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Evaluation of Mechanical Properties of Borax and Graphite Based AL 6061 Composites

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Abstract: ***Metal matrix composites have application in many areas of daily life like automobiles, aerospace, marine & consumer related industries. The aim of this present investigation is to carry out a comparative study of the mechanical properties and physical properties of AL6061 composites containing Graphite & Boron particulates, the reinforcing particulates in the MMC's vary from 3%, 6% & 9% by weight with proportion of base metal matrix of 94%, 88% and 82%. The "Stir casting method" production was employed to fabricate the composites, in which the reinforcements were added & Stirring the Molten metal by means of a mechanical agitator. The composites produced were subjected to a series of tests.***

For micro structural investigation the samples are polished using different grades of emery papers, alumina paste and diamond polishing and etched with reagent for 10 seconds. For micro structural evaluation of Optical microscopy (OM) and Scanning electron microscopy (SEM) are used to investigate the MMC's structural arrangements. The density of the samples was measured by using water displacement method the results found to be 2.59, 2.61 and 2.62 g/cm3. The hardness measured using Vickers hardness tester at different location of the samples and the average is found to be 66.7±1.24, 47.7±1.24 and 41.7±1.7 HV respectively. The Tensile (E M8), compression (aspect ratio of 1.66), wear test (G95) samples are obtained as per the ASTM standard. And the Tensile, compression test was carried out using the UTM machine and the Ultimate Tensile strength & compressive strength was 111.5±12.42, 95.9±6.83, 78±16.8 M Pa (with young's modulus of 70, 64, 60) & 212.3±3.26, 179.1±15.9, 130.8±26.4 Mpa respectively and with wear tests are carried out using different parameters like varying time, load, and speed the results are tabulated. The results of this study revealed that of the particulates increased, there were significant decreases in the ultimate tensile strength, Young's modulus, and hardness. However, there was only a very marginal decrease in the compressive strength, where as in graphite reinforced composites as the graphite, borax content was increased same percentage, there were significant decreases in hardness and monotonic increases in the ductility so, percentage of elongation also increases and decreases ultimate tensile strength (UTS), compressive strength and Young's modulus of the composite.

Keywords: Metal matrix composites, AL6061 composites, Scanning electron microscopy (SEM), ultimate tensile strength, Young's modulus, hardness

I. INTRODUCTION

The engineering fraternity has consistently been in search of surprise-substances which might match the charges for all forms of carrier stipulations. It stem from the must make revolutionary discoveries made via scientists, low-priced. This affordability quotient has persuaded many researchers to advance such substances which might fulfill various hitherto unexplored conditions. In at present's world practically all time-honored materials had been tried for more than a few makes use of and their barriers were met. However the on no account ending quest of civilization requires that substances qualify for harsher environments.

This unavoidable obstacle needs that new substances be created from more than a few combinations of other compatible substances. It's to be famous here that this process just isn't new, it has been with mankind given that a long time. In every part of the arena, quite a lot of substances were combined to obtain some meant properties, albeit each case differs from the others, i.E. You could create new substances with unique houses, which will also be tailored and are special from their base parts. This idea holds actual for a style of materials referred to as Composite materials where in, various types of matrices may be combined with reinforcements which contribute to the enhancement of the residences. Composite fabric is based on a mixture of extraordinary materials on interface on it. It's superiority of houses that has precipitated the penetration of composite substances into all fields of manufacturing. They ranking over in phrases of exact modulus, specific strength, excessive temperature balance, managed coefficient of thermal growth, wear resistance, chemical inertness, and so on. But the down part is populated by inferior sturdiness and excessive rate of fabrication in evaluation with Polymer Matrix Composites (p.C.). But MMCs supersede in phrases of better transverse strength and stiffness, shear strength and high temperature capabilities.

Compositionally, MMCs have as a minimum two accessories, viz. The matrix and the reinforcement. The matrix is pretty much a steel, however seldom a pure one. Besides sparing cases, it's more often than not an alloy.

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II. LITERATURE REVIEW

[1] In the present work, put together and examine the mechanical and put on homes of Al6061-Graphite and Al6061-SiC composites. The composites had been prepared utilising stir casting approach in which quantity of reinforcement is diversified from 6-12% in steps of 3wt%. The all set composites of Al6061-Graphite and Al6061-SiC are characterised by means of microstructure stories and hardness, density, and mechanical, tribological houses had been evaluated as per the specifications. The microphotographs of the composites printed quite uniform distribution of the particles in both Al6061-Graphite and Al6061-SiC composites with clustering at few areas. The experimental densities have been located to be diminish than theoretical densities in all the composites. The dispersed Graphite and SiC in Al6061 alloy contributed in bettering the tensile force of the composites.

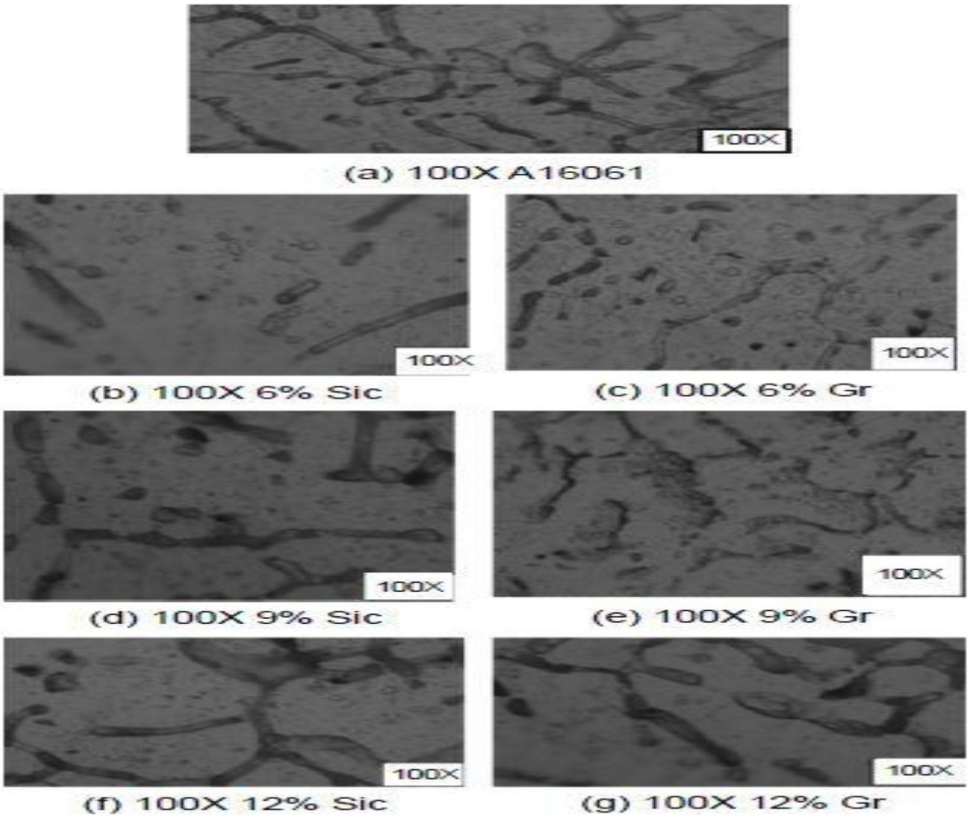


Fig. 1 Optical Microphotographs (a) 6061Al Alloy with Different wt% of SiC and Graphite Particulates Taken at 100X

III. COMPOSITE MATERIAL

A composite fabric is a bi-segment or multiphase fabric whose mechanical houses are advanced to act as independently. Probably most of phases on the whole imbalance, stiffer can be enhanced is considered as reinforcement. Actually term composite approach-one great composition that outcome when two or more different resources, each with its possess characteristics, are mixed to create a brand new substance whose homes are sophisticated to these of the original components for any distinctive application.

With this kind of giant window on hand for fabricating a composite from one-of-a-kind constituent substances, it isn't uncommon to test with substances with vividly unique houses.

A. Aluminium Matrix Composites

Research has shown that the addition of Graphite particulates to Aluminium alloys would result in an increase of modulus, and can also be accompanied by using an develop in yield stress relying upon the alloy composition, warmness therapy, and manufacturing approach.

In addition it helps in growing resistance to put on, corrosion and fatigue crack initiation as compared to the performance of the matrix alloy by myself. It has been mentioned that addition of Gr particulate reinforcement to Aluminium alloys typically lowers the fracture toughness. Nonetheless this drop in the fracture durability has been discovered to be prompted by means of the ameliorations in float stress, fracture of Gr particulates, terrible dispersion of Gr and a lower in tensile ductility. Different reasons such because the volume fraction of the reinforcement.

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B. Processing techniques of MMC's

There is a multitude of fabrication methods of steel matrix composites relying on whether they're aimed at consistently or discontinuously reinforced MMC production. The tactics can extra be subdivided, according to whether they are particularly headquartered on treating the metallic matrix in a liquid or an effective kind. The creation motives have an foremost influence on the style of factor to be produced, on the micro-structures, on the cost and the application of the MMC's.

Processing methods of MMC's can be categorised into two classes.

1) Strong state processing.

2) Liquid state processing.

C. Solid State condition

1) *Powder formed and Consolidation:* Mixing of aluminium composite powder with fired short fiber/hair/molecule is flexible strategy for the generation of AMCs. Mixing can be completed dry or in fluid suspension. Mixing is typically trailed by cool compaction, canning, degassing and high temperature union stage, for example, hot expulsion.

2) *Diffusion Bonding:* Monofilament bolstered AMCs are mainly produced by using this procedure. This approach constitutes the evaporation considered rather thick layers aluminium on outside number of fibre. Titanium situated fiber bolstered composites are produced via this route. However, this procedure is tedious and obtaining excessive volume and homogeneous fibre distribute in problematic.

3) *Physical Vapor Deposition:* This procedure includes persistent entry of fiber by method for an area of high fractional weight of the metal to be stored, where the build-up takes circumstance and an entirely thick covering of aluminum on the fiber. Composites with uniform dispersion of fiber and amount division exorbitant as eighty% can likewise be created by method for this way.

D. Liquid State Processing

1) *Stir Casting:* This involves fuse of artistic particulate into fluid aluminum relax and allowing the blend to cement. Right here, the significant element is to make simply right wetting between the particulate support and the fluid aluminum amalgam melt. The least difficult and most industrially utilized procedure is known as vortex technique or blend throwing framework. The vortex technique includes the presentation of pre-taken care of clay particles into the vortex of liquid combination made with the guide of the pivoting impeller (Fig 1).

Miniaturized scale auxiliary in homogeneities can reason prominently molecule agglomeration and sedimentation inside the relax and in this manner all through hardening. In homogeneity in support dissemination in these fashioned composites may likewise be a test 9 in this manner of interchange between suspended clay particles and moving strong fluid interface all through cementing. Usually it's suitable to join as much as 30% fired particles in the estimation range 5 to one hundred μm in a type of liquid aluminum compounds. The melt–ceramic molecule slurry is likewise exchanged specifically to a framed buildup past to whole hardening or it might be permitted to cement in billet or pole shape all together that it might be warmed to the slurry sort for additional handling with the guide of way proportional to kick the bucket throwing, and financing throwing. The technique isn't reasonable for the fuse of sub-micron measurement clay particles or stubbles. An additional variation of mix throwing framework is compo-throwing. Right here, fired particles are joined into the combination in the semi stable state.

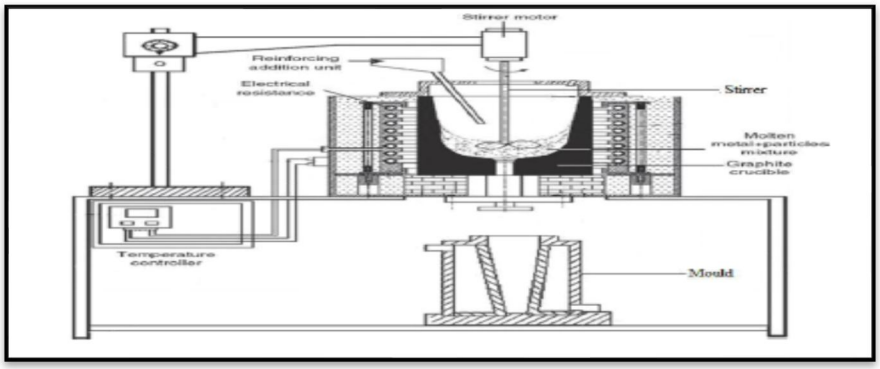


Fig. .2 Stir casting process [4].

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Overwhelming variables to be review for the span of blend throwing

a) Trouble of accomplishing of uniform dispersion of the fortification substances.
b) Wet capacity between the two most vital substances.
c) Porosity in strong steel lattice composites
d) Chemical response between the fortification material and lattice composite. [5]

2) *Infiltration Process:* Fluid aluminum amalgam is infused/penetrated into the interstices of the permeable pre-assortments of nonstop fiber/fast fiber or bristle or molecule to deliver AMCs. Depending on the way of support and its amount portion preform may likewise be penetrated, with or without the machine of strain or vacuum. AMCs having fortification volume division going from 10 to 70% will likewise be delivered making utilization of a style of penetration frameworks. The framework is by and large used to deliver aluminum network composites having molecule/hair/brief fiber/consistent fiber as fortification.
3) *Spray Deposition:* Shower testimony procedures fall into two one of a kind classes, depending regardless of whether the bead stream is created from a liquid shower (Osprey framework,) or by method for ceaseless nourishing of icy steel into a zone of rapid warmth infusion (warm splash strategy). The splash technique has been generally investigated for the development of AMCs by infusing fired molecule/stubble/speedy fiber into the shower. AMCs created in this methodology consistently show inhomogeneous dissemination of clay particles.

E. In-situ Processing (Reactive Processing)

There are various particular strategies that may fall under this class together with fluid gas, fluid solid, fluid and blended salt responses. In these procedures obstinate fortifications are made in the aluminum amalgam grid.

IV. FACTORS TO BE CONSIDER AMID MIX THROWING

So as to achieve the best living arrangements of the metal framework composite, the circulation of the fortification fabric inside the grid combination must be uniform, and the wet capacity or holding between these segments must be advanced. The porosity stages must be minimized, and concoction responses between the fortification substances and the network combination must be avoided.

A. Distribution of the support materials
B. Wettability of reinforcement

V. MECHANICAL CHARACTERISTICS

Mechanical houses of material like strength, hardness, elasticity are of central value in picking the form of fabrication and viable sensible utility.

A. Strength

The capability of a material to resist failure beneath the action of stresses triggered by way of a load is known as its strength. The weight to which a fabric is regularly subjected to are compression, anxiety, shear and bending. The corresponding strength is obtained by means of dividing the ultimate load with the go-sectional area of the specimen.

B. Hardness

The potential of a fabric to resist penetration by using a more difficult physique is referred to as its hardness. It's a most important element in identifying the workability. The hardness bears a fairly consistent relationship to the tensile force of given material.

C. Ductility

It's the property of a material which permits a fabric to be drawn out longitudinally to a decreased section under the motion of tensile drive. A ductile fabric ought to be strong and plastic. The ductility is mostly measured in phrases of percentage of elongation or percentage of reduction in pass section subject of the test specimen. 14

D. Modulus of elasticity

Hooke's law states that when a fabric is loaded inside elastic restrict, the stress is directly proportional to the desired on pressure. I.E. Ratio of stress to stress is a consistent with in elastic restrict. This steady is often called Modulus of Elasticity or "younger's Modulus".

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Therefore,
stress α strain
i.e. = constant
i.e. = E
Where E = Young's Modulus

VI. METHODOLOGY

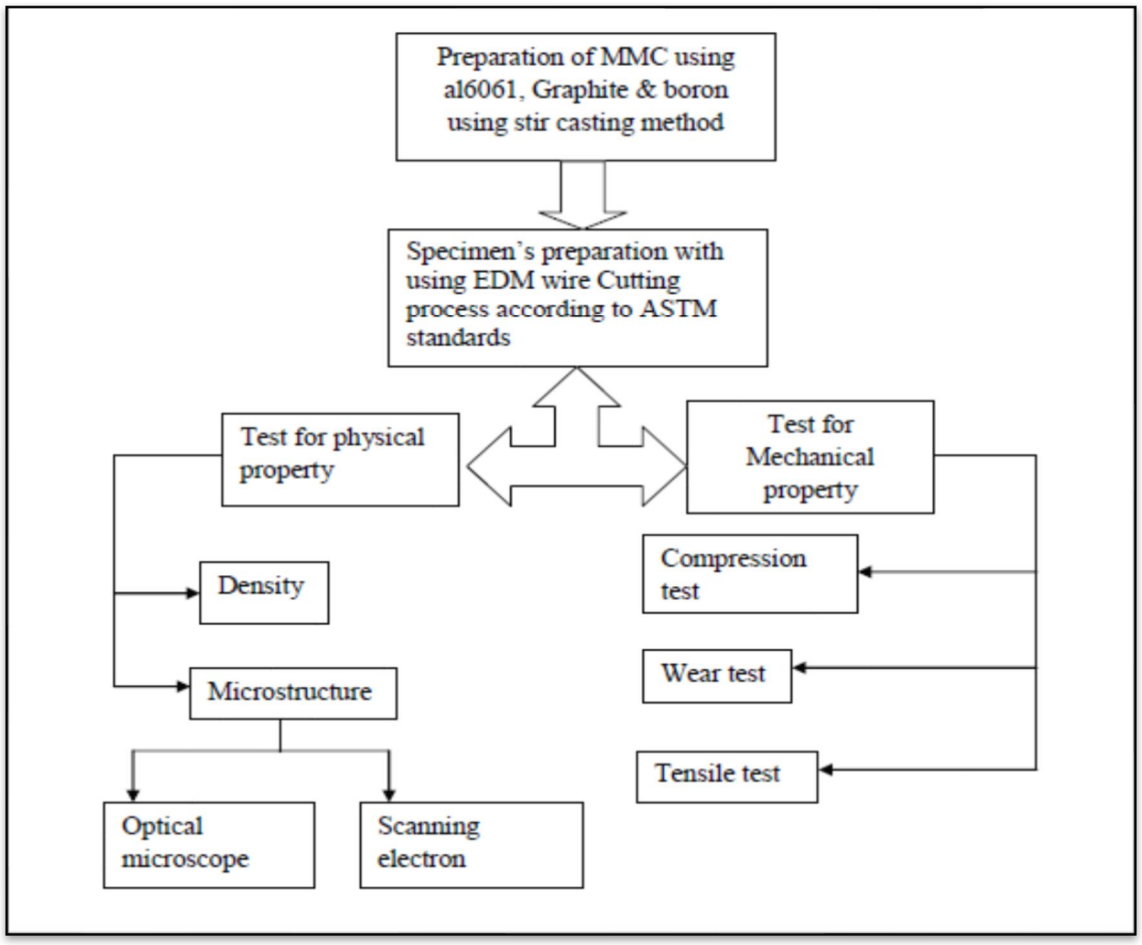


Fig. 3 Flow chart line diagram of Methodology.

Steps involved in preparation of MMC casting

1) Melting
2) Degassing
3) Impregnation of Graphite & Boron particulates and stirring
4) Pouring
5) Solidification

A. Melting

It is achieved by using mechanical furnace as shown in Fig three. Three; Al is taken in the type of ingots for the trails. Temperature about 740°C to 800°C is about in furnace and cleaned steel ingots are positioned inside crucible under a canopy of flux with a view to diminish the oxidation of molten metal. For each and every trial 1.5-2 kg of alloy is used.

The blend of the metal lattice composite utilized as a part of the present work was once connected by means of mix throwing course. Al compound was once utilized inside the type of ingots. The cleaned metal ingots had been softened to the fancied temperature of 800°C in graphite pots. Quilt flux used to be conveyed into the liquid metal in order to downsize the oxidation.

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Fig. 4. Melting process.

B. Degassing

Aluminium and aluminium alloys melts are purified via doing away with gaseous impurities and strong particulate impurities, fundamental aluminium oxides, using chemical response oxidation powder to take away the impurities. 33

C. Impregnation of Gr and Br particulates and stirring

Now we have taken Gr 70-240microns.Gr and Br particles are impregnated to molten metal at 800ºC and stirred regularly by means of utilising mechanical stirrer, the stirring time used to be maintained at 5-7min at a velocity of manually.

D. Pouring

After entire mixing of Gr & Br particulate with Al alloy which is within the crucible the molten mixture is taken outside the furnace and poured into die as proven within the fig 5

The casting process utilizing the metallic die (fig 5) with the specification of 110mm size and 4mm depth (peak) it's include runner and raiser as proven below fig.



Fig. 5. Die used to casting process.

E. Solidification

Even as the molten metallic mixture of Al & particulate is poured into die after some min its get solidified, practice some drive to do away with the forged product cautiously is as shown fig 6.



Fig. 6 solidification specimens after removal from die.

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VII. TESTS AND RESULTS

A. Micro structural study

The micro structural examinations had been implemented to examine distribution of reinforcement particles in matrix section. The extent of uniformity in distribution of particles plays an main role within the overall performance of the composites. Specimens for the microstructure examination were all set and examined with the support of metallurgical microscope with a magnification of 50X, 100X, 200X, 500X and 1000X. Below fig suggests the microstructure of Al steel matrix with reinforcement particles.

1) Optical microscopy: The etched specimens determined under the microscope printed the following constitution, with the aid of utilising OM (optical microscope).

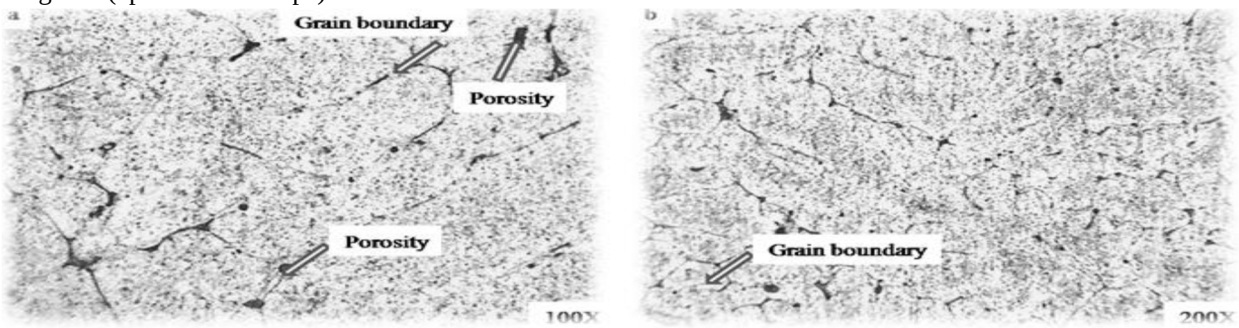


Fig. 7 Optical Micrographs of MMC's stir casting (2% Gr+2% Br).

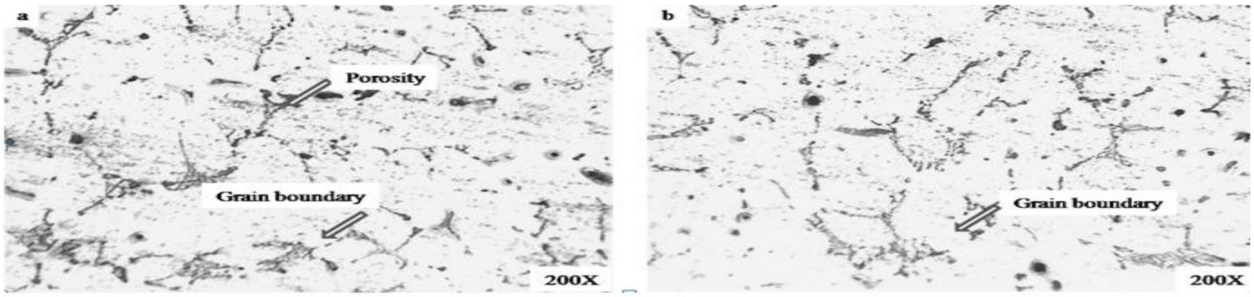


Fig. 8 Optical Micrographs of MMC's stir casting (2% Gr+2% Br).

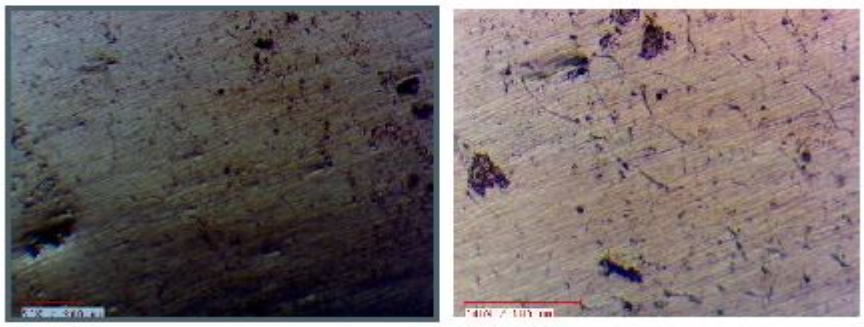


Fig. 9 Optical Micrographs of MMC's Centrifugal casting (2% Gr+2% Br)

The Optical Micrographs as proven above fig 9, four.2 stir casting composition respectively.

The optical picture micrographs of the manufactured AMCs are demonstrated in Fig. It's situated from the confirm that Graphite, Borax particulates are scattered consistently inside the aluminum framework at all weight rate. The extent of the Graphite particles is by all accounts uniform all through the aluminum network. This can likewise be credited to the hearty mixing activity and utilizing fitting procedure parameters.

The metallographic examinations of created half breed metallic framework composites make it practical to end up mindful of the degree dispersion of the strengthening particles inside the lattice area.

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The optical pix indicates the how the particulates and matrix material compacted with each and every other.

1) Metallographic examinations reveal that the presence of reinforcement particles was observed on the matrix segment as darkish spots, the number of dark areas raises within the matrix phases because the addition of particles raises.

2) exhibits the microphotographs of Al6061 reinforced with Graphite and Br particulates. From determine it's clear that, the distribution of reinforcing particulates in both the composites is rather uniform in the entire compositions studied even as increasing the % of reinforcements the grain boundaries arrangement is decreases on the grounds that the mechanical defects are raises (located in above fig 9)

B. Scanning Electron Microscopy (SEM)

The etched specimens determined under the microscope published the next constitution, through utilizing SEM

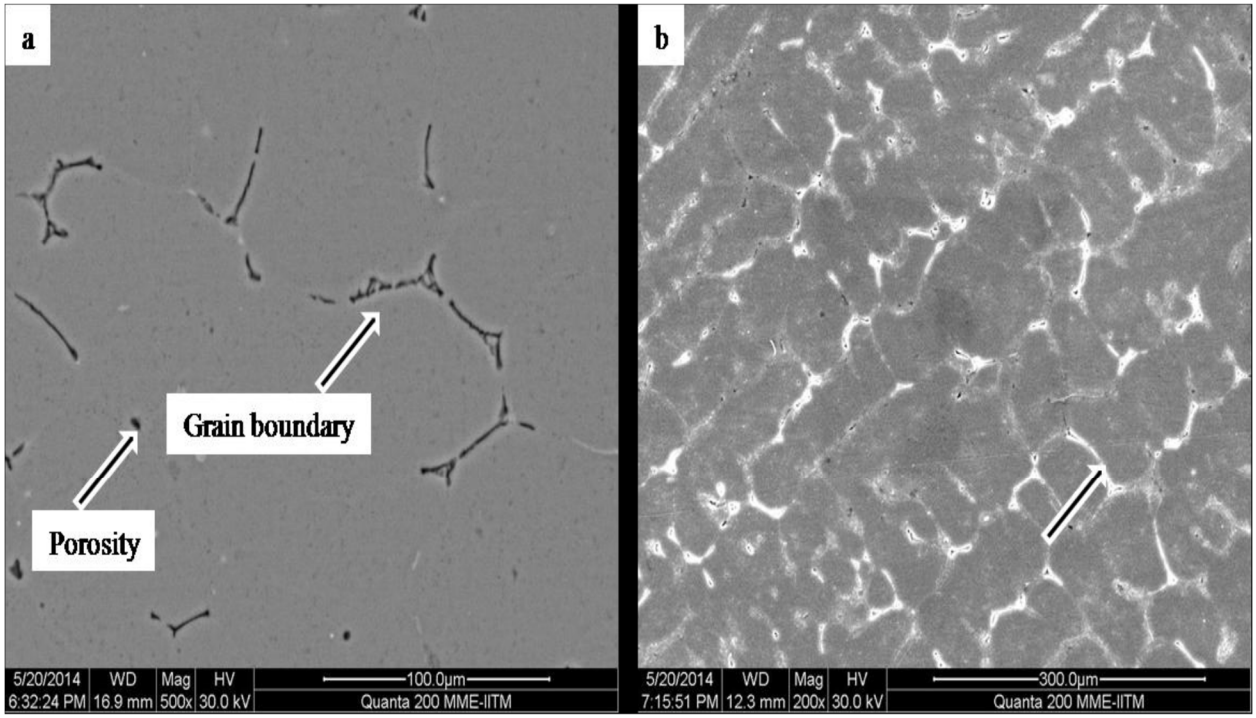


Fig. 10 SEM of MMC's stir casting (2% Gr+2% Br).

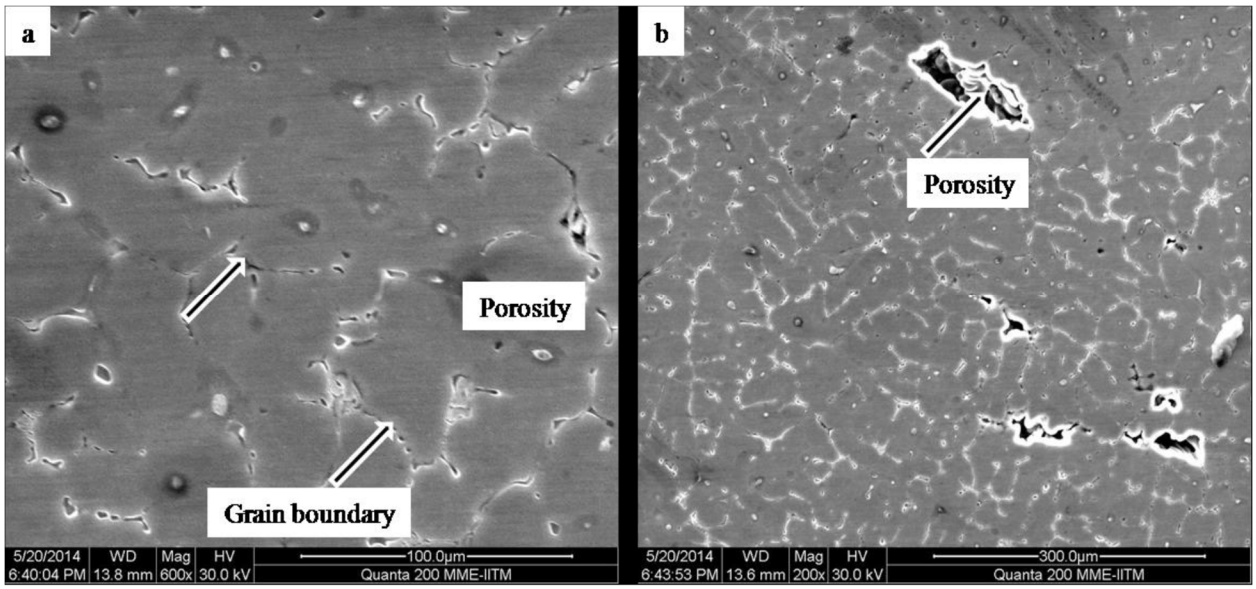


Fig. 11 SEM Micrographs of MMC's Centrifugal casting (2% Gr+2% Br).

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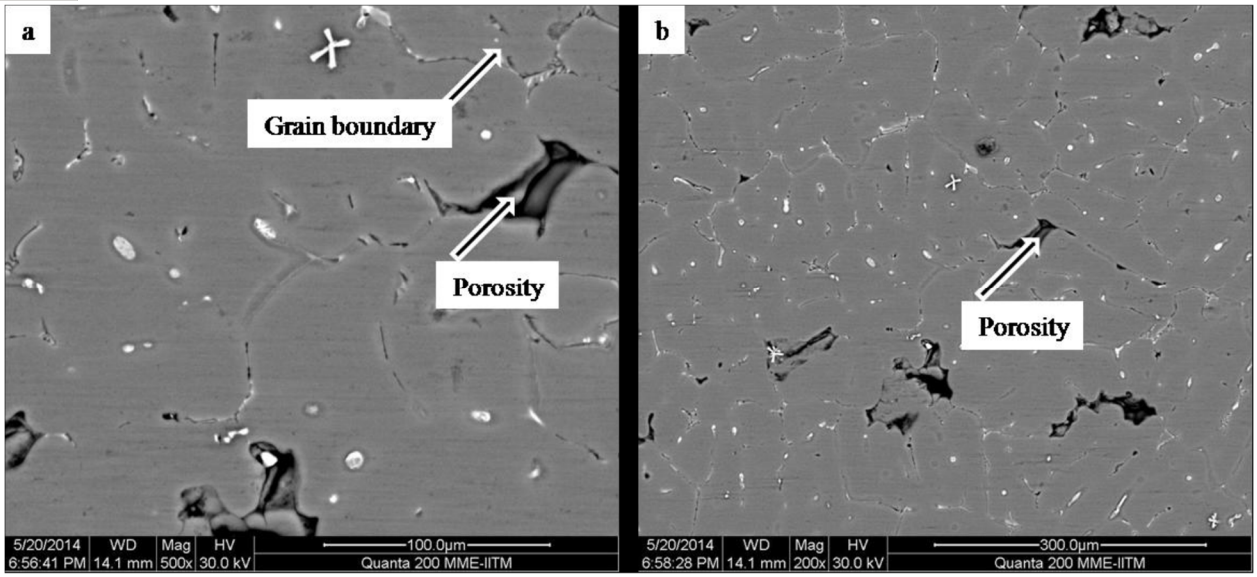


Fig. 12 SEM Micrographs of MMC's Centrifugal process (2% Gr+2% Br).

The microstructures of cast Al-Gr, Br particulate composites example were considered by SEM. The SEM micrographs plainly show that the Gr, Br particulates are scattered consistently in Al grid even at wt rate as high as 2% weight.
In microstructure of the Br, Gr p/6061 Al composites with different particle sizes are shown in above fig. The particles are tightly packed with a homogeneous spatial distribution in each composite. 49
Particulates are seen in between the matrix small sizes with grain boundaries and we can observe addition of reinforcements differ in structure increasing the porosity and mechanical defects and it's are relatively large and oval grains.
The microstructure of Al- Gr, Brp composite with 2% wt. of Gr, Br particulates is shown in Fig , with 2% wt. of Gr, Br particulates is shown in Fig 11 and Fig 12 Shows microstructure composite with 2% wt of Gr, Br particulates. The Gr, Br particulates are observed to be in irregular shape and contains large mechanical defects.

C. Hardness test

Hardness test is conducted utilizing the Micro Vickers hardness tester computing device in the room temperature. Here regarded in particular matrix and reinforcement fabric with three kg force is utilized for 10 sec. The info on three experiments had been conducted for each and every composition and tabulated in the table 1, it might be seen from the fig (13) that the hardness of the test specimen lowered as the weight percent of graphite reinforcement. Hardness of the specimen recorded at three different places.

Results of Vickers hardness test 1.1

Variations of reinforcements (wt. %)	Load applied (gm)	Time (Sec)	HV	HV
Stir Casting	50	10	69	71
			70	
			72	
Centrifugal casting	50	10	73	75
			75	
			76	

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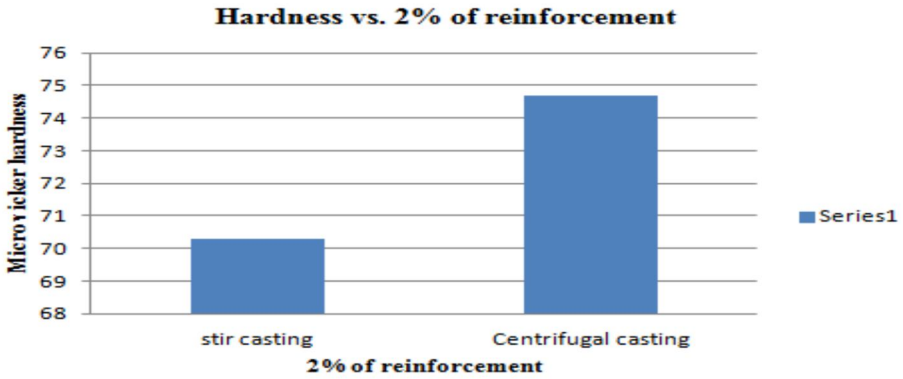


Table 2 Hardness values for varying % of reinforcements.

Fig. Graphical representation of Hardness comparison.

Hardness for MMC's specimens was once measured as per ASTM common by means of utilising the specimens and the scan used to be carried out at room temperature and results had been tabulated in desk 1.

An evident from these desk we obvious that the hardness raises with the first addition of particulates after that moderately decreases since here the growing in particulates but slash in base steel so, tremendously the fabric less toughness with the increasing of particulates and the mechanical defects are increases given that due to casting defects similar to porosity, shrinkages and many others.

The test specimens used in the experiments are proven in under fig.

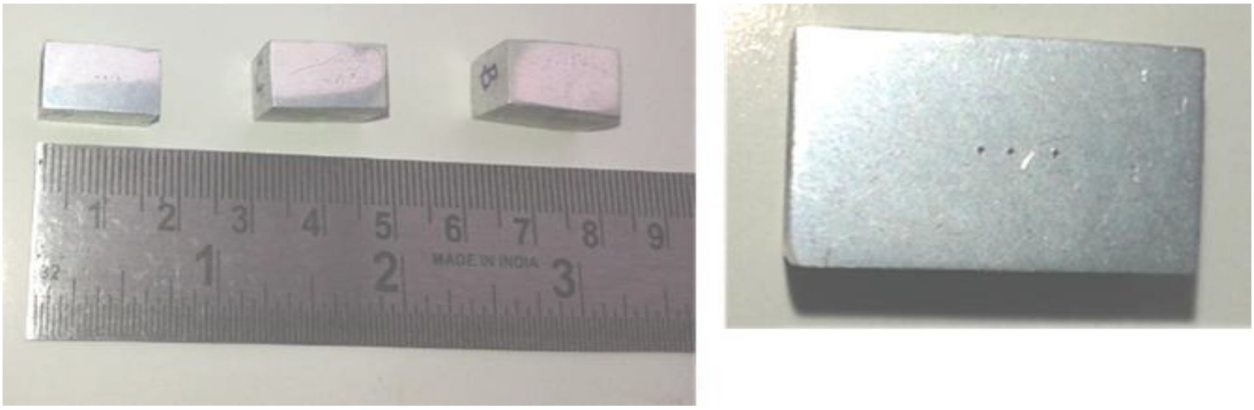


Fig. 15 Indentation on the specimen after the Hardness conduct.

D. Tensile tests

This test based on performed laptop-interfaced common testing laptop SR.NO.091101, with a potential of a hundred KN. Information acquisition application 'KALPAK' used to be used for checking out, the price of loading was once 1.Three mm/min.

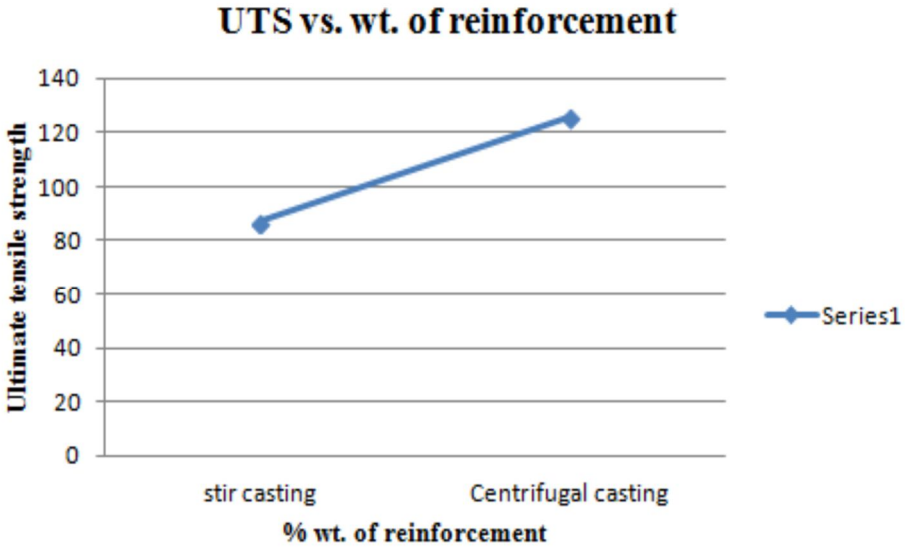
The tensile experiment was done at room temperature on specimens. experiments are repeated thrice and average readings were computed and awarded in desk.

Table 2 results of tensile strength by varying percentage of reinforcements**.**

Composition	Sample Number	Tensile Strength (MPa)	UTS (MPa)
Stir casting	1	55.56	87.223
	2	112.76	
	3	93.35	
Centrifugal casting	1	114.73	125.6
	2	132.73	
	3	129.34	

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Fig. 15 Tensile Strength variation of wt. reinforcement



The tensile strength decreases with the addition of reinforcements because the matrix material is varying by composition and increases the addition of reinforcement's cause's mechanical defects.

E. Percentage of elongation

The elongation properties of the specimen of metal matrix composite increasing gradually abased on wt% of reinforce metal increased. Improved better bonding at the interface between the hard particles present in a soft matrix observed.

Table 3 results for Percentage of elongation by varying percentage of reinforcements.

Composition	Sample Number	Percentage of elongation (%)	Avg. percentage of elongation (%)
Stir casting	1	9.69	8
	2	6.86	
	3	7.43	
Centrifugal casting	1	5.98	5.74
	2	7.19	
	3	4.06	

The specimen become less strong and exhibits ductility as these particles increases. At higher % of additions to the base alloy results in the significant reduction in the ductility.

Difficulty in achieving the uniform distribution on hard particles on matrix metal pronounced more because of clusters formation of the particles and problems associated with porosity formation increases as the addition of particles increases. Hence at higher percentage of addition, the material gains its ductility drastically.

This cluster formation also reduced the bond at the interface between matrixes alloy and the reinforcement particles.

But here the small percentage of addition of reinforcements give better results of strongest and increases the addition the strength decreases so, percentage of elongation is more.

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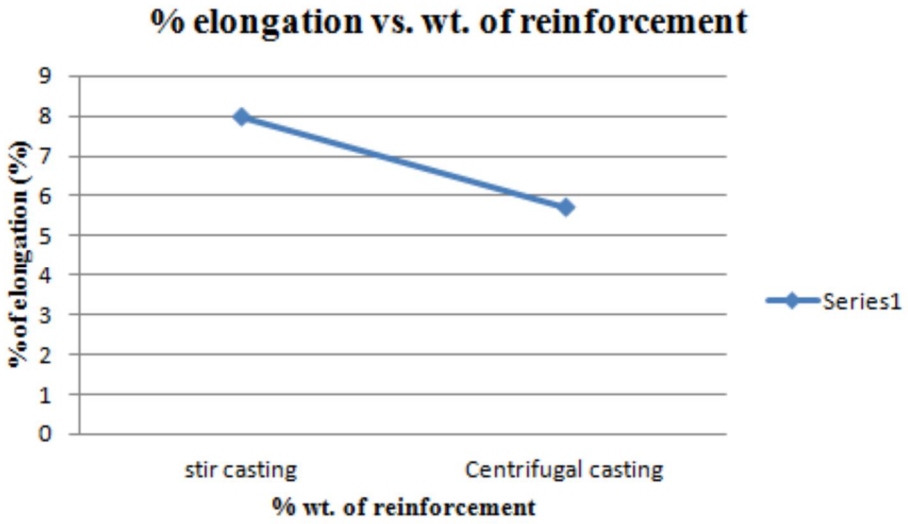


Fig. 16 Variation of Percentage of elongation with the addition of % reinforcement.

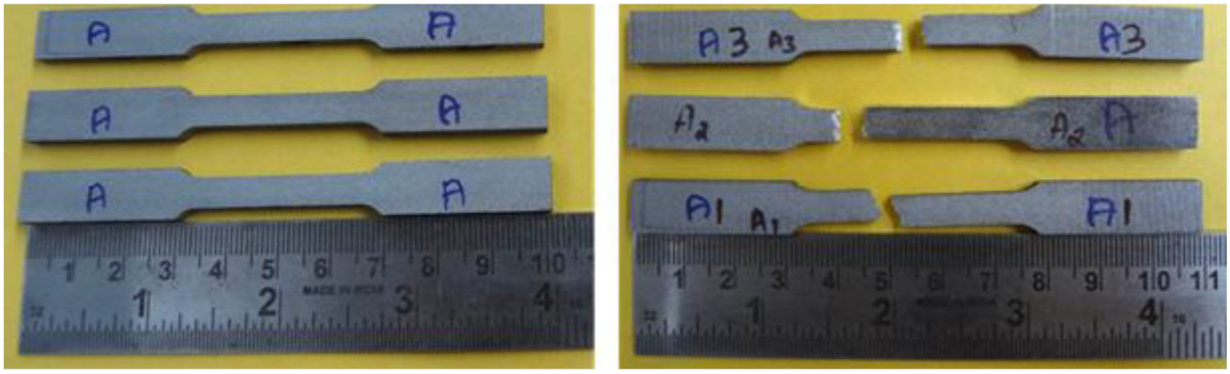


Fig. 16 Tensile test specimens before and after test conducted

F. Wear test

1) Varying speed

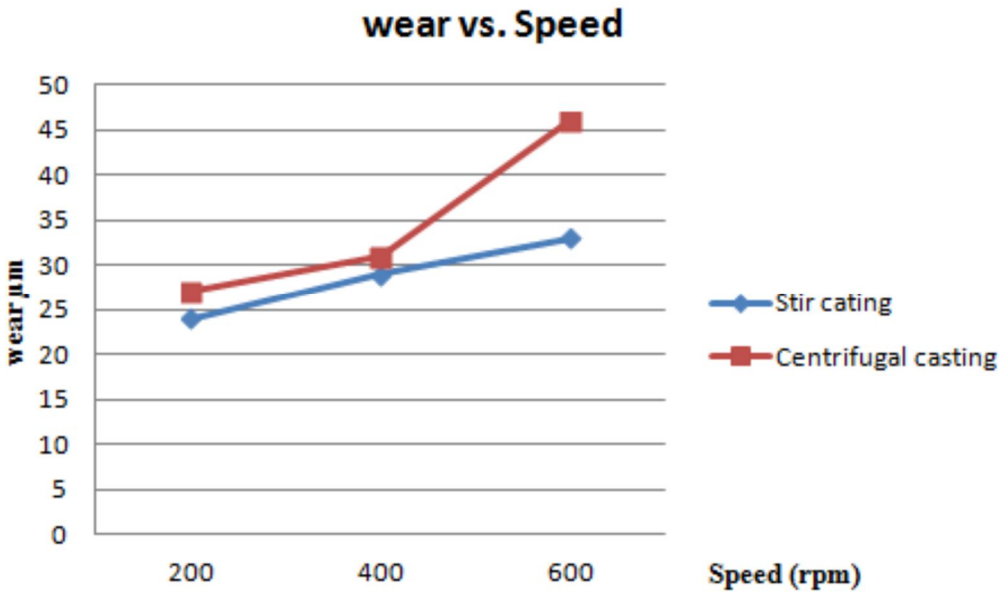


Fig.17 Comparison of wear rate with speed.

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Consider the wear rate of specimen A for 200rpm; we see that the wear rate is 3.20*10-12 and for 400rpm it is 3.98*10-12 and for 600rpm it is 4.87*10-12.We see that the wear rate has been continuously increased due to increase in speed.

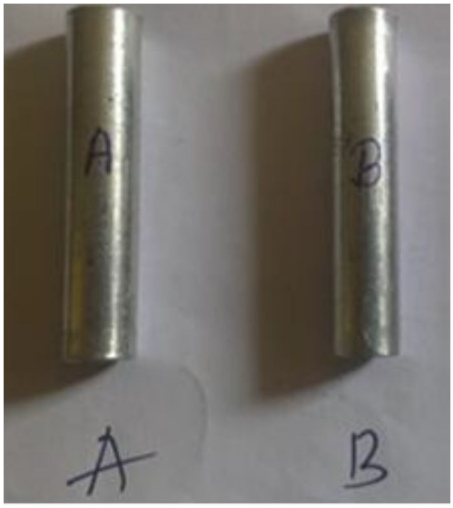


Fig. 17 Wear Test Specimen.

G. Impact test

1) Charpy Test: This test can be conduct to know about absorbed energy in the Al6061 reinforce with Graphite and borax with 2% of composition.

Sl. No.	Absorbed Energy (J)	Type of Specimen
1.	8	Centrifugal casting
2.	7	Stir casting

Table 4 results for impact test reinforcements

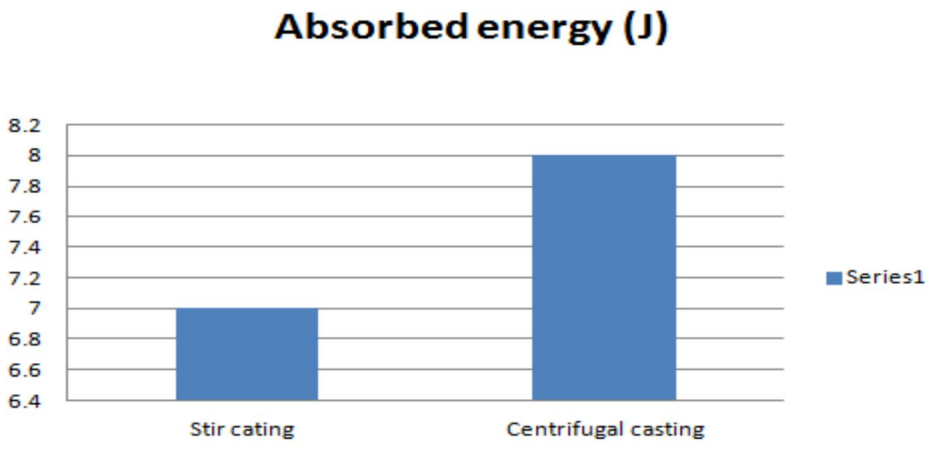


Fig. 18 Charpy Test report

2) Izod Test

In this test to know about strength of material and depending on the position of specimen after hit the hammer the energy consumed in the form of joule.

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Sl. No.	Absorbed Energy (J)	Type of Specimen
1.	11	Centrifugal casting
2.	12	Stir casting

Table 4 results for Izod test reinforcements

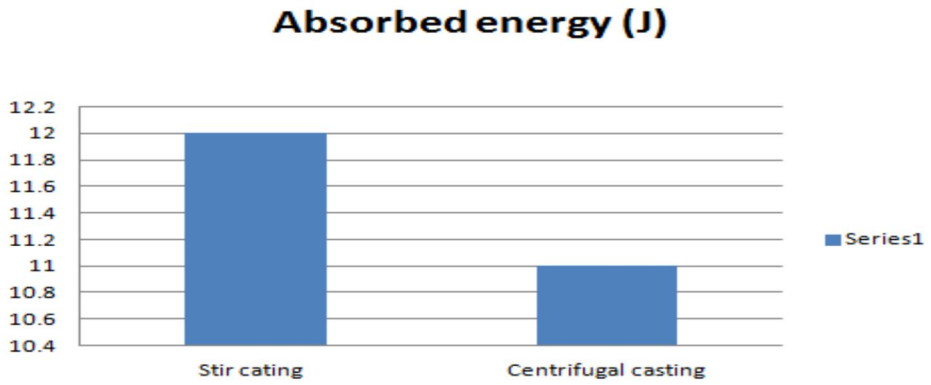


Fig. 19 Izod test report

VII. CONCLUSION

In the gift obtain capabilities of aluminium headquartered Hybrid metal matrix composites bolstered with Graphite and Boron particles. The next conclusions are drawn from the experimental results.

Mechanical residences equivalent to tensile force, compression strength and modulus of elasticity decreases and percent of elongation are raises in addition of particulates elements emerge as so much less stiff and the resistance afforded through the fabric toward the tensile & compression load decreases.

Due to the fact that of the presence of graphite and boron particles the ductility starts growing and vastly raises weight percentage of reinforcement to the base metallic percentages various with the aid of utilizing compositions. Put on price starts off evolved decreases with the expand in bolstered particles. It was once discovered that better speeds the wear and tear price reasonably lesser for any precise load. With the expand additionally of reinforcement of each the particles the hardness is decreases on account that growing the percentage of graphite and reducing the backside metallic percentages, and casting defects.

The experimental densities were determined to be curbing than theoretical densities because of the presence of porosities in the entire composites.

Proper here the most important addition is raises and subsequent addition is quite decreases when you consider that the bottom metal also various with the help of percentages and the growing the reinforcements are motives the mechanical defects like void, porosity like that so, increasing the probabilities of reinforcements outcome reducing the mechanical houses. The micro structural experiences expose that the attention of each and every particles within the matrix segment increases with the boost in percentage of reinforcements. In a magnification of 200X, the etched floor of the developed hybrid steel matrix composite suggests clear in-between matrix and reinforcement.

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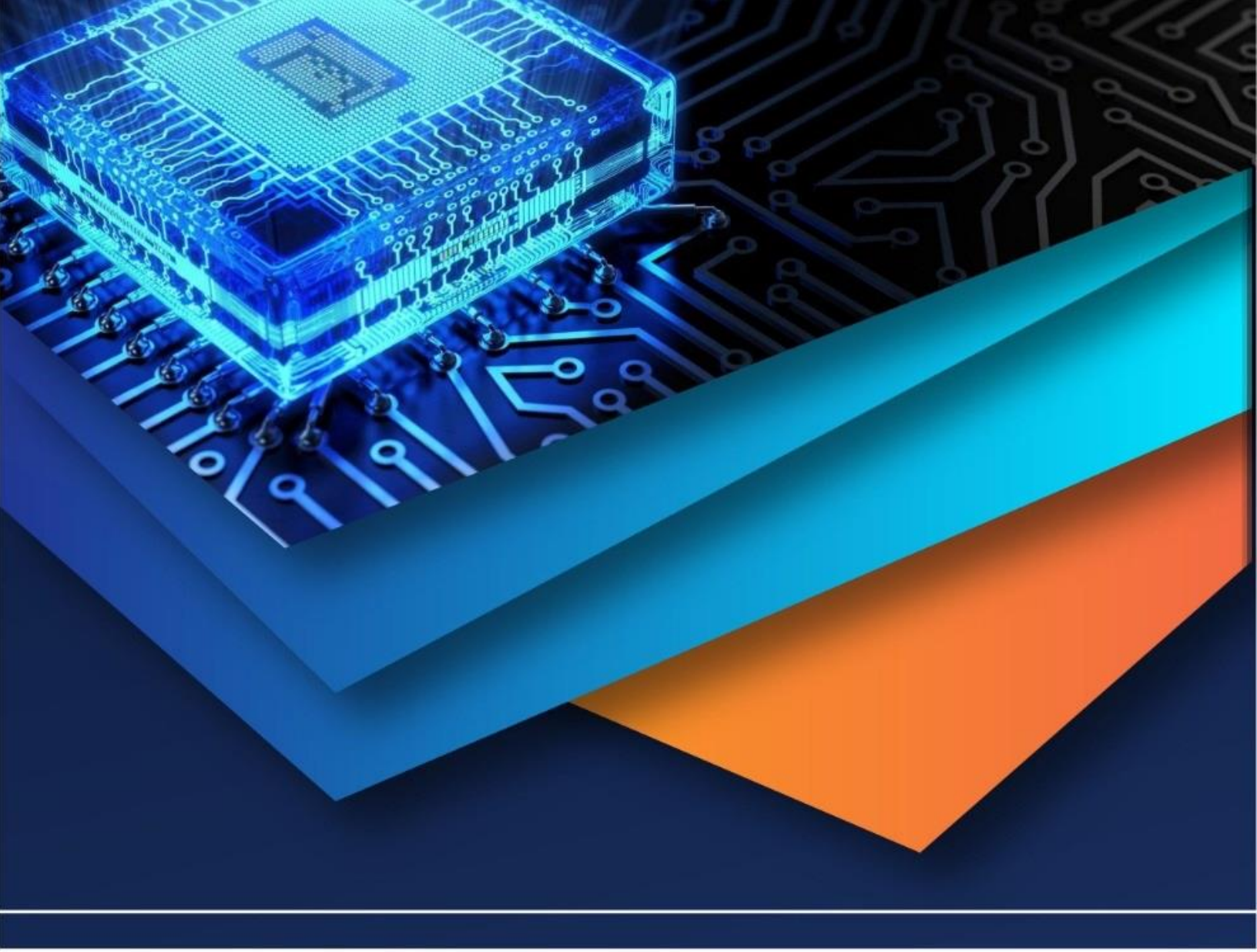
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