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Wear Analysis of Al5052 Metal Matrix Composite by Stir Casting

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ABSTRACT:

Demand rises in a worldwide series of the metal matrix composites at national and international level. A composite is made by combining at least two different materials having different properties. Among this, an MMC is a metal matrix composite which has gained credibility in the automotive industry. . In this project, we are making an AMMC which has an aluminum metal matrix and any fiber or particle as reinforcements. Manufacturing of aluminum alloy based casting composite by stir casting is one of the most economical method of processing MMC. The global need for reduced weight, low cost, quality, and high performance in structural materials. During these processing techniques, grain growth takes place due to agglomeration of the reinforcing particles, which changes the microstructures. To control the grain size and agglomeration of Nano particles during the processing and retaining the improved microstructure is a challenging task. This study is to investigate the numerous issues, their root causes, and potential solutions as they relate to the stir casting method generation of metal matrix composites. Tungsten carbide (WC) normally used for manufacturing wear resistant tools, cutting tools and carbide steel because of its wear resistance properties. In this the wear behavior of Al 5052 alloy analyzed by reinforcing with varying weight percentage of tungsten carbide (1%, 2% & 3%) fabricated using stir casting process. Dry sliding wear behavior is performed by means of Pin-on-disc wear testing apparatus. The process parameters are composition, Speed, Load, distance and the responses are Coefficient of Friction and specific wear rate. The results show that the addition of WC particles has a significant effect on the wear properties of the composite material.

Keywords: Stir Casting, Al-5052, MMC-Metal Matrix Composite, Reinforcement material (WC), Pin on Disk.

Introduction:

The process of metal matrix composite materials is to combine the desirable attributes of metals and ceramics. By carefully controlling the relative amount and distribution of the ingredients of a composite as well as the processing conditions, these properties can be further improved Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production, and allows very large sized components to be fabricated. In general, the solidification synthesis of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispersoids under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix. Unwanted irregularities in the metal casting process are known as casting defects. Specific strength of hybrid composite materials is much higher than other materials, such as steel. In the automotive industries, weight reduction is the primary goal which promotes to replace the ordinary components with MMCs. Several ranges of secondary particle materials are available and the innovative casting technologies are paying attention on mass production of various MMCs. The various hybrid composite materials are generally categorized into two types the reinforcement particle and matrix materials used for manufacturing. As per the matrix material composites; it is categorized as Polymer Matrix Composites (PMCs), Metal Matrix Composites (MMCs), Carbon Matrix composites, and Ceramic Matrix Composites (CMCs). Metal matrix composites (MMC) are advanced materials that consist of a metallic matrix reinforced with a second material, often a ceramic, to enhance mechanical properties. One of the most popular methods for manufacturing MMCs is stir casting, which involves adding ceramic particles or fibers into a molten metal matrix, followed by stirring to distribute the reinforcements uniformly. Stir casting is a cost-effective and versatile method for producing MMCs, and it is particularly suitable for creating composites with high particle loading and complex geometries. It also allows for the use of a wide range of matrix materials, including aluminum, magnesium, copper, and nickel, and various ceramic reinforcements such as silicon carbide, alumina, and zirconia. One of the advantages of stir casting is its ability to produce MMCs with high particle loading and complex geometries. The method is also cost-effective and versatile, allowing for the use of a wide range of matrix materials, including aluminum, magnesium, copper, and nickel, and various ceramic reinforcements such as tungsten carbide, alumina, and zirconia. Additionally, the properties of MMCs produced by stir casting can be tailored to meet specific performance requirements by adjusting the composition and processing parameters.

Stir Casting:

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten Aluminum by mechanical stirring. A typical stir casting process of Aluminum alloy matrix composite is illustrated in **Fig** .Mechanical stirring in the furnace is a key element of this process. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added. An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum Al5052 reinforced with WC particles.

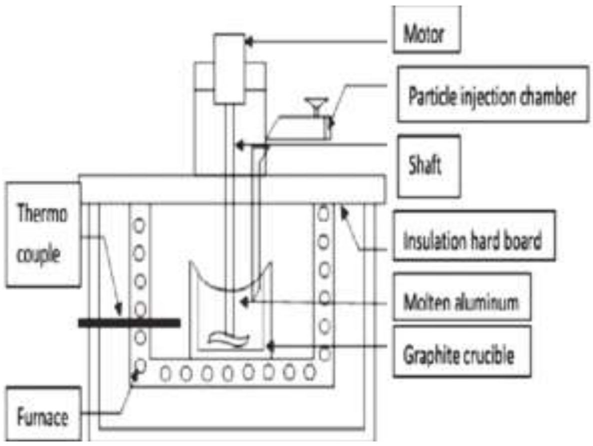


Fig: Schematic view of stirring mechanism for the Fabrication of composite

Methodology:

Stir casting is a liquid-state method for the fabrication of metal matrix composites. It involves mixing molten metal with a reinforcing material, such as ceramic or carbon fibers, using a stirring device to disperse the reinforcing material evenly throughout the metal matrix. The process begins by melting the metal matrix in a furnace or crucible, followed by the addition of the reinforcing material into the molten metal. The stirring device is then inserted into the mixture and rotated at a high speed to promote the even distribution of the reinforcing material. The stirring can be performed using various types of stirring devices, including electromagnetic stirrers, impeller stirrers, and rotating rod stirrers. The benefits of using stir casting include the ability to produce composites with a high-volume fraction of reinforcing material, good adhesion between the matrix and reinforcing material, and the ability to fabricate complex shapes and sizes. Additionally, stir casting can be performed at relatively low temperatures, which reduces the risk of thermal degradation of the reinforcing material. The limitations of stir casting include the potential for the formation of oxide films on the surface of the molten metal, which can reduce the adhesion between the matrix and reinforcing material. Additionally, the stirring process can cause the reinforcing material to break down, leading to the formation of undesirable particles and voids in the composite. Overall, stir casting is a widely used method for the fabrication of metal matrix composites, offering a range of benefits and limitations that should be carefully considered during the research design and execution. In pin-on-disk testing, a pin or a ball is loaded against a rotating disk, and the wear behavior of the composite material is analyzed based on the wear scar diameter and the weight loss of the pin or ball. In scratch testing, a sharp stylus is drawn across the surface of the composite material, and the wear behavior is analyzed based on the scratch depth and width. Wear rate measurements involve the measurement of the mass loss of the composite material over a specified period of time under controlled environmental conditions. The wear characteristics of Al 5052 alloy reinforced with various percentage of WC whose wear resistance is studied by means of pin-on-disc wear testing apparatus. The pin specimen of dimension 8 mm diameter and 32 mm height were made by machining and polishing. The disc material used was EN 31 were grounded and polished well to make the surface even and smooth. The tests were conducted by varying load of 9.81N, 19.62N and 29.43N at a room temperature of 30°C and 62 to 65% of relative humidity with three different speeds of 100, 200 and 300rpm. The 8 pins were made ready for the test as Taguchi L27 orthogonal array were used for designing the experiments. In order to find the mass loss, each pin is weighted in electronic weighing machine before and after the test. The specific wear rate and co-efficient of friction can be calculated by equation (1) and (2) respectively.

Three different compositions Al 5052 alloy reinforced with tungsten carbide are shown below.

- Aluminum – with 1%of WC

- Aluminum – with 2% of WC
- Aluminum – with 3% of WC

Al 5052 alloy of 750gm is heated at 850°C in a graphite crucible. Once the temperature of the alloy reaches the pouring temperature the stirrer is introduced into the crucible. When the alloy gets melted the reinforcement alloy Tungsten carbide (WC) of 1%wt were poured inside the crucible and stirred continuously for the complete mixture of alloy ceramics. The mixture was stirred for a period of 10 min at 400 rpm with the temperature of 950°C. After well diffusion of melt and reinforcement it is then poured in preheated cylindrical die of 8 mm diameter and 32 mm length and allowed to cool in the atmosphere. Then this process is repeated for remaining percentages of Tungsten carbide (3, 5 and 7%wt). It shows the stir casting used for the preparation of alloy.

Nano particles used in Stirring Process:

Reinforcements which increases the Mechanical Properties of the Specimen are the Nanoparticles like Tungsten Carbide (WC). Tungsten carbide (WC) is a ceramic material composed of tungsten (W) and carbon (C) atoms in equal parts by weight. It is a very hard and dense material with exceptional wear resistance, high melting point, and good chemical stability. It is commonly used as cutting tools for machining applications, such as drilling, milling, and turning. The metal matrix composites were prepared using Stir casting technique by varying the WC in wt.% of 1%, 2%, 3%. When the WC content in tungsten carbide is increased from 1% to 2%, the hardness and strength of the material also increase. This is because the higher percentage of tungsten carbide leads to a denser and harder material. Similarly, increasing the WC content from 2% to 3% can further increase the hardness and strength of the composite, but it may also reduce its toughness and ductility. Additionally, the increased tungsten carbide content can lead to increased processing difficulties and higher production costs.

Materials:

Selection of Base Material :

EN31 is a very high strength steel alloy that is hardened and tempered before supplying and has nickel, chromium, molybdenum making its high tensile steel strength, with good ductility and wear resistance. With relatively good impact properties at low temperatures, EN31 is also suitable for a variety of elevated temperature applications. EN31 have good internal strength and high external strength, which makes them highly wear-resistant. EN31 steel round bars offer a good combination of ductility, strength, and wear resistance. EN31 is a very high-strength alloy engineering steel.

Preparation Of Disc Sample :

Disc having diameter of 100mm with the design specifications of the apparatus.

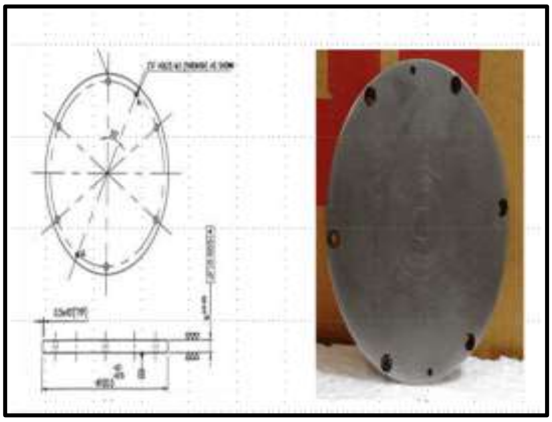


Fig shows the dimensions of EN 31 disc

Selection of Pin Material :

5 series aluminum alloy is mainly magnesium. Good corrosion resistance, good welding performance, good fatigue strength, cannot be strengthened by heat treatment, only cold processing can be used to increase strength. The main features are low density, high tensile strength and high elongation. Under the same area, the weight of aluminum magnesium alloy is lower than that of other series, so it is commonly used in aviation, such as aircraft fuel tank, and is also widely used in conventional industry. Common grade of 5 series aluminum plate: 5052.5083.5a02, etc. 5052 aluminum plate has good corrosion resistance, excellent weldability and good cold workability, and has medium strength. It is mainly used for low load parts that require high plasticity and good weldability and work in liquid or gas media, such as oil tank, gasoline or lubricating oil conduit, various liquid containers and other low load parts made by deep drawing. As the hardness of the pin material should be very low in comparison to the hardness of the disc material in order

to properly understand the wear and friction properties. Aluminum was chosen as a pin material that exhibits good wear and provides smooth graphical representation with the EN 31 base material.

Fig shows the Al pin

Pin on Disk Test:

Friction and wear (typically wear rates and wear resistance) characterization of materials is typically performed using various types of tribometers, while pin on disk test being probably one of the most common. The popularity of the method is due to its relative simplicity and abundance of the tribological contacts that can be well described by a simple pin on disk motion: from dry contacts of bolt screws to rail wheels to rail contact and to lubricated contact of biological implants.

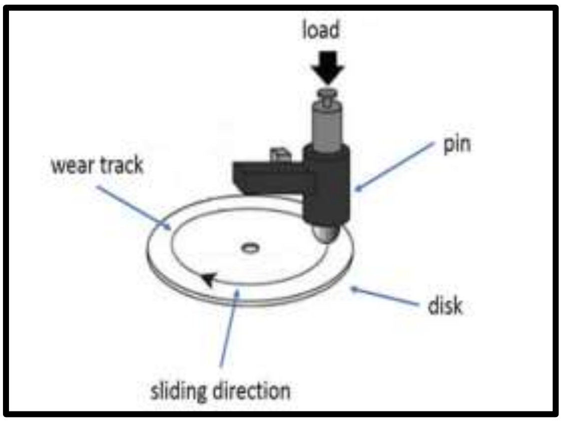


Fig : Pin on Disk Test

Pin on Disc tribometer:

A tribometer is a device that measures tribological properties such as coefficient of friction, frictional force, and wear volume. Several arrangements are present based on the contact arrangement: Four ball, three ball, pin on disc, block on ring, twin disc, bouncing ball. Schematically, the pin on disk test is depicted in the figure above. The stationary pin is pressed against rotating disk under the given load. The pin can be of any shape; however, the most popular shapes are spherical (ball or lens) or cylindrical due to ease of alignment of such pins (flat pins are typically subject to certain misalignment which can lead to non-uniform loading and difficulties for theoretical analysis). During the test, the friction force, wear and temperature are continuously monitored. A typical friction curve measurement recorded on a pin on disk apparatus is shown in the figure below:

As can be seen form the figure, at the start of the test, the measured coefficient of friction (COF) is high and with further progress drops. This behavior is typical friction measurements and is attributed to a running-in phenomenon. During the running-in, the surface topography changes, chemical reactions takes place until the system comes to a steady-state state. This steady state COF is then usually reported.

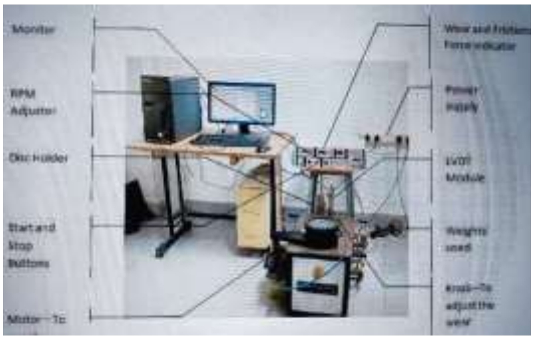


Fig shows the Pin on Disc Tribometer

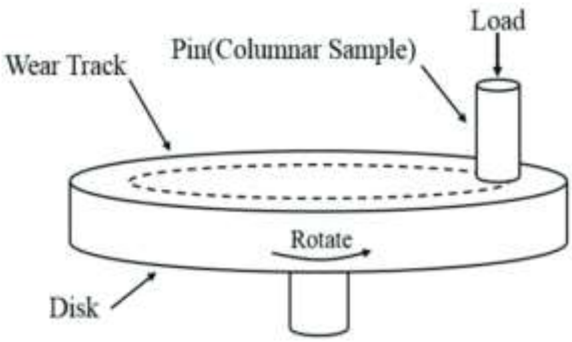
Test parameters :

- Load
- Track diameter
- Time
- Rotational speed
- Sliding Distance

Experimental Procedure :

- The disc and pin needs to be fixed to the wear test module with the help of suitable Allen keys.
- With the help of Allen key adjust the wear track diameter.
- Connect the power and switch on the module and the Software system attached to it.
- Open and Create the required Data file in WINDUCOMM Software.
- Lift the pin contact and adjust the speed by turning the knob and also press the time buttons to set the required time.
- Add the required loads and adjust the LVDT module readings(wear and friction force) by adjusting the rotating screws.
- Ensure all the experiment conditions are set and begin the Experiment by clicking “Run continuously” and then press start by simultaneously clicking Start on both software and wear test module.
- Record the Data and save the graphs.
- Record the values of Coefficient of friction by using View file option.

Calculations:



We know that,

Density$(\rho) = \frac{m}{V}$

By using this formula, we can calculate the actual volume lost after the grooves are made

V=$\frac{m}{\rho}$

Where m= mass of the materials

ρ =Known Density of the materials

Also, we can calculate Wear co-efficient by the formula,

V= $\frac{K}{H} \times F \times S$

From this, K= $\frac{V \times H}{F \times S}$

Where V= Volume lost (mm^3)

K= Wear coefficient of the material

H= Hardness Number ×9.81 (MPa)

F= Force applied on the material (N)

S= Rubbing distance (mm)

S can be calculated by S= $C \times N \times t$

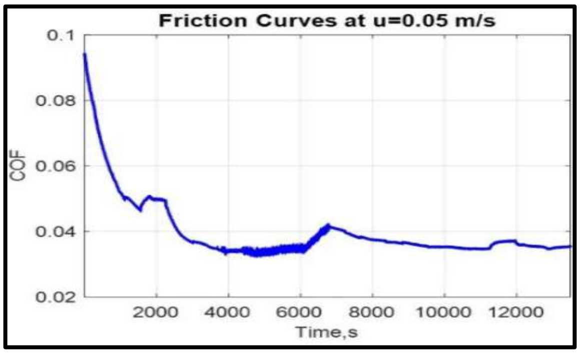
Where C= Circumference of the disc (mm/rev)

C= 2Πr

N= Number of revolutions per minute (rpm)

t= time taken for n number of rev (min)

Here the Force and Rubbing distance are constant for both the materials used.



Graph represents COF vs Time

Conclusion:

This preliminary study has shown that it is feasible to use a new moving pin technique for pin-on-disc wear testing. This technique is not only able to fully utilize the disc surface area but also to minimize the time required for disc regrinding as the depth of worn wear track is lower. Due to high toughness MMC can be used as shock absorber in various automobiles parts and other parts subjected to high impact. This paper presents pin on disk technique and wear properties of Al-MMCs reinforcing nano WC particles. The nano reinforced Al-MMNCs despite showing good over the unreinforced alloys. Microstructural evaluation showed the uniform distribution of nano WC in the metal matrix, as well as strong bonding between the particle and matrix at the interface. The porosity levels obtained in these composites are within acceptable limits.

References:

1. Guicciardi, S., Melandri, C., Lucchini, F., & De Portu, G. (2002). On data dispersion in pin-on-disk wear tests. *Wear*, *252*(11-12), 1001-1006.
2. Pawar, P. B., Wabale, R. M., & Utpat, A. A. (2018). A comprehensive study of aluminum based metal matrix composites: challenges and opportunities. *Materials Today: Proceedings*, *5*(11), 23937-23944.
3. Chandra, D., Chauhan, N. R., & Rajesha, S. (2020). Hardness and toughness evaluation of developed Al metal matrix composite using stir casting method. *Materials Today: Proceedings*, *25*, 872-876.
4. Kumar, P., Hirani, H., & Agrawal, A. (2015). Scuffing behaviour of EN31 steel under dry sliding condition using pin-on-disc machine. *Materials Today: Proceedings*, *2*(4-5), 3446-3452.

5. Yang, L. J. (1999). Pin-on-disc wear testing of tungsten carbide with a new moving pin technique. *Wear*, *225*, 557-562.
6. Baburaj, A., KB, S. S. C., Khatirkar, R. K., & Sapate, S. G. (2013). Abrasive wear behaviour of heat treated En31 steel. *ISIJ international*, *53*(8), 1471-1478.
7. Sharma, V. K., Singh, R. C., & Chaudhary, R. (2017). Effect of flyash particles with aluminium melt on the wear of aluminium metal matrix composites. *Engineering science and technology, an international journal*, *20*(4), 1318-1323.
8. Venkateshwar Reddy, P., Suresh Kumar, G., Satish Kumar, V., & Veerabhadra Reddy, B. (2020). Effect of substituting SiC in varying proportions for TiC in Al-552/TiC/SiC hybrid MMC. *Journal of Bio-and Tribo-Corrosion*, *6*(1), 25.
9. Samal, P., Vundavilli, P. R., Meher, A., & Mahapatra, M. M. (2022). Multi-response modeling for sliding wear behavior of AA5052/TiC composites by stir casting: a comparative analysis using response surface methodology and fuzzy logic system. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, *236*(2), 254-266.
10. Kishore, P., Kumar, P. M., & Dinesh, D. (2019, July). Wear analysis of Al 5052 alloy with varying percentage of tungsten carbide. In *AIP Conference Proceedings* (Vol. 2128, No. 1, p. 040003). AIP Publishing LLC