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RESEARCH ARTICLE

WEAR CHARACTERIZATION OF LM29 ALLOY WITH40 MICRON SIZED B_4C REINFORCED METAL COMPOSITES

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Abstract

This paper deals with the fabrication and evaluation of wear properties by introducing40 micron size B4C particulates into LM29 alloy matrix. LM29 alloy based metal matrix composites were prepared by stir casting method. 3, 6 and 9 wt. % of 40 micron sized B4C particulates were added to the base matrix. For each composite, the reinforcement particles were pre-heated to a temperature of 600 degree Celsius and then dispersed in steps of two into the vortex of molten LM29 alloy to improve wettability. The Micostructural study was done by using Scanning Electron Microscope (SEM), which revealed the uniform distribution of B4C particles in matrix alloy, EDS analysis confirmed the presence of B4C particles in the LM29 alloy matrix.A pin-on-disc wear testing machine was used to evaluate the wear loss of prepared specimens, in which a hardened EN32 steel disc was used as the counter face. The results revealed that the wear loss was increased with increase in normal load and sliding speed for all the specimens. The results also indicated that the wear loss of the LM29-B4C composites were lesser than that of the LM29 matrix. The worn surfaces and wear debris were characterized by SEM microanalysis.

Introduction:-

Aluminum alloys are extensively defined on the composition of compounds which are ordered into casting and wrought alloys. These are additionally subdivided into heat treatable and non-heat treatable amalgams. Cast and wrought alloy combination terminology have been created. The aluminumassociation system is most generally perceived in the United States. Their alloy distinguishing system utilizes distinctive terminologies for cast and wrought alloys. Casting compositions are described by a three-digit system followed by a decimal value. For wrought alloys four-digit systems is used to produce a list of wrought composition as 1xxx series to 8xxx series based on major alloying elements in the aluminium [1-3].

Aluminium alloys consisting of aluminium as major element is alloyed with other elements like silicon, copper, magnesium, manganese etc., based on the composition of alloying elements these aluminium alloys are given several grades [4, 5]. Basically, aluminium alloys have very good properties like strength, strength to weight ratio, ductility at low temperature, corrosion & wear resistant etc., [6-8] among which major advantage is it possesses 1/3rd the weight of iron, steel, copper or brass. Considering all the above advantages, aluminium alloy was chosen as

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matrix material in the study. Furthermore, a silicon-based aluminum alloy (AlSialloy), also known as LM29 aluminum casting alloy, which has very good meltability and flowability, was selected as the aluminum-based metal matrix among the aluminum alloys [9, 10]. Studies show that LM29 castings have high resistance to wear and corrosion, good weldability, resistance to hot tearing and, above all, a high strength-to-weight ratio [11].

In particle-reinforced metal-aluminum matrix composites (MMC), ceramic or clay enrichments are mainly oxides or carbides or borides, eg Al_2O_3, TiB_2, TiO_2, SiC, TiC, B_4C [12-14], etc. Particle CMMs have been found to offer improvements in quality, wear resistance, structural efficiency, reliability, and control of physical properties such as density and coefficient of thermal expansion, resulting in improved engineering performance over non-material. LM29 alloy is a low-density, moderate-strength metal alloy that has low resistance to wear. To overcome this disadvantage, this alloy is reinforced with B_4C particles. The wear behavior of the aluminum alloy LM29 is investigated by synthesizing different B_4C particles with a size of 40 microns and evaluating tribological properties. In this study an attempt was made to produce compounds from LM29 alloys by adding 3, 6 and 9% by weight. % 40 micron size B_4C particles in matrix using a novel two-step reinforcement addition process. In addition, the produced LM29 B_4C compounds were tested for the influence of load and sliding speed on wear properties using a pin-on-disc wear testing machine.

Experimental Details

Materials Used

Metal matrix composites containing 3, 6 and 9 weight percent 40 micron size B_4C particles were prepared by liquid metallurgy. For the manufacture of MMC, an LM29 alloy was used as the matrix material, while the B_4C particles with a mean size of 40 µm were used as reinforcements, as shown in Fig. 1. The chemical composition of the alloy used in the present study is given in Table 1.

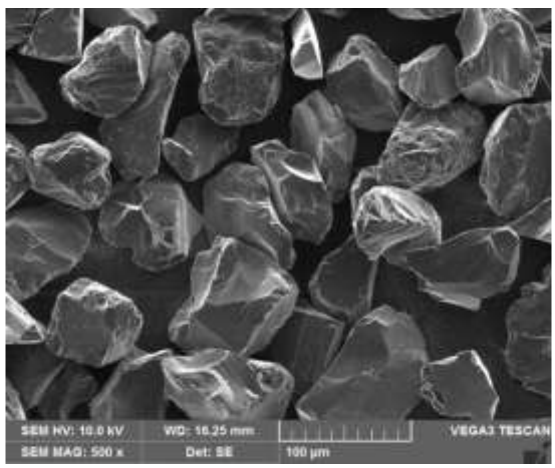


Fig.1:- Showing the SEM micro-photograph of 40 micron sized B_4C particles used in the study.

Table 1:- Chemical composition of LM29 alloy.

Elements	Si	Cu	Mg	Ni	Al
Wt. %	24.0	1.0	1.0	1.0	Bal

Preparation of Composites

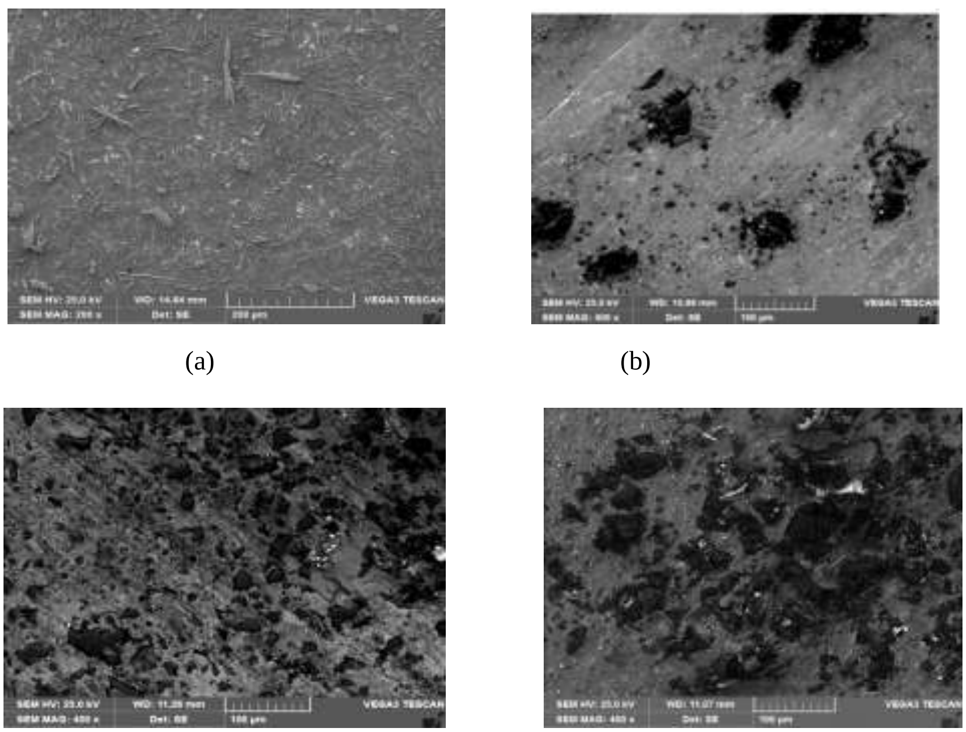
LM29 B_4C compounds with 40 micron particles were manufactured by liquid metallurgy using stirring technology. The calculated quantity of LM29 alloy ingots is placed in the furnace for melting. The melting point of the aluminum alloy is 660°C. The melt was reheated to a temperature of 750°C. The temperature is recorded with a chromed aluminum thermocouple. The molten metal is then degassed with solid hexachloroethane (C_2Cl_6) for 3 minutes [15, 16]. A zirconium coated stainless steel impeller is used to stir the molten metal and create a vortex. The stirrer rotates at a speed of 300 rpm and the impeller immersion depth was 60 percent of the height of the molten metal from the surface of the melt. Furthermore, the B_4C particles are preheated to 600°C in an oven and introduced into the vortex. Stirring is continued until the interfacial interactions between the reinforcing particles and the matrix promote wetting. Then LM29 3, 6 and 9 by weight The C mixture is poured into a permanent castingmoldwith dimensions of 120 mm in length and 15 mm in diameter. In addition, based on microstructural research, an evaluation of wear properties according to ASTM G99 standards was carried out at different loads, sliding speeds and sliding distances

Wear Test

Dry sliding wear tests were performed on LM29 alloy and LM29 -B_4C compounds using a pin-on-disc wear tester. Cylindrical samples 8 mm in diameter and 30 mm in length were mounted vertically on a dowel holder. The ends of the samples were polished with 600 grit sandpaper and then 1000 grit spaper. During the test, the pin was pressed against the EN32 counterpart steel disk with a hardness of 60 HRC. Before each pass, the steel mating surface was sanded with 320 grit abrasives and then 600 gradeSiCabrasives for a few minutes, then cleaned with acetone. The test conditions included load speed settings of 100, 200, 300 and 400 rpm under a normal load of 4 kg and loads of 1, 2, 3 and 4 kg at a speed of 400 rpm. The initial weight of the sample was measured on an electronic balance with an accuracy of ± 0.01 mg. Data collected and analyzed for attrition rates in the form of weight loss.

Results and Discussion:-

Microstructural Analysis



(a) (b) (c) (d)

Fig.2:- Scanning Electron Microphotographs of (a) as cast LM29 alloy (b) LM29-3% B_4C (c) LM29-6% B_4C (d) LM29-9% B_4C with 40-micron B_4C particles.

SEM microstructure of as cast LM29 aluminium alloy is shown in Fig. 2(a) from the figure it is clear that there is no presence of B_4C particles. Fig. 2(b-d) denotes SEM microstructure of LM29-3 wt. % 40 µm B_4C, LM29-6 wt. % 40 µm B_4C and LM29-9 wt. % 40 µm B_4C reinforcement particles.

The SEM micrographs disclose that the distribution of 40 micron size B_4C reinforcement particles with different % of weight is almost uniform throughout the LM29 matrix; it is evident as revealed in the Fig.2(b-d) above. It also reveals that there are no discontinuities, voids and cold shuts. Good interfacial bonding between B_4C reinforcement particles and LM29 alloy matrix is observed. From the above SEM images explanation, it is evident that the uniform distribution of reinforcement particles, no defects in castings and good interfacial bonding in these LM29 - B_4C particulate composite, thereby increasing the overall strength of the MMC and its substantial effect on both mechanical and tribological properties.

The graphical representations of EDS analysis of as cast LM29 aluminium alloy and LM29 alloy with 9 weight % of 40 micron size B_4C particle composites are explained in detail below.

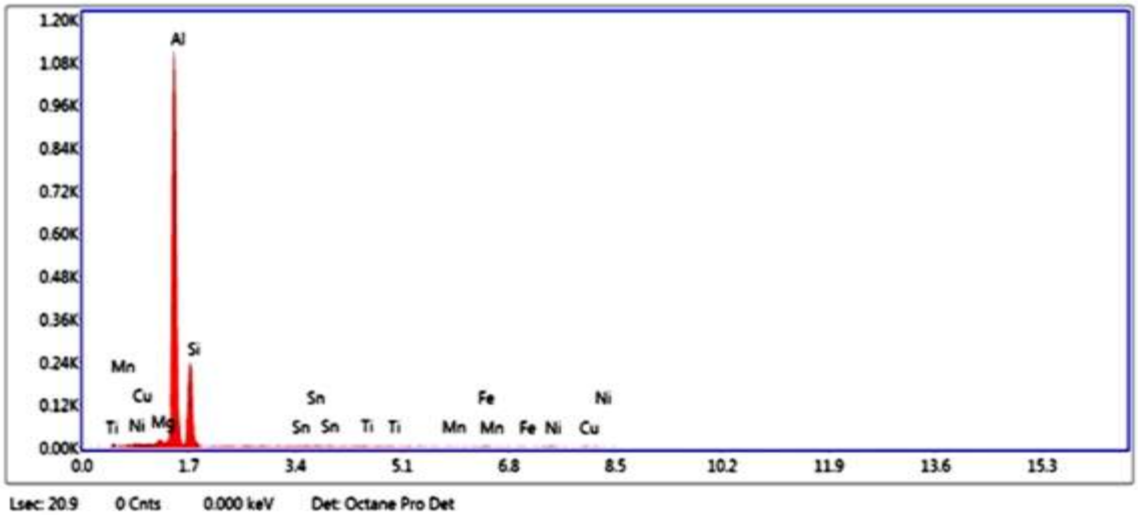


Fig. 3:- Energy dispersive spectrograph of as cast LM29 aluminium alloy.

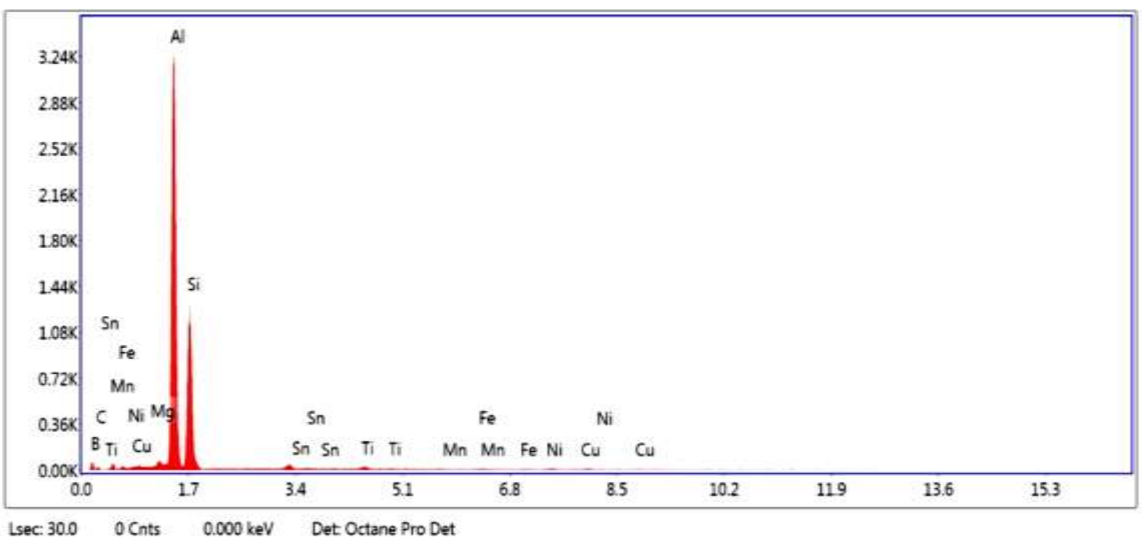


Fig. 4:- Energy dispersive spectrograph of LM29 - 9 wt. % 40 µmB4C composite.

In theFig. 4 convey the EDS spectrograph of LM29 - 9 wt. % 40 µmB_4C composite, from the graph it is evident that the presence of boron (B) and carbon(C) along with the elements of LM29 aluminium alloy. Besides in the scanned image the dark patches observed, which are scattered nothing but 40 µmB_4C particulates and it confirms the presence of B_4C in LM29 alloy.

Density Measurements

The density of as cast LM29 alloy, LM29-3 wt. % of 40 micron size B_4C, LM29-6 wt. % of 40 micron size B_4C and LM29-9 wt. % of 40 micron size B_4C composites, are measured experimentally by 'weight method'.

Table 2 below explains the details of the theoretical as well as experimental values obtained for different samples. The theoretical values calculated are near to the values obtained by experimental method and it is expected in this study that experimental values are to be close to the theoretical values. The possibility of obtaining the experimental values exactly as theoretical values is almost impossible because theoretical values are calculated using standardized formulae [17].

Table 2:- Theoretical and experimental densities of LM29 alloy 40 micron size B_4C composites.

Sl. No	Composition	Theoretical Density (g/cm^3)	Experimental Density (g/cm^3)
1	LM29 Alloy	2.680	2.610
2	LM29 Alloy + 3 wt. % B_4C	2.674	2.581
3	LM29 Alloy + 6 wt. % B_4C	2.669	2.553
4	LM29 Alloy + 9 wt. % B_4C	2.664	2.526

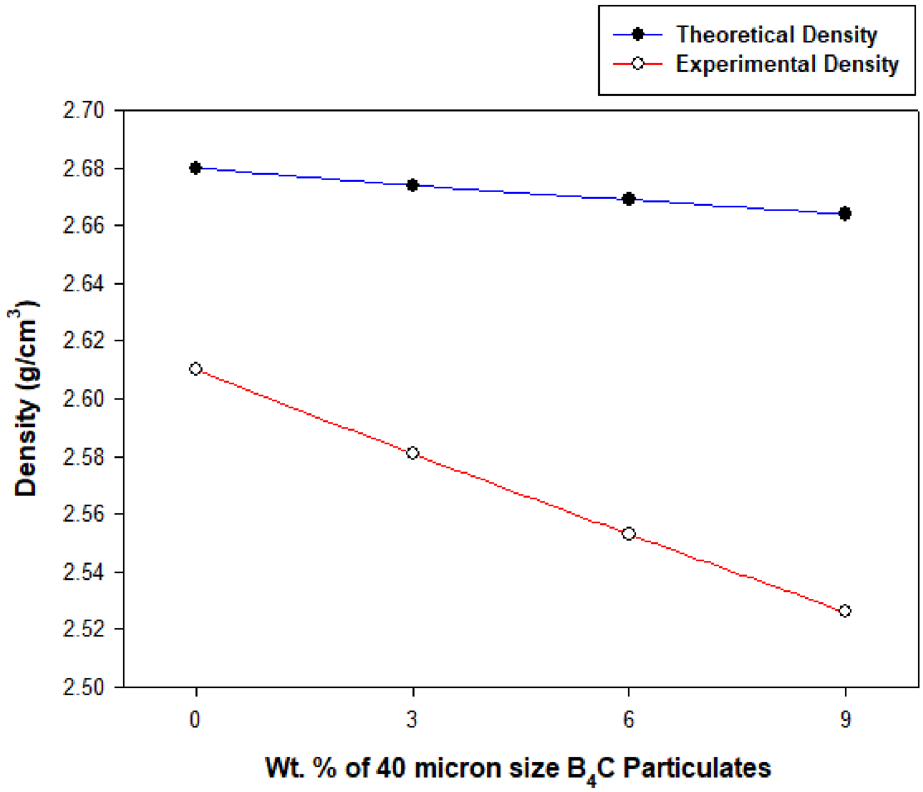


Fig. 5:- Theoretical and experimental densities of LM29-B_4C composites with 40 micron size particles.

In the Fig. 5 above compares the theoretical & experimental densities of as cast LM29 alloy, LM29-3 wt. % of 40 micron size B_4C, LM29-6 wt. % of 40 micron size B_4C and LM29-9 wt. % of 40 micron size B_4C composites. Aluminium alloy LM29 has density of 2.68 g/cm^3, boron carbide has density of 2.52 g/cm^3, when aluminium alloy LM29 is reinforced with 3 wt. % 40 micron B_4C, the overall density of composite becomes less as B_4C density is lesser than the LM29 alloy and the density of LM29-3 wt. % of B_4C is 2.674 g/cm^3. Similarly, when 6 and 9 wt. % of B_4C particles are reinforced within LM29 alloy the overall density of composite tends to become lesser than that of previous/base aluminium alloy. Further, it can be observed that experimental densities are lesser than the theoretical densities. The decrease in density with addition of boron carbides is in good agreement with the other researchers.

Wear Behaviour

Effect of applied load on wear loss

The load is one of the essential parameters thatplayan important role in the loss of wear. To understand the wear rate of aluminum alloys, much work has been done on the effect of normal loading in wear experiments. To investigate the effect of load on wear, graphs were created for wear loss against different loads of 1 kg, 2 kg, 3 kg and 4 kg at a constant distance of 3000 meters and a speed of 400 rpm. Figure 6 shows the influence of the load on the wear behaviour of the LM29 alloy and the composite materials reinforced with B4C.

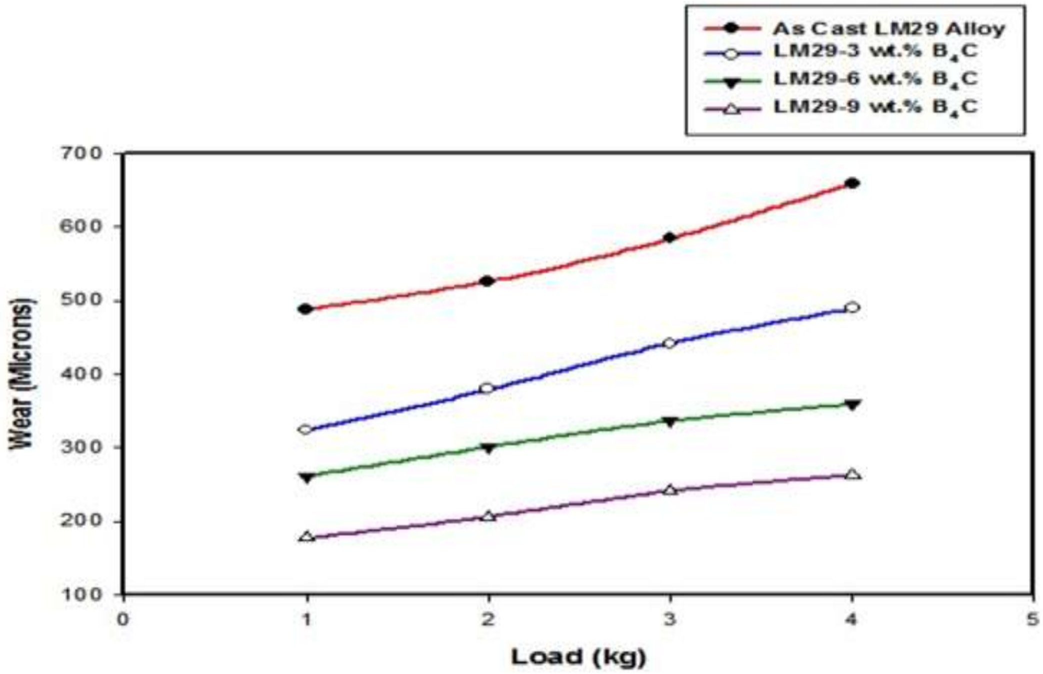


Fig. 6:- Shows wear loss of LM29 Alloy and its 40 micron size B_4C reinforced composites at varying loads and 400 rpm constant speed.

In diagram 6 it can be seen that with an increase in load from 1 kg to 4 kg, wear increases for all composites and the base alloy LM29. With a maximum load of 4 kg, the temperature of the sliding surface and the bolt exceeds the critical value. It can be seen that the wear loss of the composites decreases as the weight % of the reinforcements in the LM29 alloy. The increase in wear resistance of LM29 with 3, 6 and 9 wt. % alloy compounds with B_4C with increasing wt. %. B_4C reinforcements can be attributed to the high hardness of the B4C particles, which act as a barrier against wear loss [18].

Effect of sliding speed on wear loss

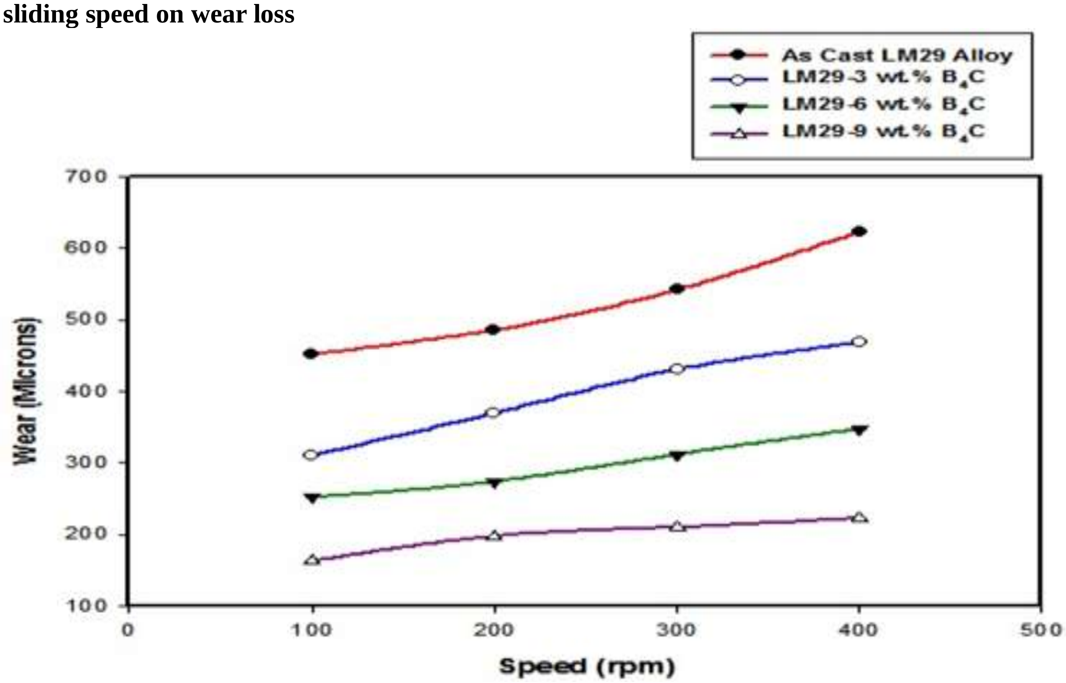


Fig. 7:- Shows wear loss of LM29 and its 40 micron size B_4C reinforced composites at varying speeds and 4 kg constant load.

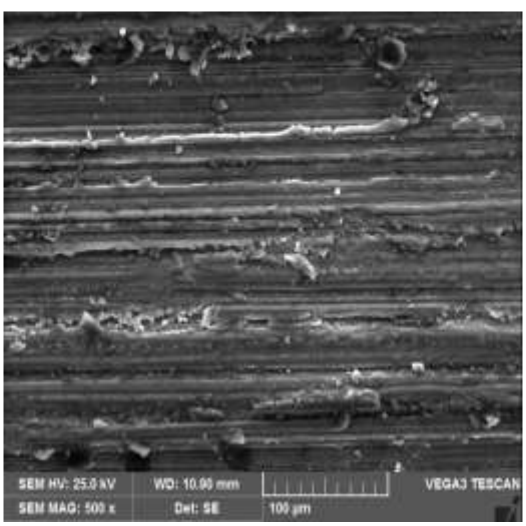
Figure 7 shows the wear loss when changing the speed for various test objects with different compositions. The test is carried out with different disc speeds of 100 rpm, 200 rpm, 300 rpm and 400 rpm with a holding load of 4 kg. From the previous figure it is concluded that the volume of loss due to wear increases with increasing sliding speed. With the alloy based on LM29, the influence of the sliding speed is greater than with a composite material based on B_4C.

Fig. 7 shows the dependence of all the wear loss of LM29 matrix alloy along with B4C composites on sliding speed. As the sliding speed is increased from 100 rpm to 400 rpm, the loss due to wear is increased for both LM29 matrix alloy and its constituent composites.

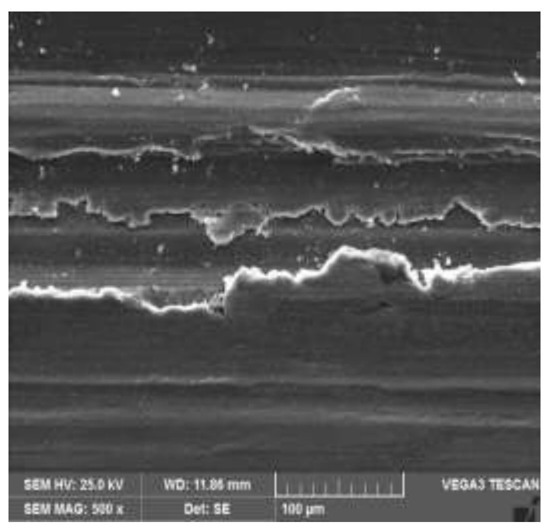
Although at all sliding speeds, the wear loss of the composites is much lower compared to the matrix alloy LM29 and much lower in the case of the alloy LM29 with 3, 6 and 9% by weight% of 40 µm B_4C compounds. In principle, the wear losses of the composite material decrease as the amount of B_4C particles increases. Furthermore, when the sliding speed increases further, the wear loss also increases due to the softening of the composite material at an elevated temperature due to the effect of friction. The increase in temperature resulting from higher sliding speeds also leads to plastic deformation of the test object. Therefore, there is greater delamination, which contributes to greater wear loss. The results of the present work are similar and are in line with previous research by other researchers [19, 20].

Wear Surface Morphology

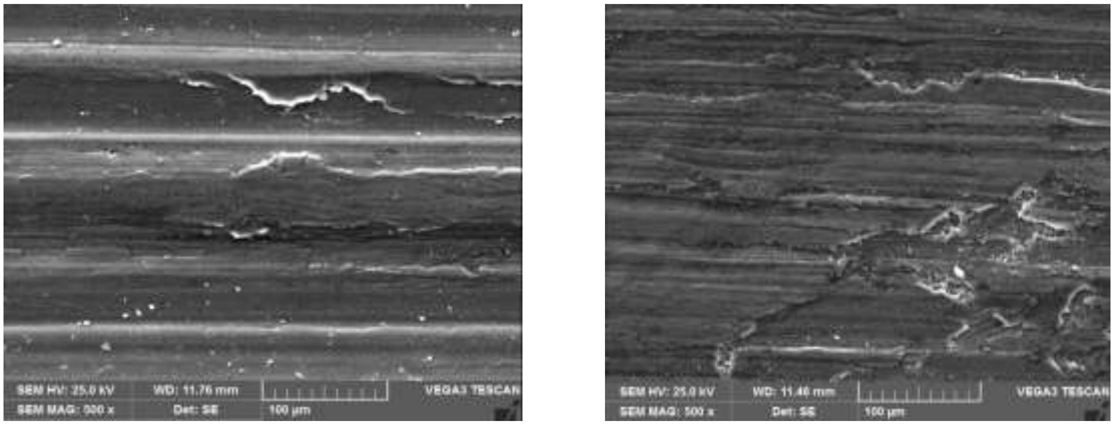
It is important to study the morphology of the worn surface of the LM29 alloy and its compounds, since it shows the type of wear that materials of different composition have suffered. During sliding, the LM29 matrix is softer than the friction disc material and therefore exhibits a viscous flow in the LM29 matrix, which is in the shape of a pin and causes a plastic deformation of the sample surface which leads to a very high loss of material. The weathered surface of the LM29 alloy shows the presence of grooves, micropits, and a cracked oxide layer as shown in Figure 8 (a), which would have increased wear loss. While the B_4C particles in LM293, 6 and 9 wt. % of 40 µm.The B_4C composites restrict the viscous flow of the matrix, as shown in Fig. 8 (b-d), it is observed that the grooves or erosion have decreased with the increase of B_4C particles, which means that there are more and more resistance to bear loss. Meanwhile, the stress seems to transfer to the B_4C particles and the concentration of strain occurs around these B_4C particles, and the weathered surface shows fewer and fewer cracks and grooves as the B_4C particles.



(a)



(b)



(c) (d)

Fig. 7(a-d):- Worn surfaces SEM micrographs of (a) LM29 Alloy (b) LM29-3 wt. % B_4C (c) LM29-6 wt. % B_4C (d) LM29-9 wt. % B_4C composites with 40 micron particles.

Conclusions:-

The present work on the processing and evaluation of LM29-B_4C metal matrix compounds by melt stirring has led to the following conclusions. Composites based on LM29 alloys have been successfully produced by melt stirring processes, using a two-stage addition process for reinforcement combined with preheating of the particles. SEM photomicrographs of composites showed a uniform distribution of reinforcing particles in the LM29 metal alloy matrix. The addition of B_4C particles to the LM29 alloy matrix improves the wear resistance of the composite. Wear loss is dominated by load factor and sliding speed. The increase of loads and sliding speeds leads to a significant increase in the wear loss. The LM29-B_4C composites have shown lower rate of volumetric wear loss as compared to that observed in as cast LM29 alloy matrix. SEM micrographs of worn surface revealed the presence of smooth grooves in the LM29-B_4C composite compared to the base matrix.

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