sliding speed of 3.5 m/s*

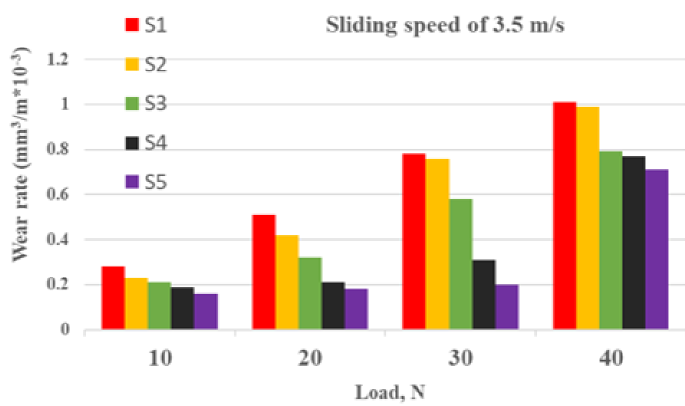

***Fig.6** variation in the wear rate vs load of at sliding speed of 5 m/s*

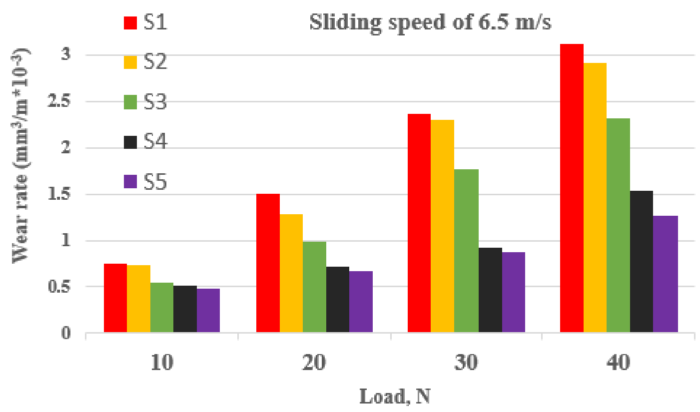

Fig.7 *variation in the wear rate vs load of at sliding speed of 6.5 m/s*

3.2. Sliding speed and nano-fillers effect on wear rate

Zirconia enhancement has a clear effect on the wear rate of different composites this can be seen in Fig.8 which shows variation of wear rate of different ZrO_2 wt.% content at constant load of 30 N and different sliding speeds. From this figure it can be noticed that the addition of ZrO_2 has a significant effect on reducing wear rate and this can be seen obviously at high sliding speed of 6.5m/s. Also, it can be noticed that the rate of wear resistance increases with further increase of ZrO_2 weight ratio within alloy. By addition of 8 wt.% ZrO_2 the wear resistance enhanced by 63.29% compared to 0 wt.% ZrO_2 nanocomposite.

3.3. Applied load and nano-fillers effect on the coefficient of friction

Fig. 9 shows variation of friction coefficient for different percentage of ZrO_2 reinforces Al-7075 nano composites. From figure it is clear that the friction coefficient increases when the load increases. In addition, the friction coefficient decreases with increasing of zirconia percent in aluminum nanocomposites. This is because of the presence of very strong and well distributed ZrO_2 particles. The friction coefficient at 10 N decreased gradually with the increase in ZrO2 at the different weight percentage. Similarly, the friction coefficient at the various load levels 20, 30 and 40 N. That shows the higher wear resistance Capacity.

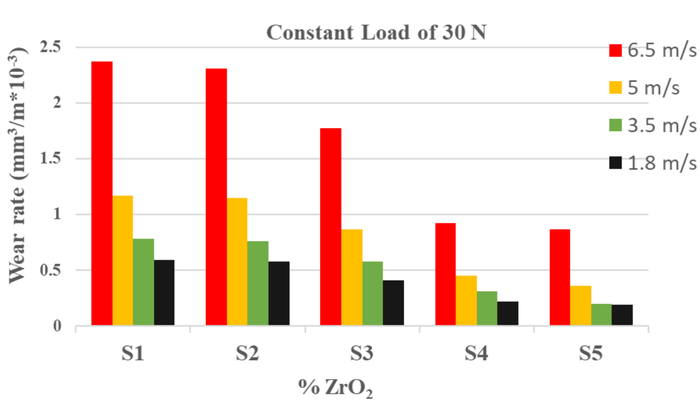

Fig.8 *variation of wear rate of different ZrO2 wt.% content at constant load of 30 N*

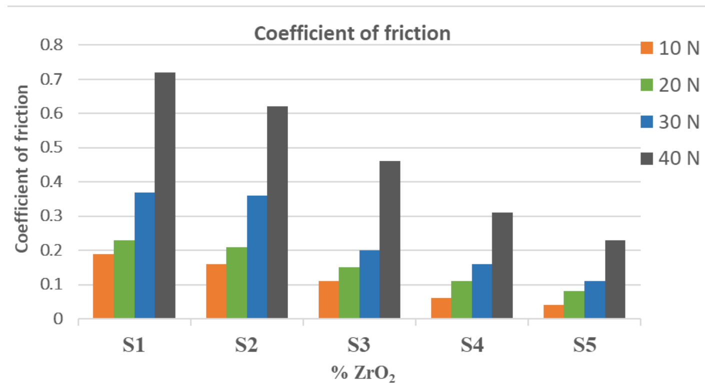

Fig. 9 *variation of COF for different percentage of ZrO2 reinforces Al-7075 HMMCS.*

4 CONCLUSIONS

(Al-7075+Al_2O_3+B4C) and (Al-7075+Al_2O_3+B4C +ZrO_2) nano composites tribological behavior has been investigated at a different value of applied loads and sliding speeds. The addition of ZrO_2 to the aluminum HMMCs reduces wear rates. By increasing the ZrO_2 addition percentage from 0 to 8wt.%, ZrO_2 nanofiller reduce wear rate as the transition load increases. With the increase in sliding speed, both wear rate and the friction coefficient are decreased specially in (Al-7075 HMMCS+ 8% ZrO_2) compared to other composites. (Al-7075 HMMCS+ 8% ZrO_2) has greater wear resistance. With increasing sliding speed, the wear rate reduces that shows a good tribological performance of composites reinforced by nano ZrO_2 particles.

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