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IN SITU WEAR PERFORMANCE ON AL 3102 ALLOY HYBRID COMPOSITES FABRICATED BY STIR CASTING METHOD

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ABSTRACT

This paper deals with the tribological behavior of Aluminium 3102 alloy reinforced with Boron Carbide and Titanium Dioxide fabricated with the stir casting method. The composite fabricated by this particular method can be used for applications like manufacture of brake disks with high wear performance and efficiency at high temperatures. The wear performance and frictional properties of the Aluminum based metal matrix composites were studied by various tests such as pin on disc, surface roughness test and so on. The experiments were employed at ambient temperature and as well as at 300°C with various concentrations of reinforcement. B_4C and TiO_2 were the two reinforcing materials used in this study. Further Al-B4C composites exhibited better wear resistance compared to monolithic Aluminium. In the current project there are 3 test specimen compositions, one is pure Aluminium and others are hybrid composites with 95.5% Al 3% TiO_2 1.5% $B_4C$and 91% Al 6% TiO_2 3% B_4C compositions. The present investigation of the work is to find the most feasible composition of MMC + B_4C in various weight percentages. Moreover, Boron Carbide is widely used for its hardness and Titanium Dioxide is selected considering it's properties in reducing microholes and porosity.

KEYWORDS: Stir Casting Method, Wear, Composite Materials, Hardness, Porosity.

I. INTRODUCTION

A few selected research journals related to MetalMatrix Composites (MMC) and Hybrid casting has been discussed in this chapter. These studies mainly focus on the physical properties such as wear resistance, fatigue resistance, strength to weight ratio etc. Special concentration is provided on particle reinforced aluminum hybrid composite as the current paper is based on this process. Properties of aluminium matrix composite are highly influenced by nature of reinforcement which can be either in continuous or discontinuous fibre form. It also depends on the selection of processing techniques for the fabrication of aluminium matrix composites which depends on many factors including type of matrix and reinforcement, the degree of microstructural integrity desired and their structural, mechanical, electrochemical and thermal properties Devendra Kumar et.al (2019). J.W.Kaczmar et.al (2000) inverstigated the production methods and properties of metal matrix composite materials reinforced with dispersion particles, platelets, non-continuous (short) and continuous (long) fibres. The most widely applied methods for the production of composite materials are based on casting techniques such as the squeeze casting of porous ceramic preforms with liquid metal alloys and powder metallurgy methods. On account of the excellent physical, mechanical and development properties of composite materials, they are applied widely in aircraft technology and electronic engineering, and recently in passenger-car technology also. the microstructures of the HAMCs produced by stir casting process have been found to be stable with uniformdistribution of reinforcing particles. Also, the HAMCs can be produced with different combinations of reinforcements to derive desirable mechanical properties not available in ceramic reinforced composites. The study concludes that HAMCs can be used as a replacement for conventional materials in advanced applications Jaswinder Singh and Amit Chauhan(2016). Discusses the Tribological conduct of aluminum compound (Al-Si10Mg) strengthened with alumina (9%) and graphite (3%) created by stir casting process. The wear and frictional characteristics of the hybrid metal matrix composites was investigated by dry sliding wear test using a pin-on-disc wear tester. The Experiments were conducted based on Taguchi's technique. The results show that sliding distance has the greatest influence followed by load and sliding speed The confirmation procedures were carried out to verify the experimental results and Scanning Electron Microscopic was used to perform studies on the wear surface N.Radhikaet.al(2011). The composition of fly ash in the MMC is 8% and 10% respectively. The MMC is produced in the gas furnace by heat treatment at 350 and 400°C.Hard testing process, tensile test and impact test are conducted on MMC before heat treatment and after heat treatment. The test results showed an increase in hardness, tensile strength and impact test for the heat treatment at a temperature of 3500C Heat treatment at a temperature of 400 0C does not improve the mechanical properties of the MMC Aminnudin Aminnudin and Moch. AgusChoiron (2018). Arun Kumar D T et.at (2018) Investigated fly ash has been reinforced in Al-SiC metal matrix, and its mechanical properties were evaluated. 10% of the molten metal after solidification, mechanical properties, Impact test and Hardness test were carried out, and results were noted. The microstructure of the composite was observed using Scanning Electron Microscope (SEM).The results shows an increase in the hardness and impact strength up to 15% of fly ash content. Hariharanet.al (2017) the addition of graphite content to aluminium alloy increases the wear resistance and also act as a solid lubricant material. The hardness, tensile strength, flexural strength and compression strength of the Hybrid aluminium matrix composite are found to be increased by increasing the weight percentage of ceramic particles. The results show that the addition of graphite content to aluminium alloy increase the wear resistance up to certain wt. % of graphite particles and decrease the hardness of composites. Also the machinability is increased with addition of graphite particles. The effect of adding ceramic particles such as SiC, Al2O3 and B4C in AA 7075 to increase the mechanical properties such as tensile strength, compressive strength and flexural strength. study was carried out to investigate the mechanical properties such as hardness, tensile strength, compression strength. As a result hardness decreases with the increase in the percentage of Gr, tensile strength and compression strength increases with the increase in Gr particulates with the influence of SiC particulate AL 6061 hybrid composite material containing SiC and Gr particulates were fabricated successfully by varying wt% of Gr from 3% to 9% using stir casting method Niranjan K N et.al (2017). The composites materials fabricated by stir casting by using different types of reinforcement materials are the better replacement with aluminium. Wear behavior of composites materials made by stir casting are reviewed in this literature and also the effect of the wear parameters on the properties of aluminium composites Anil Parmar (2015). It was found that the hardness increases as reinforcement content increases. From analysis of variance reveals that the applied load has the highest influence on both wear rate and coefficient of friction, followed by sliding speed and weight percentage of reinforcement. The results obtained by this method are useful in improving the dry sliding wear resistance Subramaniam et.al (2013). Kenneth Kanayo Alaneme et.al (2015) author performed of these materials is mostly dependent on selecting the right combination of reinforcing materials since some of the processing parameters are associated with the reinforcing particulates. This paper presents the overview of the different reinforcement materials used in AMMCs and their effects on the mechanical and tribological properties like hardness, compression, tensile strength and wear resistance of the materials.

II. METHODOLOGY

In this chapter discuss about the experimental work using hybrid aluminium matrix composite fabricated by hybrid casting.In this experimental setup the selection of material, equipment,wear testing, surface roughness testing,VMS testing etc. are done. The hybrid casting process was carried out on the stir casting equipment of Nano Tec Ltd. Installed at Composite materials Lab of Manufacturing Engineering Department, College of Engineering , Anna University Guindy, Chennai-25,Tamil Nadu, India. The discussions related to the measurement of parameters such as surface roughness, wear resistance etc. are presented in this chapter.

The experimental setup consists of a conical shaped crucible for melting the aluminium alloy. The maximum operating temperature of stir casting equipment is 1000 Celsius. The temperature inside the furnace is manually adjusted to 900 Celsius for the purpose of melting aluminium 3102 alloy. At liquid stage aluminium is very reactive to atmospheric oxygen, and hence oxide formation occurs while aluminium is in contact with the atmosphere. And therefore the slag produced by oxidation process must be removed. A stirrer which is connected to an electric motor is used to create a vortex to mix the reinforcement. A digital control interface is provided in the stir-casting equipment so that we may control different parameters such as temperature and rpm.

The digital display will give the temperature readings and analogue pointer shows electric current readings in ampere (A). Casting is a manufacturing process in which molten metal is pored into a mould of desired shape. The metal is allowed to solidify and then it is ejected out of the mold to complete the process. Stir casting (Figure 1) is a liquid state manufacturing method used for the fabrication of composite materials. A mechanical stirrer is used for stirring and mixing the reinforcements into the matrix and casting parameters also being mentioned in the Table 1. Melting of matrix material is the primary step in this process. And then the molten material is stirred by a mechanical stirrer followed by the feeding of reinforcement. The reinforcements used in this project are Boron Carbide (B_4C) and Titanium Dioxide (TiO_2). The reinforcements are preheated in a box furnace to a temperature of 400°C. And then the mixture is continuously stirred and poured into a mouldand later it is allowed to cool. After the complete solidification the material is either ejected or broken out of the mould to complete the process.

Fig-1: Shown A Flow Diagram of Casting Process.

VMS can be manual or CNC depending upon the applications. When a large number of dimensions are to be measured, then a CNC system is best suited and manual for smaller dimensions. The VMS optically magnifies the image of a part captured using a camera and is converted into a video signal that can be analyzed to determine the edges and features. The relationship among edges and features are compared to other imaged areas to provide dimensions were measured. Surface roughness or roughness is a component of surface texture. Roughness is used to determine the performance of a component or a work piece. Roughness is quantified by the deviations in the direction of normal vector from its ideal form. The surface is rough if these deviations are large and if they are small the surface is smooth. Ra is the parameter for surface roughness. The average roughness is measured by comparing all the peaks and valleys to the mean line and then averaging all over the entire cut of length. Cut of length is defined as the length that the stylus is dragged across the surface. Larger cut off length is preferred because it will give a better average value and a shorter cut off length might give a lesser average value than the larger cut off length.

Table-1: Process Parameters of Stir Casting Process

SL. No	Parameters	Range
1	Matrix Material	Aluminium 3102
2	Reinforcement (composition 1)	1.5% B_4C & 3% Tio2
3	Reinforcement (composition 2)	3% B_4C & 6% Tio2
4	Melting Temp of Al 3012	700^{o}C
5	Preheating Temp	400^{o}C
6	Max. Temp of Equipment	1000^{o}C
7	Stirring Speed	350 – 400 rpm

III. RESULTS AND DISCUSSION

In this chapter, the tribological behaviour of the Al 3102 Alloy hybrid composite under different temperatures and compositions of reinforcements based on the factors like surface roughness, wear resistance are discussed.

Non Contact Surface Roughness Test:

The non contact surface roughness tester uses light instead of the stylus used in contact type measuring instrument. The profiles of the surfaces for each composition are measured under two different temperatures i.e room temperature and 3000C. Figure 2 above is an illustration of the surface roughness profile of pure Aluminium at ambient temperature. It provides a good general description of height variations in the surface. The mean Roughness (Ra) is calculated as 1.231 µm from the figure 2. It is the arithmetic average of the absolute values of the roughness profile ordinates. The 2D surface geometry of the specimen. The height and depth of the peaks and valleys along the surface are represented by it's respective color code. The top most colors on the spectrum symbolize the parts with the highest peak height and vice versa. Figure 2 is a 3D visualization of the surface geometry. On visual inspection, the surface of the specimen exhibits a moderate roughness. The roughness profile (Fig.2) of the surface helps in predicting how the surface will interact with its environment. The roughness parameter (Ra) is determined with the help of the roughness profile. It is calculated as 1.231 µm which displays an intermediate roughness. illustrates the surface roughness profile of pure Aluminium at a temperature of 300^{o}C. The mean roughness (Ra) is calculated as 1.231 µm which is same as the average roughness of the metal at ambient temperature. The surface geometry of the specimen at a temperature of 300^{o}C. By visually inspecting it is evident that there is no considerable change in surface roughness on comparison with that of pure Aluminium at ambient temperature. The roughness parameter (Ra) calculated from the roughness profile has a value of 1.231 µm which is the same as that of pure Aluminium at ambient temperature. So it can be concluded that the surface roughness of pure Aluminium undergoes only a negligible change with increase in temperature. illustrates the surface roughness profile of the HAMC withthe composition Al 95.5% TiO_2 3% B_4C 1.5 % . The mean roughness (Ra) is calculated as 1.826 µm. Figures 2 represent the surface geometry of the composite with Al 95.5% TiO2 3% B_4C 1.5 % at ambient temperature. On visual inspection it is evident that there is an increase in surface grooves which results in an increase of surface roughness. The mean roughness (Ra) is calculated as 1.826 µm. Therefore it is clear that the surface roughness has increased with the addition of reinforcement. On examining the surface geometry in the figures 2, with the increase in temperature a small increase in the surface grooves can be seen. This points out the fact that with the increase in temperature surface roughness increases. But, the volume of the reinforcement is not directly proportional to roughness. The second composition has the highest roughness among the three cases considered. the effect of surface roughness on wear performance, we have to consider the contact area between the two surfaces. When the surface is more rough, the surface consists of higher peaks and deeper valleys. This reduces the area of contact between the two surfaces. Lesser area under contact means lesser wear rate. Therefore the roughest surface will be having the highest wear performance. From the above study, the HAMC withthe composition Al 95.5% TiO_2 3% B_4C 1.5 % exhibits higher wear performance.

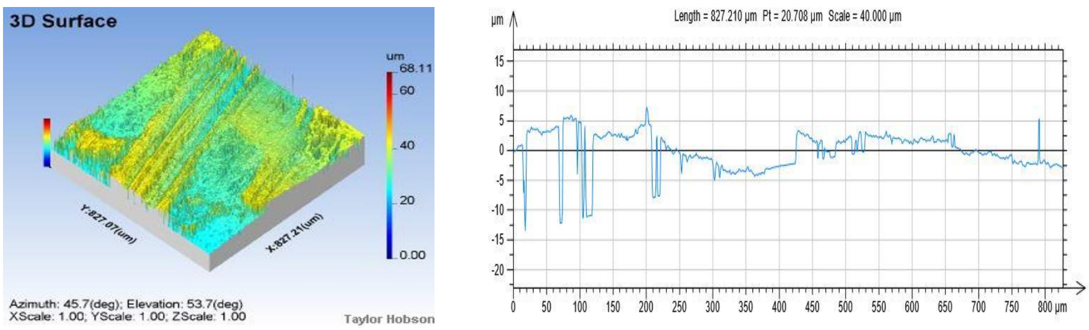

Fig-2: Different Surface Geometry Representation for Pure Aluminum.

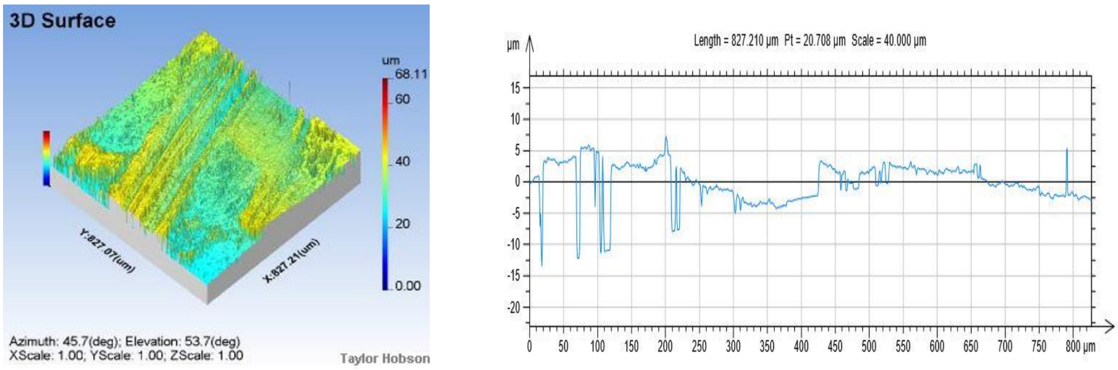

Fig-3: Roughness Profile of Pure Al at Room Temperature.

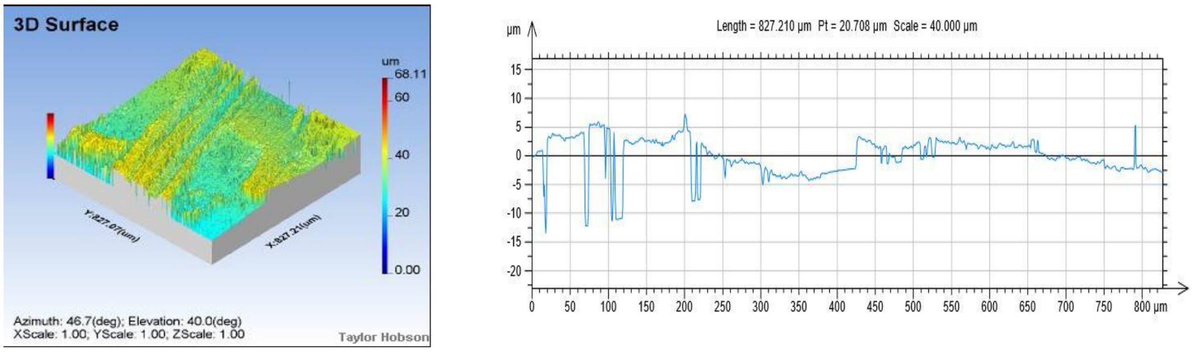

Fig-2: Roughness Profile of Pure Al at 300^oC.

Pin on Disc Test:

Pin on disc test is one of the most commonly used tribometers and it is used because of its relative simplicity and abundance of the tribological contacts.In this test the pin is loaded on the disc by a dead weight loading system. In this study the pin is loaded on to the disc rotating at a speed of 637 rpm. The coefficient of friction and frictional force is calculated by loading the pin on the rotating disc for a time interval of 8 minutes under a constantload of 2kg. The maximum load that can be applied on the disc is 5kg. Sliding distance is considered as negligible in this experiment. The pin on disc test is carried out on pure Aluminium specimen under two different temperatures, primarily ambient temperature and followed by 300^oC for 8 minutes each.

Coefficient of Friction:

Figure 3 shows the relationship between time and coefficient of friction. The test was carried out for a time period of 8 minutes. The graphs are plotted by taking the values of coefficient of friction of the material at corresponding time periods. The value of co-efficient of friction is seen to be increasing with increase in time. Figure 4 is the time vs coefficient of friction relationship for Al at ambient temperature. Fig 4.20 (b) is plotted for Al at 300^oC. The pin on disc test is carried out in 95.5% Al 3% TiO_2 1.5% B_4C specimen under two different temperatures. , primarily room temperature and followed by 300^oC for 8 minutes.

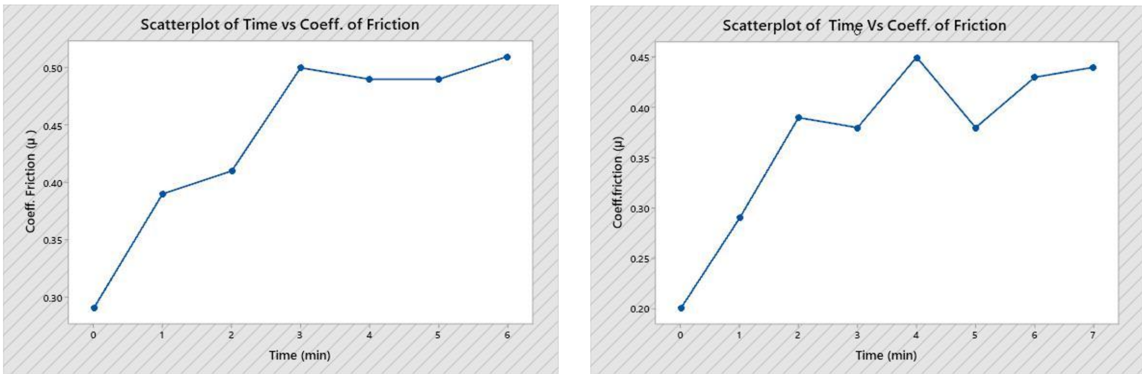

Fig-3: Graph plot between Time and Coefficient of Friction.

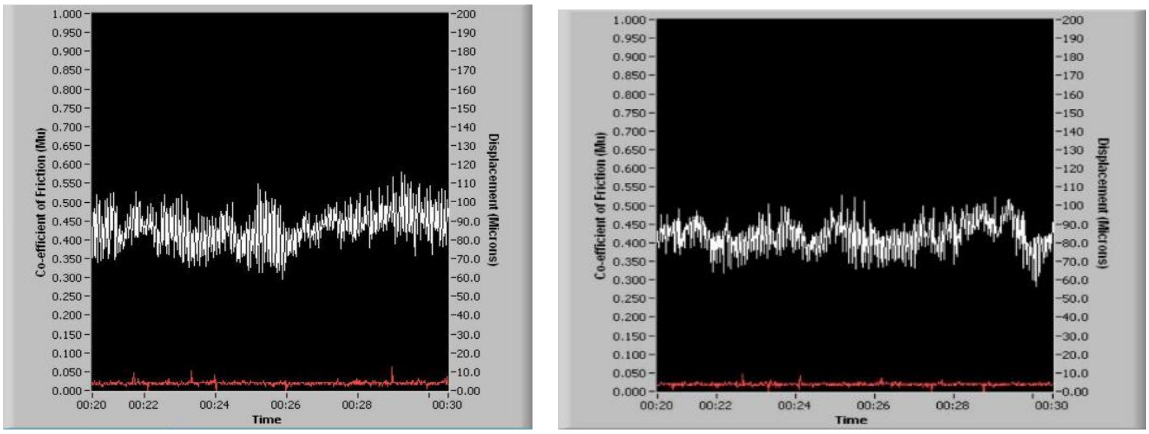

Fig-4: Shows Online Co-Efficient of Friction Chart Composition of 95.5% Al 3% Tio_2 1.5% B_4C Under Pin on Disc Testing.

Figure 4 shows the relationship between time and coefficient of friction. The test was carried out for a time period of 8 minutes. The graphs are plotted by taking the values of coefficient of friction of the material at corresponding time periods. The value of coefficient of friction is seen to be increasing with increase in time. Figure 4 is the time vs coefficient of friction relationship for Al at ambient temperature. Figure 4 is plotted for Al at 300^oC. The figure 4 above shows 95.5%Al 3% TiO_2 1.5% B_4Cpins that were used to conduct the Pin on disc test. The left pin was used to perform the test at ambient temperature while the one at the right was used to perform the test at a temperature of 300^oC. The test was carried out for a time period of 8 minutes. The graphs are plotted by taking the values of coefficient of friction of the material at corresponding time periods. The value of coefficient of friction is seen to be increasing with increase in time. The test was carried out for a time period of 8 minutes. The graphs are plotted by taking the values of coefficient of friction of the material at corresponding time periods. The value of coefficient of friction is seen to be increasing with increase in time. Figure 5 is the time vs coefficient of friction relationship for the composition at ambient temperature.

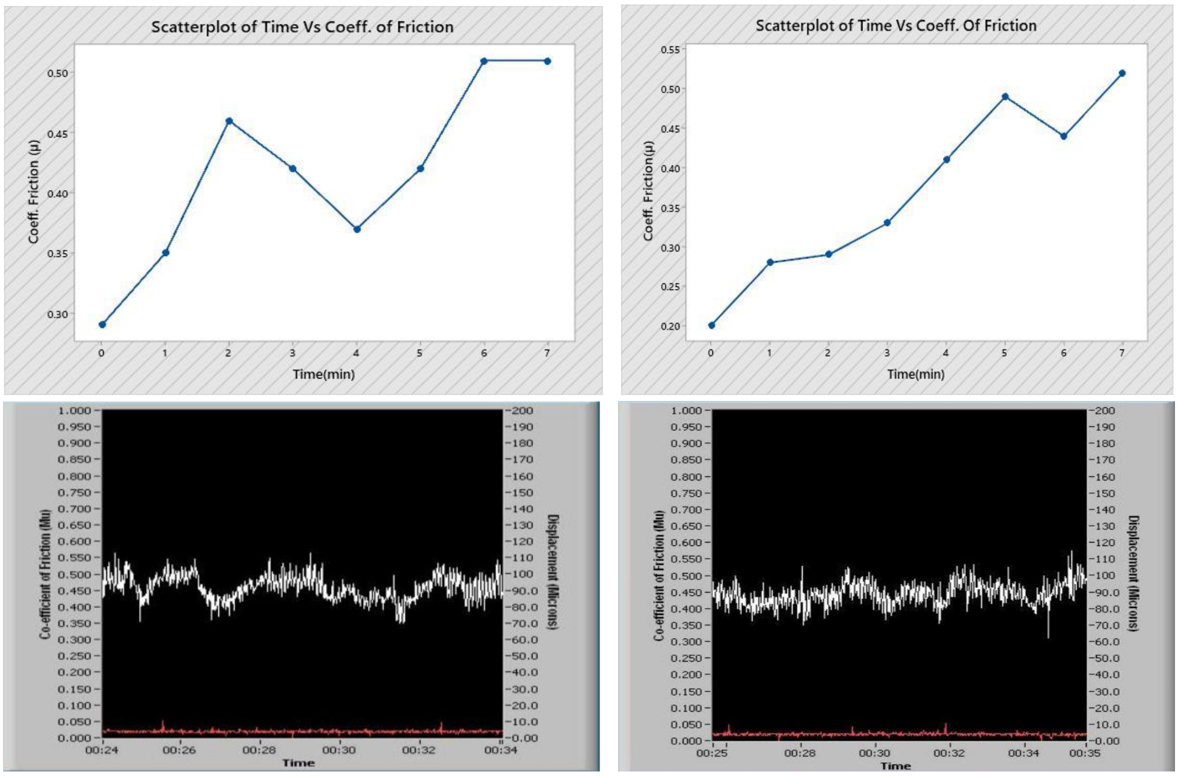

Fig-5: Shows Online Co-Efficient Of Friction Chart Composition Of 91% Al 6% Tio_2 3% B_4C Under Pin On Disc Testing.

VMS Testing:

Video measurement system or co-ordinate measuring machines are specially designed for precise dimensional measurements of small parts. The ends of pins in contact with the disks during the pin on disk test are observed through the video measurement system. The Figure 6 shows the surface of the pin in contact with the disk during pin on disk test at ambient temperature. A large number of grooves can be seen on the surface. It is evident that the surface has undergone wear. The pin surface temperature of 300°C was measured. It has a greater number of grooves which seem to be deeper upon visual inspection.Therefore it is clear that pure Aluminum undergoes greater wear at high temperatures.

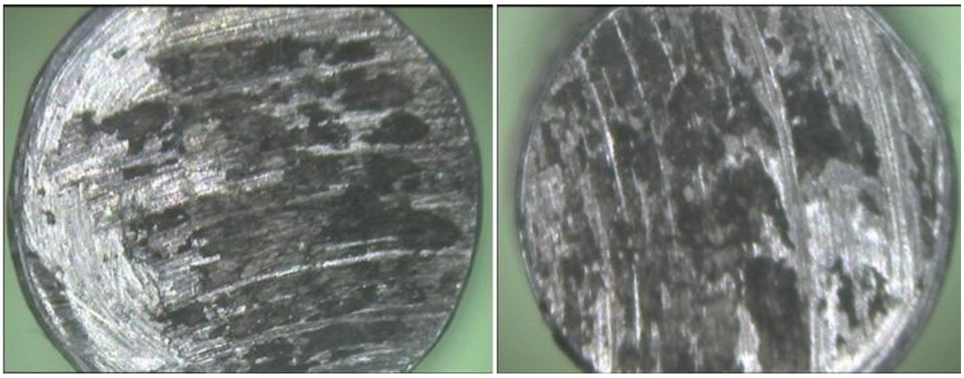

Fig-6: Shows Worn Surface 95.5% Al 3% Tio2 1.5% B_4C at Ambient Temperature.

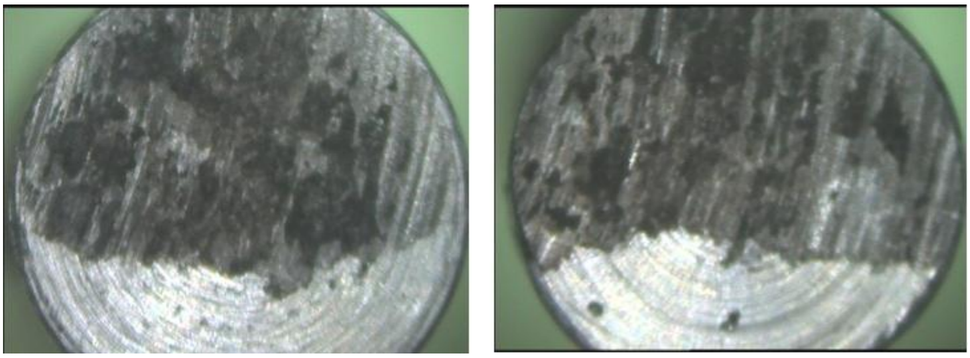

Fig-7: Shows Worn Surface 95.5% Al 3% Tio2 1.5% B_4C at 300°C.

Figure 7 shows the surface of the particular pin in contact with the disk during the pin on disk test at ambient temperature and 300^{O}C respectively. Upon visual inspection, it can be noted that the surface has undergone lesser wear as compared to pure Aluminium pin. Therefore the HAMC with the composition 95.5% Al 3% TiO_2 1.5% B_4C has a significantly improved the wear perfomance at higher temperatures. Therefore it is evident that the addition of the reinforcement has a large impact on the wear perfomance. The surface of the particular pin where is contact with the disk during the pin on disk test both at ambient temperature and 300°C respectively. Upon visual inspection, it is seen that the surface has a considerably larger number of gooves and surface wear when compared to the surface of the previous composition. It is evident from the results that wear perfomance is not directly proportional to the volume of the reinforcement added.

IV. CONCLUSION

The investigation on the wear behavior of Al 3102 reinforced with B4C and TiO2 led to the following conclusions; the surface roughness increases with the increase in Temperature. At increased temperature (300°C), the change in surface roughness of the pure Aluminum is negligible. At increased temperature (300°C), the hybrid composites reinforced with with B4C and TiO2 had an increase in surface roughness. Among the two composites, the composite with the composition 95.5% Al 3% TiO2 1.5% B4C has the highest surface roughness. So this is considered as the optimum composition to provide the best wear resistance. The composite exhibits high wear resistance at high temperatures. As the composite exhibits higher roughness and wear resistance at elevated temperatures, this can be used for the manufacture of brake disks. The behavior of the HAMCs greatly depend on significant parameters of the reinforcements like volume content, grain size and temperature.

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