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Influence of Artificial Aging on the Dry Sliding Wear Behavior of ADC12 Alloy-B_4C-Rice Husk Ash Particulates Reinforced Hybrid Composites

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Abstract: ***The influence of artificial aging on the wear behavior of ADC12 alloy reinforced with Boron carbide (B_4C) and Rice Husk Ash (RHA) composites have been investigated. Hybrid composites with 5 wt. % of B_4C fortification constant and variable quantity of rice husk ash particles in steps of 9 and 12 wt. % in the ADC12 alloy prepared by melt stir process. ADC12 aluminium alloy, ADC12 alloy-5 wt. % B_4C-9 wt. % RHA and ADC12 alloy-5 wt. % B_4C-12 wt. % RHA Samples were solutionized at a temperature of 525˚C for 1 h. Further, these solution heat treated samples were artificially aged at the temperature of 175˚C for 10 h. Microstructural characterization was carried out by using SEM and EDS. A pin-on-disc wear testing machine was utilized to assess the wear loss of specimens, in which a solidified EN32 steel plate was utilized as the counter face. Wear tests were accompanied on ADC12 alloy, ADC12 alloy-5 wt. % B_4C-9 wt. % RHA and ADC12 alloy-5 wt. % B_4C-12 wt. % RHA hybrid composites at varying loads of 10 N, 20 N and 30 N with varying sliding distances of 250 rpm, 500 rpm and 750 rpm for constant sliding distance of 1000 m. The wear resistance of ADC12 alloy enriched with the accumulation of B_4C and RHA particulates. Further, heat treated samples were exhibited the superior wear resistance as compared to the base alloy and un-heat treated samples.***

Keywords: ADC12 Alloy, Artificial Aging, B_4C, Microstructure, Stir Casting, Wear Behavior

I. INTRODUCTION

AMCs when contrasted with unreinforced alloy have better properties, for example, more prominent strength, advantage in density, great corrosion obstruction, better high temperature possessions, measured thermal extension coefficient, enhanced or tailored electrical possessions, upgraded and customized electrical execution, improved wear opposition and improved damping capacities [1, 2].

The most commonly utilized metal matrix composites comprises of aluminum alloy fortified with firm ceramic elements typically silicon carbide, alumina and soft particles normally graphite powder [3].

Contingent upon their application, the composite materials are portrayed, in connection to the matrix, by improved wear obstruction, high strength properties, good sliding attributes, protection from thermal shocks and fatigue behavior with consideration of decreased load of the end or final product. Along these lines the use of hard ceramic particles strengthened composites relies upon mechanical properties of composite yet in addition the expenses of its assembling and ecological part of the item.

Among the different matrix materials accessible, aluminum alloys are promising materials because of their high explicit strength and stiffness [4]. In any case, their applications are limited due to their poor wear opposition. Particulate fortified aluminum network composites are presently being considered for their better mechanical and tribological properties over the regular alloys, and in this manner, these composites have increased broad applications in automotive and aviation businesses. The accentuation has been given on creating moderate Al-based MMCs with different hard and delicate fortifications like SiC, Al_2O_3, B_4C, zircon, tungsten carbide, graphite and mica [5, 6].

The essential capacity of the fortification in MMCs is to convey the greater part of the applied load, where the matrix ties the reinforcements together, and transmits and circulates the external loads to the individual particle. Great wetting is a basic condition for the age of a palatable bond between particulate fortifications and liquid Al metal framework during casting composites, to permit relocation and circulation of load from the alloy to the fortifications without failure [7, 8].

It is demonstrated that the ceramic particles are powerful support materials in aluminum composite to upgrade the mechanical and different properties. The fortifications in MMCs are for the most part of ceramic materials; these fortifications can be separated into two main groups, continuous and discontinuous. The MMCs created by them are called consistently strengthened composites and irregularly fortified composites [9]. In any case, they can be subdivided comprehensively into five significant classifications: continuous fibers, short fibers, whiskers, particulate and wire (only for metal) except for wires,

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fortifications are for the most part ceramic production, regularly these being oxides, carbides and nitrides.

The properties of MMCs can be enhanced by using the heat treatment process. The combined effect of the heat treatment and addition of particles usually enhances the mechanical and wear properties of metal matrices. Semegn et al. [10] conducted the experiments on Al2024-TiB_2 composites, which were processed by semi sold casting method. The effect of artificial aging was studied on the Al2024-TiB_2 composites. The prepared samples were subjected to the solution treatment at 490˚C for 2.5 and 5 hours. Finally, artificial aging was done at 190˚C for 1 to 12 hours. The heat treated specimens exhibited the superior properties.

In the present work an effort has been made to know the combined effect of heat treatment and dual reinforcement addition on the wear behaviour of ADC12 aluminium alloy. ADC12 aluminium alloy, ADC12 alloy-5 wt. % B_4C-9 wt. % RHA and ADC12 alloy-5 wt. % B_4C-12 wt. % RHA Samples were solutionized at a temperature of 525˚C for 1 h. Further, these solution heat treated samples were artificially aged at the temperature of 175˚C for 10 h. Further, these prepared samples were evaluated for dry sliding wear behaviour at varying loads and sliding speeds as per ASTM G99 standards. A comparison of dry sliding wear behaviour was made between the un-heat treated and heat treated specimens.

II. EXPERIMENTAL DETAILS

In the existing effort silicon based Al alloy ADC12 is utilised as the matrix substantial. ADC12 Al alloy encompasses silicon as the key alloying constituent in the aluminium alongside with iron and copper. Table 1 is displaying the chemical configuration of the ADC12 amalgam used in the existent study.

Table I: Chemical composition of ADC12 Alloy

Elements	Content wt. %
Si	12.0
Fe	1.3
Cu	2.5
Mg	0.3
Mn	0.5
Ni	0.3
Zn	0.8
Pb	0.3
Ti	0.2
Al	Bal

Micro B_4C particulates with 40 micron in the size are used as the reinforcement particles, which were procured from the Speedfam India Limited, Chennai. Boron carbide particles are having density of 2.52 g/cm^3, which is lesser than the base metal. The chemical configuration of B_4C particulates is shown in the Table 2.

Table 2: Chemical configuration of Boron Carbide particles

Elements	B	C
Wt. (%)	63.68	36.32

The natural reinforcement rice husk ash is obtained from the agricultural waste. Enormous quantity of rice husk is produced across the sphere every year. This produced amount of waste is an atmosphere nuisance. The existing exploration directed to convert the RH surplus into useful fortification material by attaining Si through rice husk ash. The chemical arrangement of arranged RHA is shown in the Table 3. The usual particle size of used RHA is 30 µm.

Table III: Chemical composition of Rice Husk Ash

Elements	Content wt. %
SiO_2	93.1
K_2O	1.28
CaO	1.10
MgO	0.56
Fe_2O_3	0.49
Al_2O_3	0.47
C	0.33
Na_2O	0.60
LOI*	2.61

*Loss of Ignition

ADC12 alloy, ADC12-5 wt. % B_4C-9 wt. % RHA and ADC12-5 wt. % B_4C-12 wt. % RHA composites were manufactured by melt stir casting process. The electric resistance furnace is used to melt the ADC12 aluminium alloy by using graphite crucible. Further, the 750˚C temperature is maintained in the resistance furnace. Before addition of the support elements into the ADC12 alloy the preheating of fortification was completed in the preheater at a temperature of 300˚C. This preheating process helps in removing the moisture content from the B_4C and RHA particle, which enhances the wetting between the matrix and dual reinforcement particles. Since, Silica is the major content in the RHA particles, which is the combination of Silicon and Oxygen. The expansion in the wettability is very significant to have the resilient interface connection between the ADC12 alloy and dual fortifications. It is necessary to create the vortex in the ADC12 alloy melt before the incorporation of the reinforcement; this is carried out by a zirconia coated steel rod at rpm of 500. After the incorporation of the preheated B_4C and RHA particles in the ADC12 alloy melt, stirring has been carried out for a period of 5 minutes. The entire molten melt of ADC12 alloy-B_4C and RHA particulates is poured into a cast iron die of 120 mm in length and 15 mm in diameter. The castings are detached from the cast iron mould after steady cooling. One set of the un heat treated samples were machined for wear studies as per ASTM G99 standards.

Further, another set of casted samples were exposed to the heat treatment process.

In the present work heat treatment of ADC12 alloy, ADC12-5 wt. % B_4C-9 wt. % RHA and ADC12-5 wt. % B_4C-12 wt. % RHA hybrid composites were heat treated in two stages, first one is solutionizing and second

one is the artificial aging. Solutionization of ADC12 aluminium alloy and its composites were carried out at a temperature of 525˚C for 1 h. Further, these solutionized samples are allowed to quench in the water. The temperature of the water is maintained at room temperature. These solutionized and the water quenched samples were allowed to cool at room temperature for 1 h. After cooling at room temperature, the solution heat treated samples were artificially aged at the temperature of 175˚C for 10 h. After completion of 10 h, these artificially aged ADC12 alloy and B_4C-RHA reinforced composites were kept in the air for natural cooling.

The SEM and EDS representation of ADC12 alloy with B_4C and Rice Husk Ash hybrid composites with and without heat treatment were inspected by SEM with EDS machine made by Vegas. The surface morphology of ADC12 alloy and hybrid composites were analyzed by the SEM. The elemental analysis of all the prepared samples of ADC12 alloy, ADC12-5 wt. % B_4C- 9 wt. % RHA and ADC12-5 wt. % B_4C-12 wt. % RHA composites were carried out by EDS.

The wear behavior of ADC12 alloy and B_4C-RHA reinforced composites with and without heat treatment were analyzed by using pin on disc wear machine. The trials were accompanied as per ASTM G-99 wear testing standard [11] on 10 mm in diameter and 15 mm length circular specimen as shown in Fig. 2.

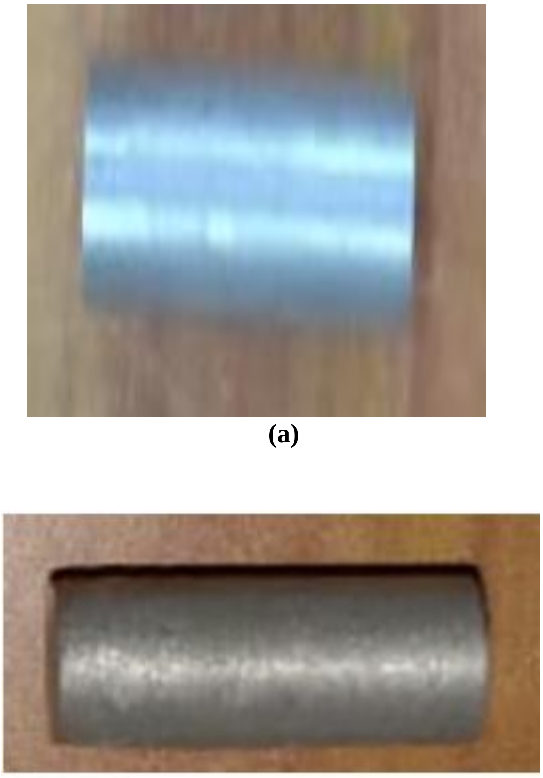
The wear rate was calculated after conducting the dry sliding wear tests at 10 N, 20 N and 30 N varying loads at 750 rpm sliding speed for 1000 m sliding distance in 50 mm diameter wear track.

Similarly, one more set of dry sliding wear behavior of ADC12 alloy composites were analyzed at varying sliding speeds of 250 rpm, 500 rpm and 750 rpm at 30 N load and 1000 m sliding distance.

The wear loss was noted in terms of weight loss, which further used to calculate the volumetric wear loss of ADC12 alloy and ADC12-B_4C and RHA reinforced hybrid composites. Finally, the wear of the specimens was expressed in the wear rate.

At the time of conducting wear tests using pin on disc wear machine, wear debris were collected and these debris were studied for the various wear mechanisms using SEM micrographs.

Further, worn surface morphology also analysed using scanning electron micrographs to know the various wear behaviour involved in the ADC12 alloy and ADC12-5 wt. % B_4C-9 wt. % RHA and ADC12-5 wt. % B_4C-12 wt. % RHA hybrid composites with and without heat treatment process.



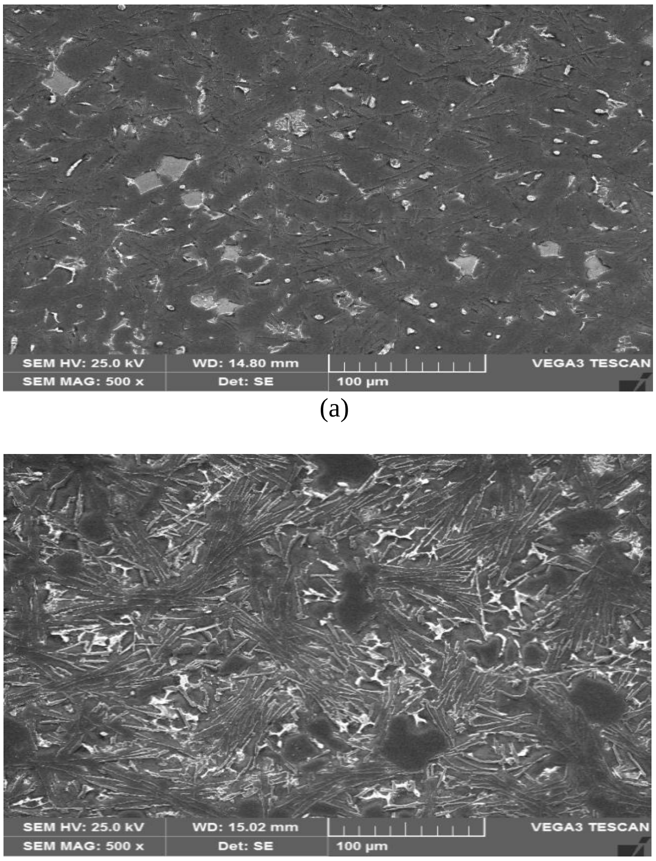
(a)

(b)

Figure 2: Wear test specimens (a) without heat treatment (b) with heat treatment

III. RESULTS AND DISCUSSION

A. Microstructural Analysis



(a)

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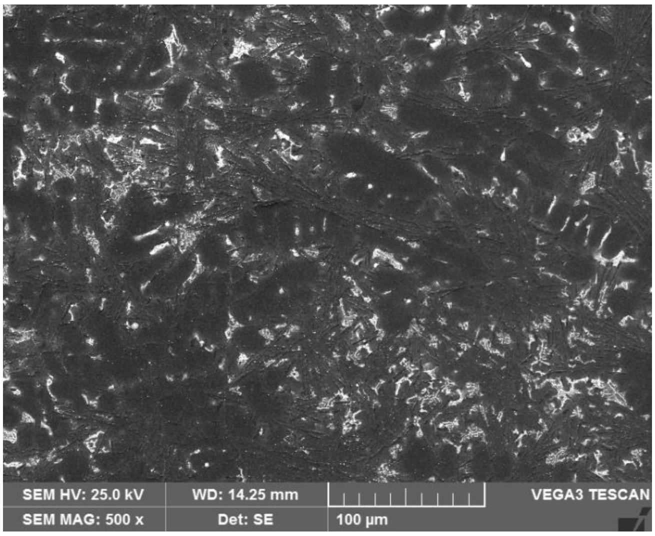
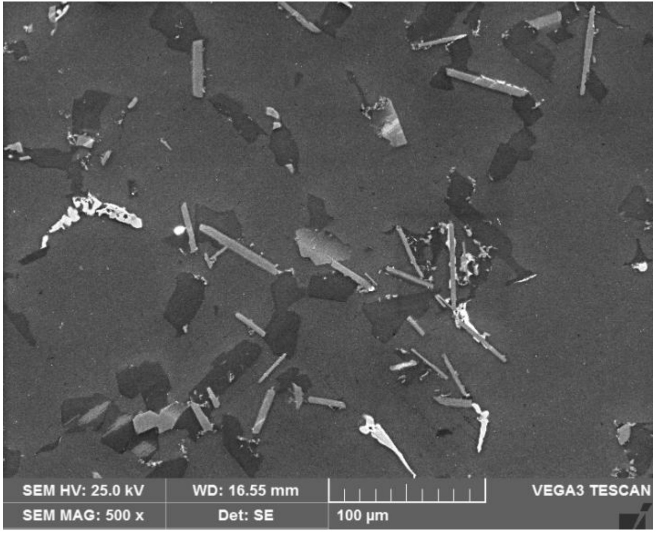


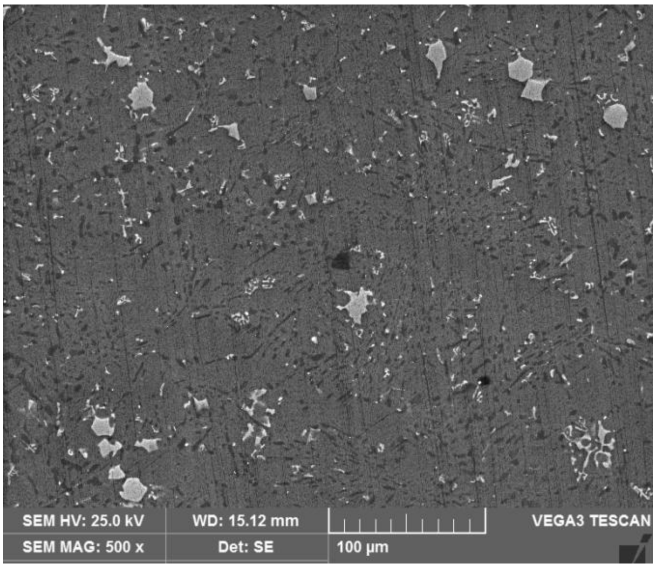
(c)

Figure 2: SEM of (a) as cast ADC12 alloy (b) ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA (c) ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites without heat treatment

Fig. 2 directs the SEM micrographs ADC12 alloy, ADC12 -5 wt. % B_4C-9 wt. % RHA composites and ADC12 -5 wt. % B_4C-12 wt. % RHA composites. Fig. 2a signifies the SEM micrograph of ADC12 alloy without particles. The microstructure of ADC12 alloy covers flakes kind construction. Since ADC12 is the one kind of silicon built alloy, these flakes characterizes the occurrence of silicon content in the alloy. Also, it is observable in the micrograph tiny dark coverings, which displays the high wt. % of Si in the ADC12 alloy. Fig. 2b and 2c are the SEM images of ADC12 alloy with dual elements reinforced composites. Fig. 2b-c demonstrations fine microstructures with sturdy interfacial connection between the ADC12 alloy with B_4C and rice husk ash particles. In the dual element composites B_4C and RHA particles are evenly dispersed and there is no discrimination. Fig. 2b indicates B_4C and 9 wt. % of RHA particles in the ADC12 alloy along with the Si content. As the wt. % of RHA rises from 9 to 12 wt. % in the ADC12 alloy along with 5 wt. % of B_4C, only RHA and B_4C particles are noticeable in the microstructure as in Fig. 2c.



(a)



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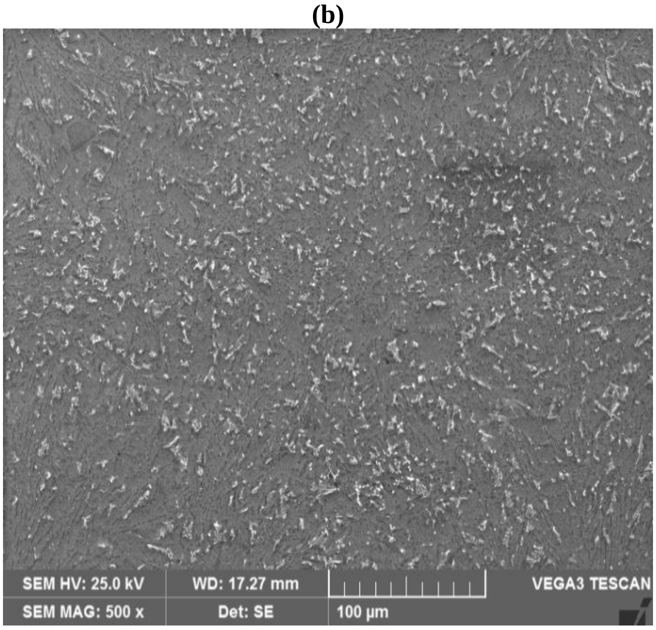
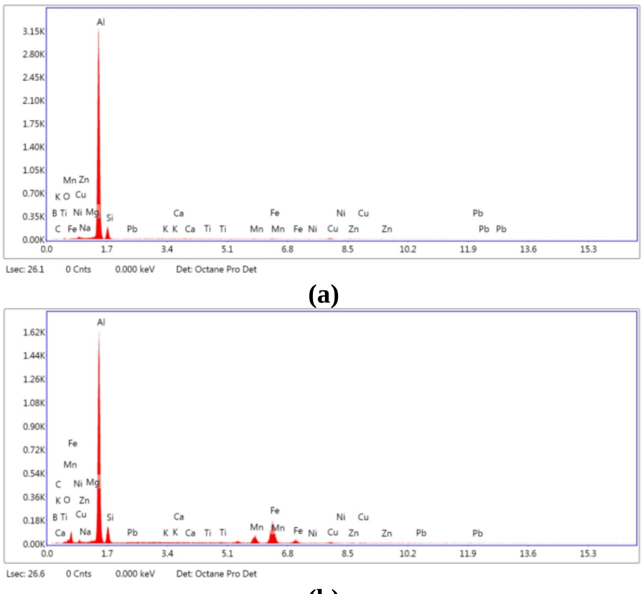


(c)

Figure 3: SEM of (a) as cast ADC12 alloy (b) ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA (c) ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites with heat treatment

The SEM micrographs of heat treated ADC12 aluminium alloy is shown in the Fig. 3 (a). Similarly, Fig. 3 (b-c) is showing SEM micrographs of ADC12 alloy-5 wt. % of B_4C-9 wt. % of RHA composite and ADC12 alloy-5 wt. % of B_4C-12 wt. % of RHA composites respectively. Shows SEM images of the ADC12 alloy and the B_4C-RHA reinforced hybrid composites, solution heat treated at 525˚C for 1 h, followed by a water quench at room temperature and then artificially aged at a temperature of 175˚C for 10 h. The microstructural changes after age hardening are studied in this section. During the heat treatment of ADC12 alloy and related micro composites containing silicon and copper as an alloying element with little magnesium, Al_2Cu precipitates as the strengthening phase. The most commonly occurring intermetallic phases during heat treatment of Al-Cu-Si alloys are Al_2Cu, $CuMgAl_2$, Mg_2Si and Cu_2FeAl_7.



(a)

(b)

Figure 4: Energy dispersive spectrum of (a) ADC12-5 wt. % B_4C-12 wt. % RHA composites without heat treatment (b) ADC12-5 wt. % B_4C-12 wt. % RHA composites with heat treatment

Fig. 4 (a-b) is presenting the EDS of ADC12 alloy with 5 wt. % of B_4C and 12 wt. % of RHA reinforced composites un heat-treated and with heat treatment. Since the band contents the more Si in the Al, which authorizes the occurrence of more Silicon content in the ADC12 alloy. Further, from the scale the occurrence of B_4C particles in the form of B and C elements are confirmed.

B. Wear Properties

The comparison of wear rate of ADC12 alloy, ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA and ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites with and without heat treatment process is discussed. A comparison of wear rate of ADC12 alloy without heat treatment and ADC12 alloy which is solution treated at 525˚C and artificial aged 175˚C has been made.

Effect of Load on Wear Rate

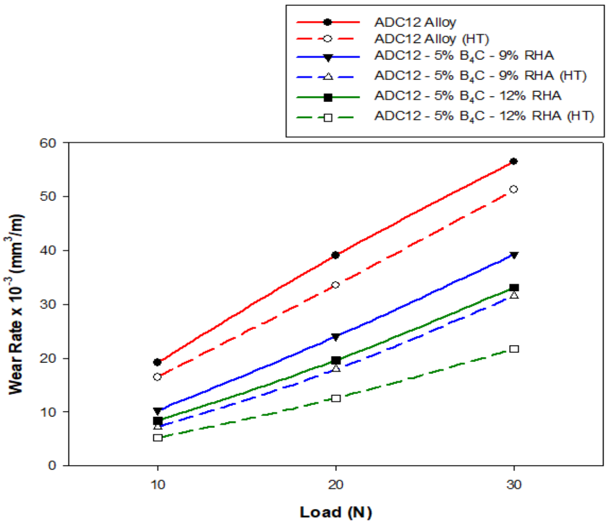


Figure 5: Comparison of wear rate of ADC12 alloy and its B_4C and RHA reinforced hybrid composites at varying loads and constant speed with and without heat treatment process

Fig. 5 is showing the comparison of wear behaviour ADC12 alloy, ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA and ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites with and without heat treatment process at varying loads of 10N, 20N and 30N at 750 rpm constant speed for 1000 m sliding distance. From the graph it is evident that as the load increase from 10 N to 30 N, there is increase in wear loss in ADC12 alloy and ADC12 alloy-B4C-RHA particles reinforced hybrid composites with and without heat treatment. The load affected the wear behaviour of both un heat treated and heat treated samples. The increased wear loss as load increases from 10 N to 30 N is mainly due to the enhanced contact area between the specimen and the steel disc. This increased area of contact during wear test generates more heat, which causes the delamination in the alloy and composites. Further, from the plot 5 it is observed that solutionized and artificially aged ADC12 alloy, ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA and ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites exhibits superior wear resistance properties as compared to the un heat treated samples. The solutionizing and artificial aging process forms the precipitates in ADC12 aluminium alloy and its composites. These formed precipitates acts as a wear resisting elements in ADC alloy and its hybrid composites composites along with B_4C-RHA particulates these precipitates forms the barrier for the material loss [12].

Effect of Sliding Speed on Wear Rate

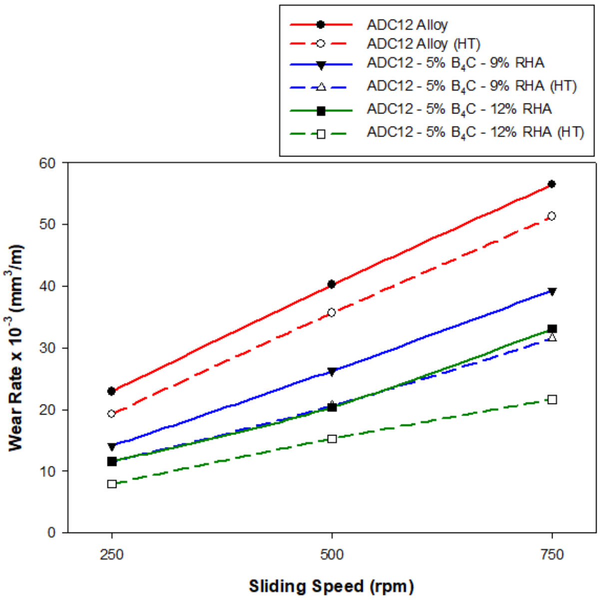


Figure 6: Comparison of wear rate of ADC12 alloy and its B_4C and RHA hybrid composites at varying speeds and constant load with and without heat treatment process

Fig. 6 shows the wear loss with the variation of speed for several test samples with varying compositions. The test is conducted with varying disc speed of 250 rpm, 500 rpm, and 750 rpm by retaining load of 30 N.

From the Fig. 6, it is concluded that wear rate increases with the increasing sliding speed. For base ADC12 alloy the effect of sliding speed is more when compared to B_4C and RHA reinforced hybrid composites.

From the graph 6 as the speed increases from 250 rpm to 750 rpm, there is increase in wear of ADC12 alloy, ADC12 alloy – 5 wt. % B_4C – 9 wt. % RHA and ADC12 alloy – 5 wt. % B_4C – 12 wt. % RHA composites with and without heat treatment. Further from the Fig. 6 it is noted that wear resistance of the heat treated samples are superior to the un heat treated ADC12 alloy and B_4C-RHA reinforced composites. During solution treatment of ADC12 alloy based micro composites, the formation of solute elements is more, the local distortion of the ADC12 alloy matrix is greater, and henceforth the resistance to the affecting condition is larger during wear test. Therefore, it will enhance the wear resistance.

IV. CONCLUSIONS

ADC12 alloy-B_4C and RHA micro composites have been manufactured by stir casting technique by taking 5 wt. % of B_4C particles constant and varying rice husk particles in 9 and 12 wt. %. The microstructure and wear behaviours of ADC12 alloy hybrid composites with and without heat treatment were examined. SEM microphotographs revealed the even distribution of B_4C and RHA particles in the ADC12 alloy. Further, these reinforcement particles were renowned by the EDS analysis. The effect of load and the sliding speed was observed on the ADC12 alloy and its B_4C and RHA particles reinforced composites. As the load and speed improved, there was surge in wear rate of un heat treated and heat treated ADC12 alloy and hybrid composites. The enhanced wear resistance was noticed in the case of heat treated ADC12 alloy and ADC12 alloy-B_4C-RHA hybrid composites.

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