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FABRICATION OF AL7075 METAL MATRIX WITH VARYING COMPOSITIONS OF REINFORCEMENTS

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ABSTRACT

In these days the demand for aluminium and aluminium alloys have been increased in the areas like Aerospace, Missiles, Automobiles etc., Generally, Aluminium Metal Matrix composites consists of a low-density material i.e., Aluminium or Aluminium alloy as Base material or Matrix. In this work, Al7075 is considered as the Matrix or Base material and ceramic materials such as B4C, SiC, and Graphite particles were mixed as reinforcing materials for fabrication of Aluminium metal matrix composites through Stir Casting method by varying compositions of reinforcing materials. 0%, 2%, 4%, 8%, and 10% of B4C and SiC were incorporated into Al7075 alloy, maintaining the volume fraction of Graphite particles as 2% for these proportions. Density of Base material and reinforced materials were found using Archimedes' Principle. As percentage of reinforcement increased, density also increased. And to analysis the effect of Silicon carbide, graphite, and boron carbide reinforcements using Micro-Vickers hardness and pin-on-disc experiment. By the addition of reinforcements particles of B4C and SiC, the hardness increased when compared to base material. Wear test demonstrated at 2% Graphite, loss of wear decreased gradually and then it is increased.

KEYWORDS: AMMC, Al7075, Boron Carbide, Silicon Carbide, Graphite, Stir Casting technique, Micro-Vickers hardness test, pin-on-disc method.

1. INTRODUCTION

A composite is a material consists of two, but sometimes more, chemically distinct phases on a microscopic scale, separated by a distinct interface. One of these, the reinforcement, is said to enhances or reinforces the mechanical properties of the matrix. Matrix phase is continuous, harder, and stiffer and is often but not always, present in the highest percentage in the composite. Composite materials must satisfy, these three also. First one, both matrix and reinforcements must be present in reasonable proportions, say greater than Five percentage. Second one, the constituent phases must have different properties, that results improved properties of composite material obtained from the properties of the constituents. Third one, synthetic composites were usually manufactured by intimately mixing and combining the constituents by various means. Composites are classified as ceramic, metallic or organic matrix. In Early's 1960 and 1970s production of fibers of boron carbide and silicon carbide as reinforcements of light metals and particularly for aluminium alloys. The production of fibers of boron and of silicon carbide in the 1960s and early 1970s enabled the reinforcement of light metals and particularly aluminium alloys to be considered seriously. MMC'S have some superior mechanical properties like transverse strength, stiffness, compressive strength and better higher temperature capabilities. The coefficient of thermal expansion (Alpha) of metals is large, due to this led to problems with metallic components with close tolerances, because of significant changes in dimensions with temperature. Metals have good ductility and toughness, but these properties are degraded by the addition of reinforcement. MMC'S generally have higher values for specific modulus and specific strength than those for the unreinforced matrix, but this is achieved at the expense of toughness. It was seen that these usually involved high temperatures and consequently the matrix may react with the reinforcement to give an interfacial layer which can degrade properties. Interfacial layers may also be formed during high temperature service. However, provided there is no reaction, and no micro-damage because of differences in the coefficients of thermal expansion of the constituents, the high temperature static properties (Young's modulus and strength) and creep resistance of MMCs are good.

Stir Casting process used for Aluminium alloys to incorporate reinforced particles to produce economical metal matrix composites. Aircrafts, Aerospace and Automotive fields were mostly deals with lightweight materials, which were produced by incorporating hard reinforced particles with metal alloys. Reinforced materials like silicon carbide, boron carbide will strengthen the metal matrix phase to accomplish required properties. In MMC's, the volume percentage of reinforced particles is not more than 30, because of difficulties while processing, machining, and forming of these composites to achieve low ductility and high hardness. During stir casting, there can be substantial interfacial reactions that degrade the composite properties as well as increasing the viscosity of the melt and making casting more difficult. its apparent viscosity, because they interact with the metal and with each other, causing greater resistance to shear. Typically, reinforcement levels are limited to about 30 percent. Because Viscosity is a function of reinforcement percentage, shape, and size, so a decrease in size or an increase in volume fraction will lead to a greater degree of viscosity. Porosity in cast parts usually results from gas entrapment during mixing, hydrogen evolution, and/or shrinkage during solidification.

Lower density is one of the advantages of MMCs made of metal matrix with high specific gravity compared with ceramic reinforcement. In most cases, ceramic materials have a low density and, when mixed with a denser metal, the overall weight is reduced. Aluminium and magnesium alloys may incur a weight penalty even though their densities are lower or similar to that of the ceramic reinforcement. MMCs have a low fracture toughness and low ductility, which make them unsuitable for use in damage-tolerant structures. There are several factors that affect the toughness and ductility of MMCs, which were composition and microstructure of the matrix alloy; type, size, and orientation of the reinforcement; and processing conditions. Reductions to the fracture toughness and ductility of aluminium when the reinforcement content is increased to 30–40%, which are typical concentrations used for high-strength applications.

2. LITERATURE SURVEY

MohammedImran And A.R. AnwarKhan (1) In this study, Characterization of Al-7075 metal matrix composites: a review. Reinforced particles such as silicon carbide, alumina, barium chloride, etc. are added to aluminum to increase tensile strength, hardness, yield strength, compressive strength, flexural strength, whereas ductility is reduced.

Duvvi Anvesh, G Ankith Adam, K Satyanarayana, MNV Krishna Veni (2) Studies on Investigation on Mechanical Properties of Al 7075 MMC's Reinforced with Ceramic Particles, concluded that Compared to the base material, the density of Al7075-5 % B4C composites decreased slightly, whereas Al7075-5 % SiC composites decreased drastically.

Swapnil V.Gosavia M.D.Jaybhayeb(3) Using stir casting process, microstructural study on

Al7075-SiC composite fabricated from aluminum metal matrix. it has been found that composites made from aluminium metal matrix had an enhanced microhardness with increasing reinforcement content.

G. G. Sozhamannan, S. Balasivanandha Prabu, V. S. K. Venkatagalapathy(4) In this study, Effect of Processing Paramters on Metal Matrix Composites: Stir Casting Process. When processing temperatures are increased from 750 C to 800 C for 20 minutes, hardness values increase in a linear manner.

N. Senthilkumar, T. Tamizharasan, M. Anbarasan(5) In this study, Mechanical Characterization and Tribological Behaviour of Al-Gr-B4c Metal Matrix Composite prepared by Stir Casting Technique. Wear tests on pin-on-discs demonstrate that 5% reinforcement reduces the coefficient of friction and frictional force. In an aluminum matrix reinforced with B4C, wear rates decrease.

Sudeep Roy, Shubham Sharma, Skand Sharma, Shashank, M. K Lohumi, Manohar Singh (6) In this study, Review on Fabrication of Aluminium 7075+ B4C Composites and its Testing. At 10 volume fractions of B4C, the wear rate was minimum at all load conditions, and increased with increasing applied load. B4C particles protect the softer aluminum matrix from abrasive wear and reinforce the aluminium matrix.

P. K. Rohatgi, S. Ray, and Y. Liu (7) In this study, Tribological properties of metal matrix-graphite particle composites. Under normal load, metal matrix composites with less than 10% graphite wear more rapidly.

3. OBJECTIVES OF THE PAPER

Fabrication of Al7075 Metal Matric Composites by varying compositions of reinforcements (B_4 C, SiC, and Gr). To study the properties like Density, Hardness and Wear of different fabricated specimens.

4. MATERIALS USED FOR COMPOSITES

From previous study and study of different journals these different combinations of reinforcement percentages taken for preparing Aluminium metal matrix composites as shown in Table.1.

Table 1: List of selected compositions.

S. No	Composition
1	AL 70075
2	AL 70075+2%B_4C+2%SiC
3	AL 70075+4%B_4C+4%SiC
4	AL 70075+6%B_4C+6%SiC
5	AL 70075+8%B_4C+8%SiC
6	AL 70075+10%B_4C+10%SiC
7	AL 7075+2%Gr
8	AL 70075+2%B_4C+2%SiC+2%Gr
9	AL 70075+4%B_4C+4%SiC+2%Gr
10	AL 70075+6%B_4C+6%SiC+2%Gr
11	AL 70075+8%B_4C+8%SiC+2%Gr
12	AL 70075+10%B_4C+10%SiC+2%Gr

4.1. Aluminium 7075 Alloy: Because of its low specific weight, high strength to weight ratio, and fatigue resistance, as well as its high machinability, formability, and weldability, AL 7075 alloy was selected in the form of solid rods. This material is widely used in the automotive, aerospace, and defense industries. The chemical composition of the used material is given in Table. 2.

Table 2: Chemical composition of Al 7075.

7075 Aluminum Alloy Composition by Mass %								
Zn	**Mg**	**Cu**	**Fe**	**Cr**	**Mn**	**Si**	**Ti**	**Al**
5.1-6.1	2.1-2.9	1.2-2.0	0.5 (Max)	0.18 - 0.28	0.3 (Max)	0.4 (Max)	0.2 (Max)	Bal

4.2. Boron carbide is a ceramic substance with a high melting point, hardness, strength- to-density ratio, and wear resistance. The high refractoriness property achieved by the high melting point of 2450 °C is used in high temperature applications. It has a high compressive strength and hardness and has a poor thermal conductivity. Boron carbide powder is an abrasive used in polishing because of its high hardness. For test, Boron carbide as the reinforcement-1 in the form of powder 100µm.

4.3. Silicon Carbide: - The addition of SiC to the aluminium matrix significantly improves its strength, modulus, abrasive wear resistance, and thermal stability. SiC's resistance to acids, alkalis, and molten salts at temperatures up to 8000^{o}C makes it an excellent reinforcement candidate for aluminum based MMC. The addition of SiC yields excellent mechanical properties. For test, Silicon carbide as the reinforcement-2 in the form of powder size 100µm.

4.4.Graphite: The addition of graphite particles results in low composite friction because it is a good dry lubricant and thus reduces wear and abrasion. For test, Graphite is as reinforcement -3 in the form of powder which 40 µm.

5. EXPERIMENTAL PROCEDURE AND EQUIPMENT

- **Sir casting Procedure**

At first heater temperature is set to 450°C and then it is gradually increased up to 1000°C, which was set in a graphite crucible, and it as placed in muffle. Al alloy (Al7075) iscleaned to remove impurities, and then Al 7075 materials were placed in the Graphite crucible for melting. In molten metal bath, the reinforcement particle or whisker mixed with the base metal. As the molten matrix is heated in a crucible, a motor drives an impeller that mixes it, which is submerged in the molten matrix. As the impeller rotates, it creates a vortex that pulls the reinforcement particles into the melt from the surface, ensuring a smooth and continuous flow. To ensure a continuous flow of reinforcement into the molten matrix, the impeller is rotated at a controlled rate, generating a vortex that pulls reinforcement particles from the surface into the melt. Aluminium melt is continuously stirred, which results in continuous oxidation of the melt surface, and it was due to exposure of melt to the atmosphere. Continuous oxidation reduces the wet ability of Aluminium, resulting in unmixed reinforcement particles. To avoid oxidation, the stirring process is carried out in closed chamber, in which argon gas atmosphere was created. There can be problems with settling of the secondary phases in the matrix, particle agglomeration, particlefracture during stirring, and excessive interfacial reactions. Reinforcements are preheated to 450^{o}C for half-an-hour to avoid trapped air between the particle and to remove moisture.

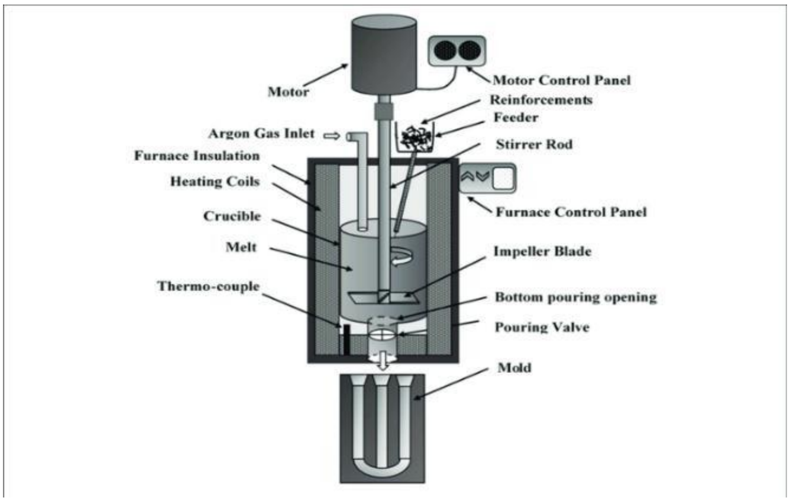


Figure 1: Experimentation on the stir casting machine.

When the matrix was in molten stage, the stirrer starts stirring process and speed is gradually increased from 0 to 600 RPM with the help of speed controller. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached to the motor. Temperature of the heater is set to 700°C which is below the melting point temperature of the matrix. A uniform semisolid stage of the molten matrix was achieved by stirring it at 700°C. Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wet ability of the reinforcement and reduces the particle settling at the bottom of the crucible.

After stirring 5-6 minutes at semisolid stage slurry was heated and hold at a temperature 900°C to make sure slurry was fully liquid. Composite slurry is poured in the metallic mould. The Mould is preheated at temperature 450°C before pouring of the molten slurry in the mould.

Figure 2: Specimens.

- **Density test**

Density is the weight of a unit volume of a material. Density is an important consideration when choosing a material to be used in the design of a part to maintain the proper weight and balance of the aircraft and spacecrafts etc. The density of the specimens was calculated based on the *Archimedes Principle*.

Figure 3: Density Test.

- **Micro Vickers Hardness Test**

To evaluate the properties of metals and other materials, the hardness test is mostwidely used mechanical test. A material's hardness is usually determined by its resistance to permanent indentation. The metal is generally indented by pressing an indenter into its surface while under a specific load for a specific duration of time. The size or depth of the indentation is measured. No quantification of hardness exists, except when it is measured in terms of a given load applied in a specified way for a specified period and according to a specified penetrator shape. For metals that were too difficult to evaluate using the Brinell test, Smith and Sandland developed a new indentation test in 1925, which was The Vickers Test. Vickers tests are conducted with a smooth and impact-free application, forcing the indenter into the test piece.

After proper cleaning of specimens, fixed the diamond indenter and then specimen was placed on the anvil for testing. Rotated the hand wheel at the worktable upwards and downwards to focus the workpiece surface for clean visibility. Select the load, and apply load by pressing the push button, then loading lever begins to move up words until it reaches the study position. Now, slowly release the loading lever and until it reaches the specimen. Adjust the display at the indentation made by the indenter to coincide with the micrometre on the display screen for major reading. Adjust the movable side of the micrometre for major and minor readings and recorded the total reading. Two opposite corners of the diagonal indentation were measured.

Fig 4: Vicker's Hardness Equipment.

- **Heat treatment**

Engineering materials were subjected to heat treatment to make them structurally and physically suitable for engineering applications. The purpose of heat treatment is to make the materials mechanically and structurally strong for engineering applications. During heat treatment, the cast composite specimens were placed in a muffle furnace. A solutioning period of 2 hours at 530^{o}C was carried out on the specimens in the furnace. Once the specimens had been solutionized, they were rapidly quenched in different water, oil, and ice quenching medias.

Fig 5: Heat treatment.

- **Wear Test**

The wear tests were conducted for fore said specimens at room temperature using a pin on disk wear test rig shown in figure. The wear test specimens were machined to 8 mm nominal diameter and a gauge length of 30 mm. Before testing, they were weighted and prior to that all the specimens were cleaned and dry. Remove all dirt and foreign matter from the specimens by using non-chlorinated, non-film- forming cleaning agents and solvents. Placed the disc in the holding device securely so that it is fixed perpendicular to the resolution axis. To maintain the required contact conditions, secure the pin specimen in its holder and, if necessary, adjust the specimen so that it is perpendicular to the disc surface when in contact.

Fig 6: wear test machine.

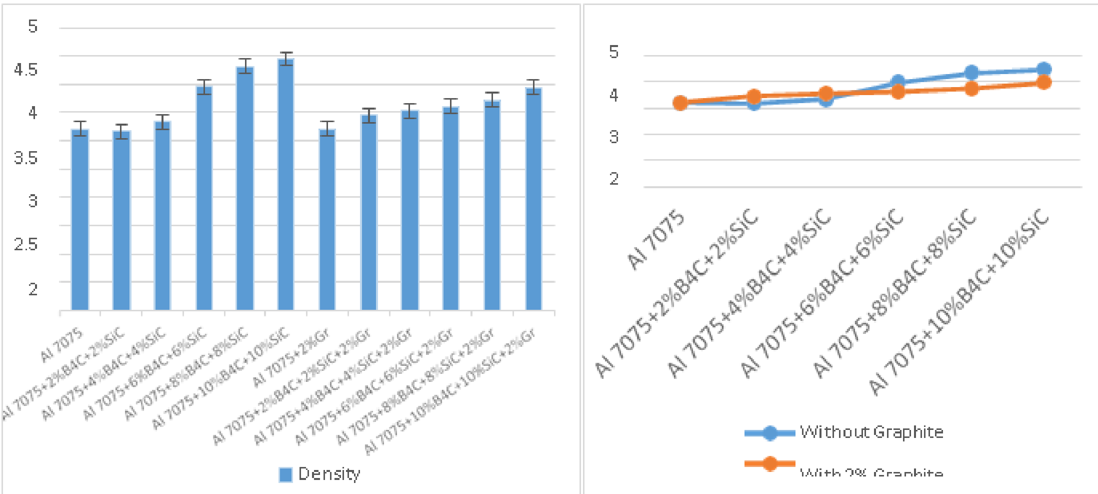
To give the required force pressing the pin against the disk, added 1kg of mass to the system lever and the sliding distance was 200m.Set the revolution counter to the 400rpm. Begin the test by introducing the specimens into contact while under load. When the desired number of revolutions is reached, the test is terminated. Remove the specimens and clean any loose wear debris off of them. Remeasure the specimen dimensions or reweigh the specimens to note the results.

6. RESULTS AND DISCUSSION

After fabricating the specimens by varying compositions of reinforcements by using stir cast technique. In which process parameters were played a crucial role for uniform distribution of reinforcement. We had conducted different tests and its results are illustrated as follows.

6.1 Density test

The density of the specimens was calculated based on the *Archimedes Principle* and the results are Tabulated in Table.3 and Graph 1 shows their results of with and without graphite of specimens.



Graph 1: Density of the specimens.

By the Archimedes' principle density of different composition specimens were taken, As the percentage of reinforcement i.e., both B_4C and SiC increases, density increases. However, the addition of graphite into the composites, it is observed that there was a decrease in density. But the density of the composites when compared with the base material is still higher. The graph 1 shows, the minimum density for Al7075 (Base material) and maximum density for Al7075+ 10%B_4C+ 10% SiC (Composite).

Table 3: Specimens Test results.

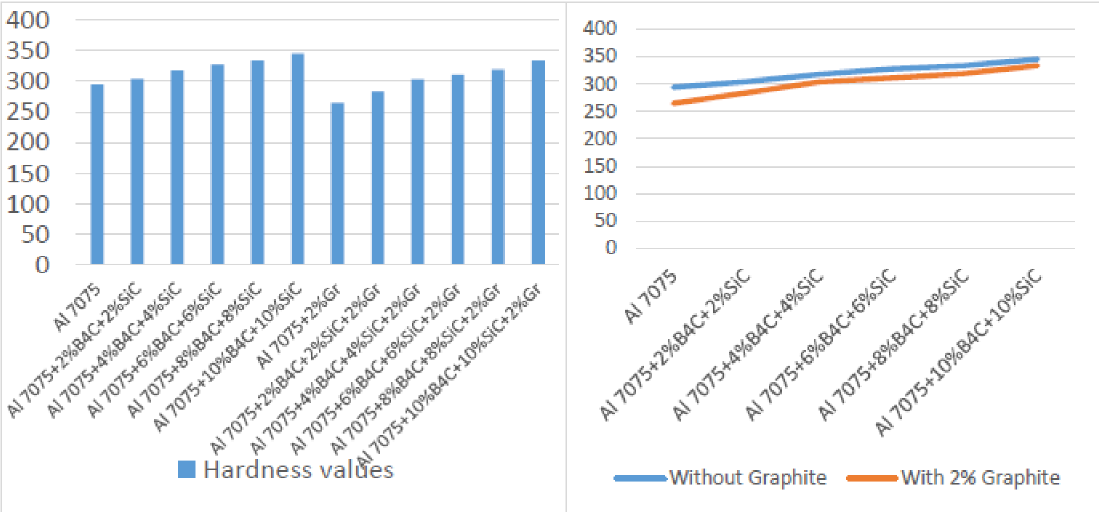
S. No	Composition	Density		Hardness								Loss of Material	
				After Specimen Prepaation		After Heat treatment Quenching in different mediums							
						Water		Ice		Oil			
		Without graphite	With 2% graphite	Without Graphite	With 2% Graphite	With out grathite	With 2% graphite	Without graphite	With 2% graphite	With out grathite	With 2% graphite	With out grathite	With 2% graphite
1	Al 7075	3.208561	3.208561	294	264.5	340	318	327	386	389	351	0.197	0.0182
2	Al 7075+2%B_4C+2%SiC	3.163002	3.451062	304	283.5	349	327	438	404	399	368	0.1798	0.01847
3	Al 7075+4%B_4C+4%SiC	3.338803	3.541648	317.5	303.5	367	340	473	419	430	381	0.2124	0.01468
4	Al 7075+6%B_4C+6%SiC	3.957793	3.613536	327.5	311	392	356	513	456	467	415	0.2874	0.01237
5	Al 7075+8%B_4C+8%SiC	4.316555	3.729448	333.5	319	411	366	540	484	491	440	0.3479	0.01678
6	Al7075+10%B4C+10%SiC	4.45117	3.94753	345.5	333.5	441	376	580	491	528	447	0.5748	0.01945

6.2 *Hardness test*

The Hardness of the specimens was calculated using Micro Vickers Hardness Equipment andthe results are Tabulated in Table.3 and Graph 2 shows their results of with and without graphite of specimens.

By the addition of B_4C and SiC, the hardness values increase gradually up to the maximum percentage. The percentage increases around are 18% compared to the matrix materials. Thehardness is much less than matrix materials by the addition of graphite, due to graphite having high machinability properties. By the continuous process by the addition of graphite same compositions were fabricated and further taken hardness values. The values of hardness were decreased due to the addition to graphite in all compositions due that the soft characters of graphite.

The minimum hardness achieved at Al7075+2%Gr specimen and Maximum hardness was achieved at Al 7075+10%B_4C+10%SiC as shown in Graph 5.2.

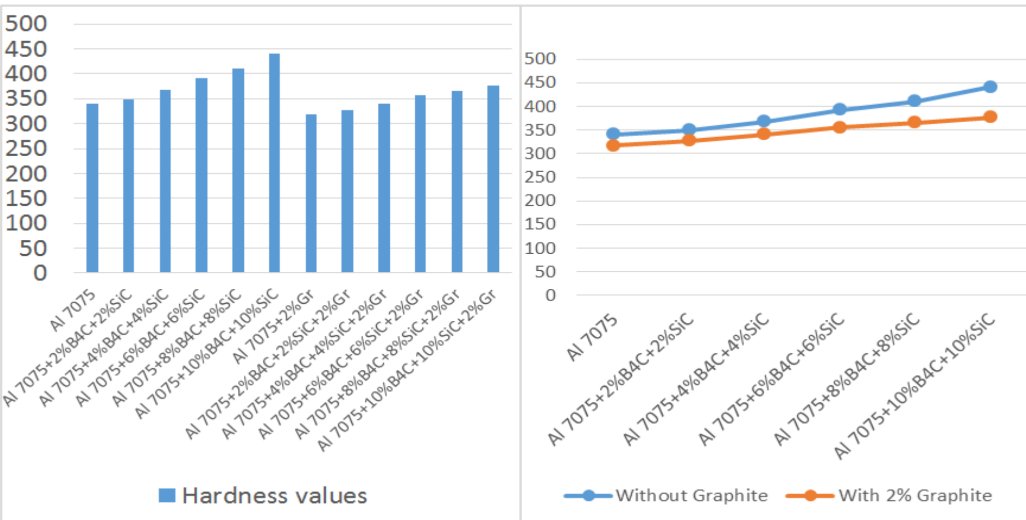


Graph 2: Hardness test results of specimens.

The minimum hardness achieved at Al7075+2%Gr specimen and Maximum hardness was achieved at Al 7075+10%B4C+10%SiC.

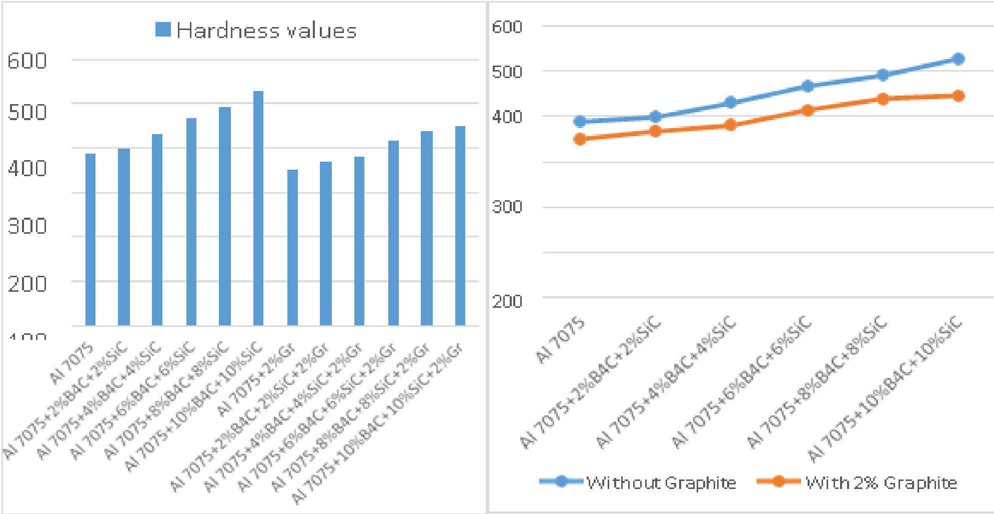
6.3 *Quenching followed by Heat treatment*

By using the muffle furnace this samples further subjected to the heat treatment process at recrystallization temperature and quenched in three different mediums. This heat treatment is done 230^{o}c in all mediums, follows to hardness by the micro-Vickers. In all these three mediums there was increases in the hardness in all the compositions are tabulated in Table 3 and Graphs shows their results of with and without graphite of specimens.



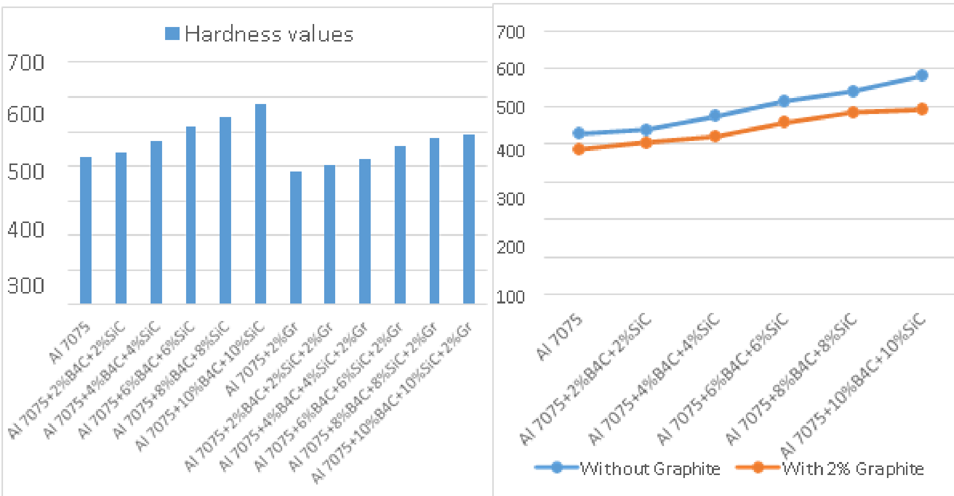
Graph 3: Specimens Hardness values followed by quenching in water.

- In the water the percentage of increases is around 27% for the highest composition



Graph 4: Specimens Hardness values followed by quenching in oil.

- In the oil the percentage of increases is around 52% for the highest compositions.

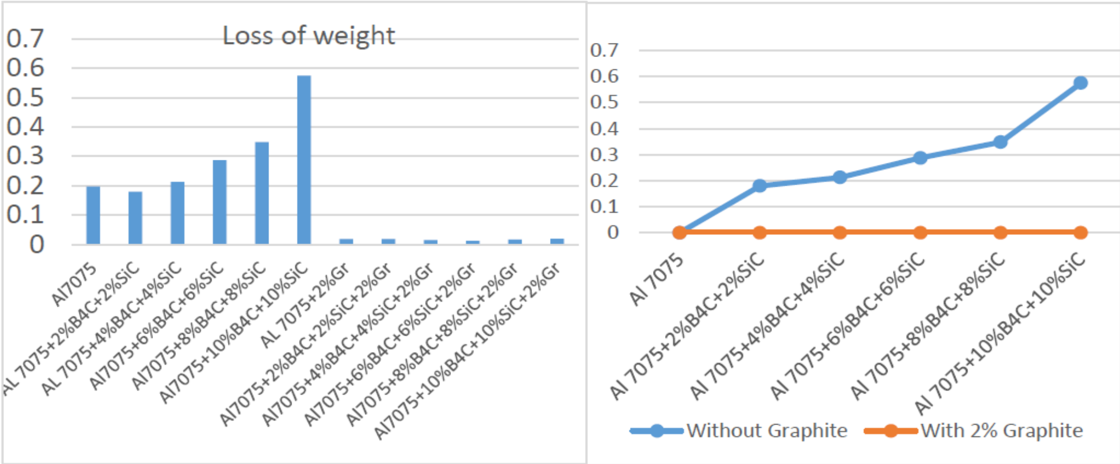


Graph 5: Specimens Hardness values followed by quenching in Ice.

- In the ice the percentage of increases is around 67% for the highest composition.
- ➢ In the water quenching maximum hardness achieved at Al7075+10%B4C+10%SiC.
- ➢ In the oil quenching maximum hardness achieved at Al7075+10%B4C+10%SiC.
- ➢ In the ice quenching maximum hardness achieved at Al7075+10%B4C+10%SiC.

6.4 *Wear test*

By the addition of both b4c and sic, the wear is higher than matrix, because of these two reinforcements are having extreme hardness their results are tabulated in Table 3. Graphs shows their results of with and without graphite of specimens.



Graph 6: Specimens' vs Wear at 1kg load 200mts.

By the addition of graphite into the composites the wear rate is decreased, as increasing percentage of b4c and sic the wear rate is increases, because of the graphite having excellent Machinability characters. From the Results the max. wear rate decrease was observed at Al7075 + 6%B4C + 6%SiC + 2% Gr. As the composite subjected to wear when it comes to graphite it will be more lubricant and it was formed a layer of lubricant which decrease further wear.

6.5 *Comparison of test Results*

Table 5.7 shows all experimental results which are conducted on different composite specimens with 2 % graphite and without graphite. And Graphs 5.7 to Graphs 5.12 shows all experimental results which are conducted on different composite specimens with 2 %graphite and without graphite. Out of all 12 specimens the density test results show base material and Al7075+2%Graphite achieve same values and these are lowest density metals compare to all the remaining specimens. From the hardness test, the maximum hardness values observed at Al7075+10%B_4C+10%SiC in Ice quenching. And from wear test, minimum wear rate observed at Al7075 + 6%B_4C + 6%SiC + 2% Gr.

Out of all specimens which has fabricated without percentage of graphite addition and different compositions of reinforcement, it is observed that as percentage of reinforcement increases density, hardness, and wear rate all are increases. Whenever addition of 2% graphite to these different compositions, graphite controls increased proportionality of the density, hardness and wear rate. And observed good results at Al7075+ 6%B_4C + 6%SiC + 2% Gr.

7. CONCLUSIONS

The Al metal matrix composites specimens were fabricated by stir casting. From the above results the following conclusions were drawn.

1) The addition of reinforcement degrades the density of the composite material, when compare to base material or matrix.
2) As percentage of SiC and B4C increases hardness values of the specimens increases, whenever graphite added to base material, Sic and B4C compositions the hardness values of the specimens decrease when compare to the respective compositions.
3) Whenever graphite added to the Base material, SiC and B4C compositions, due to its properties wear rate decreases and out of all taken specimens minimum wear loss observed at Al7075+6% SiC+6%B4C+2%Gr specimen.
4) Whenever addition of 2% graphite to these different compositions, graphite controls increased proportionality of the density, hardness and wear rate. And observed good results at Al7075 + 6%B_4C + 6%SiC + 2% Gr.

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