Synthesis, Evaluation of Micro Structure and Mechanical Characterization of Al7075-B4C Metal Matrix Composites

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Abstract: **Composite material as name itself defined as the combination of two or more materials which will give better results when compared to individual. Now a day's higher strength to weight ratio is required in almost all areas of applications .Metal matrix composites playing prominent role in all applications. For producing metal matrix composites even though several manufacturing processes available stir casting got its own importance in producing them why because its simplicity, applicability and flexibility with bulk mass production in low cost criteria. This work involves fabricate the AL7075-B4C Metal Matrix Composites by stir casting method after that mechanical characterization and micro structural investigation done. Results shows that AL7075 with of 10% B4C shows much variation than the other compositions i.e. 0%, 2.5%,5%,7.5% Composites. Mechanical properties such as Tensile strength, Hardness, Impact Strength and Compressive Strength are observed more in AL7075 with of 10% B4C MMC. Micro structural studies show that uniform distribution of reinforcement with Matrix material.**

***Keywords*: AL7075, Stir Casting, Metal Matrix Composites, B4C.**

I. INTRODUCTION

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. A composite exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. Metal-Matrix Composites (MMCs) are a diverse class of materials that consist of a metallic alloy matrix typically reinforced with a ceramic phase in the form of particles, platelets, whiskers, short fibers and continuously aligned fibers. Metal matrix composites are used in structural applications and in applications requiring wear resistance, thermal management and weight savings. By far the most common commercial MMCs are based on aluminium, magnesium and titanium alloys reinforced with silicon carbide (Sic), alumina (Al2O3).

The term metal matrix composites covers a very wide range of materials, from relatively simple reinforcement of castings with low cost refractory wool to complex continuous fiber lay ups in exotic alloys. Clearly, the applications will also vary widely to reflect the cost/property relationships offered by each type of MMC.

Modem technological applications require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater, and transportation applications. Aircraft engineers, for example, are increasingly searching for structural materials that have low densities, strong, stiff and abrasion and impact resistant and corrosion resistant. This is a rather formidable combination of characteristics. Frequently, strong materials are relatively dense and increasing the strength or stuffiness generally results in a decrease in impact strength. Advanced materials are developed to an increasing extent and their number is rapidly increasing.

The last few decades have seen the increasing use of composite materials in many engineering fields of engineering applications. Composite materials can be suitably selected to have one or more of the following specific advantages like higher strength to weight ratio, higher stiffness to weight ratio, high temperature applications, better corrosion and wear resistance, better thermal insulation, etc.

Presently composite materials are found to replace the conventional steel materials for a number of components in a wide variety of engineering applications, particularly where light weight structures are of prime importance.

The potential of metal matrix composite materials for significant improvements in performance over conventional alloys has been widely recognized. The benefit of using composite materials is the advantage of attaining property combinations that can result in a number of service benefits. The main advantage of composites lies in the tailor ability of their mechanical and physical properties to meet specific design criteria. In this chapter metal matrix composites, their classification and applications are discussed. Also the procedure followed to fabricate. The objective of the study is to estimate the microstructure, mechanical properties, at different weight percentage of Boron Carbide (0%, 2.5%,5%,7.5% 10%).

II. LITERATURE REVIEW

Sozhamannan et al. (2012) fabricated Al-SiC composites by stir casting process, and reported that SiC particles uniformly distributed at the processing temperature in the range of 750°C and 800°C.

Jillellavadlamohanachari et al. (2018) developed the Al-Sic metal matrix composites by varying the Sic percentage in steps of 0%, 4%,8% and 16% and after that they found from their experimental results as Sic percentage increases the hardness was also increased.

Rabindra Rehera, D. Chaterjee, G . Sutradhar [5] investigated and performed an experiment based on the effect of reinforcement particles on the fluidity and solidification behavior of the stir cast aluminum alloy metal matrix composites. In this experiment results indicated that on increasing the weight percentage of reinforcement particles SiC in cast aluminum alloy. MMCs the fluidity of cast composite metal decrease and the rate of solidification decreased due to which the total solidification time enhanced.

Manoj Kumar Yadav, Bijender Saini, Ashu Yadav [3] investigated and performed an experimental analysis of mechanical properties of Al and SiC composite. In this the weight of different weight percentage of Silicon Carbide in composite on tensile strength, hardness, microstructure, was studied.

Experimental analysis have done by using the Aluminum (6061) Alloy and Silicion Carbide in this experiment we use Al(6063) with Silicon Carbide at different percentage.

J. Jebeen Moses, T Dinaharan, S. Joseph Sekhar [2] investigated an experiment based on the characterization of Silicon Carbide particulate reinforced AA6061 aluminum alloy composites produced via stir casting in this experiment it was done by the process of stir casting. The reinforcement of Sic particles improved the micro hardness and ultimate tensile strength of AMC's. The details of fracture morphology.

Singh S [1] investigated and performed an experiment on primary and secondary processing of metal matrix composites. The factors embrace the constant allocation of Sic reinforcement, wettability of Sic and aluminum alloy, defect free casting of mmc's and the reaction takes place among Sic reinforcement and aluminum matrix composite at superior temp.

III. OBJECTIVES OF THE PROPOSED WORK

1. To synthesize the Al7075-B4C metal matrix composites by stir casting route with various proportions of B4C.
2. Evaluate the Mechanical characterization.
3. Micro structural studies of developed composites by using SEM & EDAX Analysis

IV.EXPERIMENTAL SETUP AND PROCEDURE

This is the layout of the stir casting apparatus. It consist of conical shaped graphite crucible is used for fabrication of AMCs, as it withstands high temperature which is much more than required temperature Along that graphite will not react with aluminum at these temperature. This crucible is placed in muffle which is made up of high ceramic alumina. Around which heating element of wound. The coil which acts as heating element is Kanthol-A1. This type of furnace is known as resistance heating furnace. It can work up to 900°C reach within 45 min. Aluminium, at liquid stage is very reactive with atmospheric oxygen. Oxide formation occurs when it comes in contact with the open air. Thus all the process of stirring is carried out in closed chamber with nitrogen gas as inert gas in order to avoid oxidation. Closed chamber is formed with help of steel sheet. This reduces heat loss and gas transfer as compare open chamber. A K type Temperature thermocouple whose working range is -200°C to 1250°C is used to record the current temperature of the liquid. Due to corrosion resistance to atmosphere EN 24 is selected as stirrer shaft material. One end of shaft is connected to 0.5 hp PMDC motor with flange coupling. While at the other end blades are welded. 4 blades are welded to the shaft at 45°C. A constant feeding rate of reinforcement particles is required to avoid coagulation and segregation of the particles. This can be achieving by using hopper. Aluminium alloy matrix will be formed in the crucible by heating aluminium alloy ingots in furnace. A stirring action is started at slow rate of 30 rpm and increases slowly in between 300 to 600 rpm with speed controller. A mixture of reinforcements (Al2O3 + SiC + Graphite) is to be incorporated in the metal matrix at semisolid level near 640°C. Dispersion time is to be taken as 5 minutes. After that slurry is reheated to a temperature above melting point to make sure slurry is fully liquid and then it is poured in mould.

PROCEDURE

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 500°C and then it is gradually increased up to 900°C. High temperature of the muffle helps to melt aluminium alloy quickly, reduces oxidation level, enhance the wet ability of the reinforcement particles in the matrix metal. Aluminium alloy Al7075 is used as Matrix material.
Initially the Aluminium alloy is in the form of round bars as shown in the Fig 1. This round bars of Alumunium alloy is cut into required small pieces as per our requirement as shown in Fig 4.2

Fig4.1.Al7075 Alloy

Fig 4.2.Cutted pieces of Al7075

Aluminum alloy is cleaned to remove dust particles, and then poured in the crucible for melting as shown in the Fig 4.3. During melting nitrogen gas is used as inert gas to create the inert atmosphere around the molten matrix. Powder of Boron carbide (B4C) and graphite are used as reinforcement. 1% by weight of pure magnesium powder is used as wetting agent. At a time total 700 gram of molten composite was processed in the crucible. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine

Reinforcements are heated for half hour and at temperature of 500°C. When matrix was in the fully molten condition, Stirring is started after 2 minutes. Stirrer rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Temperature of the heater is set to 630°C which is below the melting temperature of the matrix. A uniform semisolid stage of the molten matrix was achieved by stirring it at 630°C.Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wet ability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured was 0.5 gram per second. Dispersion time was taken as 5 minutes. After stirring 5 minutes at semisolid stage slurry was reheated and hold at a temperature 900°C to make sure slurry was fully liquid. After melting the Aluminium alloy into liquid form we have to remove the slag as shown in the Fig4.4.

Fig: 4.3 Molten Metal ready for pouring

Fig: 4.4 removing slag from Molten Metal before pouring

The stir casting apparatus is manually kept side and then molten composite slurry is poured in the metallic mould. Mould is preheated at temperature 500°C before pouring of the molten slurry in the mould. This makes sure that slurry is in molten condition throughout the pouring. While pouring the slurry in the mould the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix and finally the specimens are as shown in the Fig 4.5.

Fig 4.5 Prepared Metal Matrix composites

V. EXPERIMENTAL TESTING

MICROSTRUCTURE

For microstructure testing, the fabricated MMC's were polished in such a fine way that there should be mirror like image in upper surface of samples. The mirror like surface finishes the samples were achieved by rubbing the sample on emery papers (100 to 1000 microns) and velvet cloth with the help of polishing machine. Then surface of sample were washed by Keller etch and Kroll's reagent. In this fabrication metal matrix composites, there is a difference of distribution of B4C particles to be seen by optical microstructure tests.

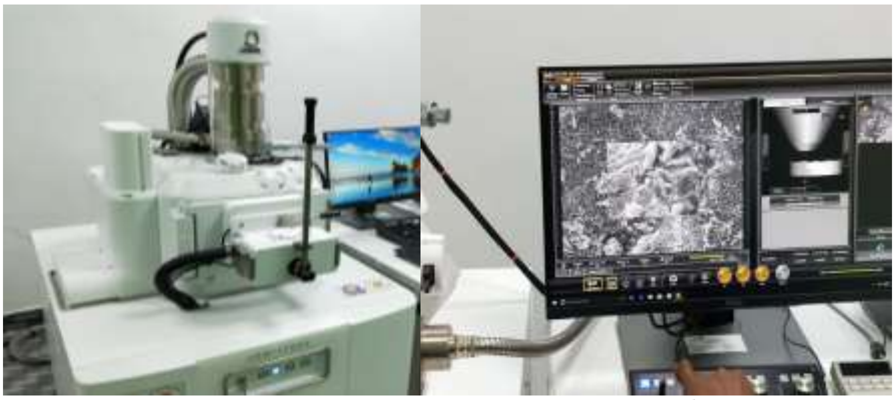


Fig 5.1 Micro structural machine

Fig 5.2 SEM Analysis Specimens

MECHANICAL PROPERTIES

TENSILE TESTING

A tensile test is one of the most fundamental and common types of mechanical testing tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress. By doing this, tensile tests determine how strong a material is and how much it can elongate. Tensile tests are typically conducted on electromechanical or universal testing instruments, are simple to perform, and are fully standardized.

Fig 5.3Universal Testing Machine

Fig 5.4Tensile Test specimens

COMPRESSIVE TEST

Compressive strength is often measured on a universal testing machine; these range from very small table-top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

Fig 5.5 Compression Test (UTM)

Fig 5.6 After Compressive Test Specimens

IMPACT TEST

Impact Test to be carried out over Impact Testing Machine. The test specimens are prepared from the casting materials and machined as per ASTM standard size. Square cross sections of size (8mmX8mmX55mm) with single V-notches are provided for the specimens.

Fig 5.7 Impact testing machine

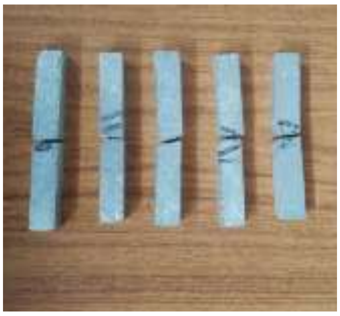


Fig 5.8 Izod Impact Test specimens

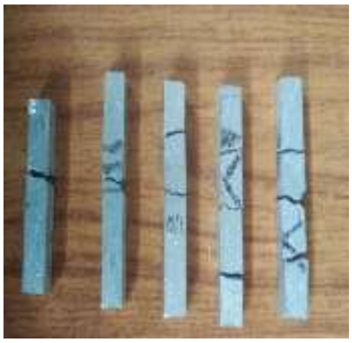


Fig 5.9 Charpy Impact Test Specimens

HARDNESS TEST

The hardness of a material indicates the resistance to permanent indentation. While testing the hardness of a material an indenter is pressed into the surface of the material to be tested under a specific load for a definite time interval. The diameter of the indentation left in the test material is measured with a low powered microscope. In the present work Brinell hardness tester with indenter diameter 5mm was used to determine the hardness of both the specimens of Al7075-B4C were composites. A load of 100kgf is applied for 30 seconds. The Brinell hardness number (BHN) is calculated by dividing the load applied by the surface area of the indentation.

Fig 5.10Brinell Hardness Test

Fig 5.11Brinell Hardness Test Specimens

VI.RESULTS AND GRAPH

MICROSTRUCTURE

In SEM micrograph presented in Fig. 6.1, the B4C appearing in cluster form and in fig. 6.2, B4C appears as spherical is a clump of B4C. It is because wetting of small individual reinforcement particle is difficult due to increase in the surface energy required for the matrix surface to deform to a small radius as the particle begins to penetrate it. The smaller particles are also more difficult to disperse due to their inherently greater surface area. Hence, these smaller particles have a tendency to clump together, resulting in good wetting of particles with molten matrix. The good wetting of reinforcement particles with the matrix and uniform distribution of B4C reinforcement increase the load bearing capacity of the AMC and as the clumped B4C particles are spherical in shape, more shear force is required to initiate the crack. Hence, wear rate of the composite decreases with increase in mass fraction of B4C in the composite.

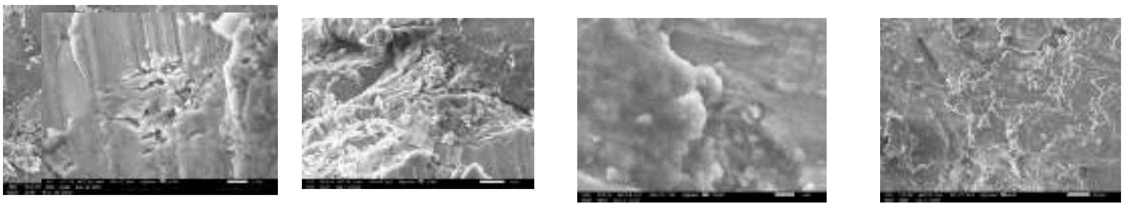


FIG 6.1 SEM IMAGES OF PURE AL7075 AT DIFFERENT MICRONS

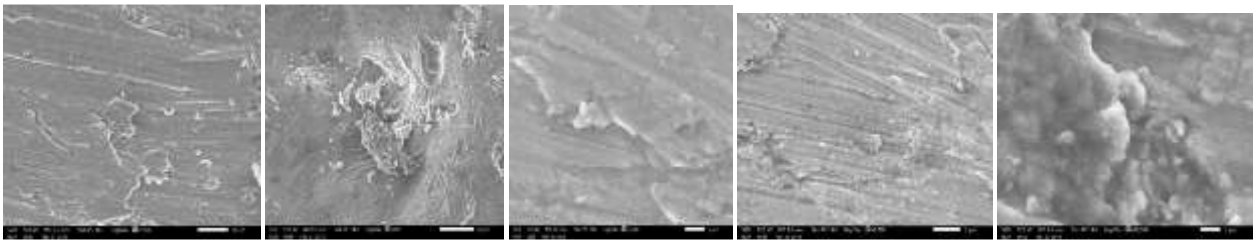


FIG 6.2 SEM IMAGES OF AL7075-B4C 2.5% MMC AT DIFFERENT MICRON

FIG 6.3 SEM IMAGES OF AL7075-B4C 5% MMC AT DIFFERENT MICRONS

FIG 6.4 SEM IMAGES OF AL7075-B4C 7.5% MMC AT DIFFERENT MICRONS

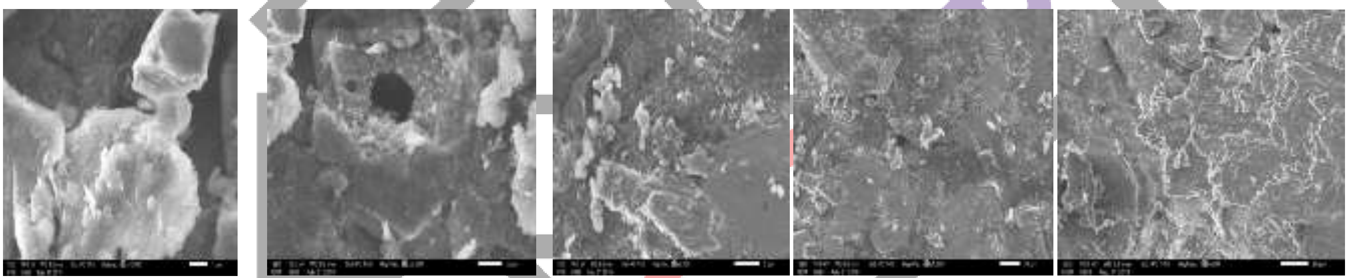
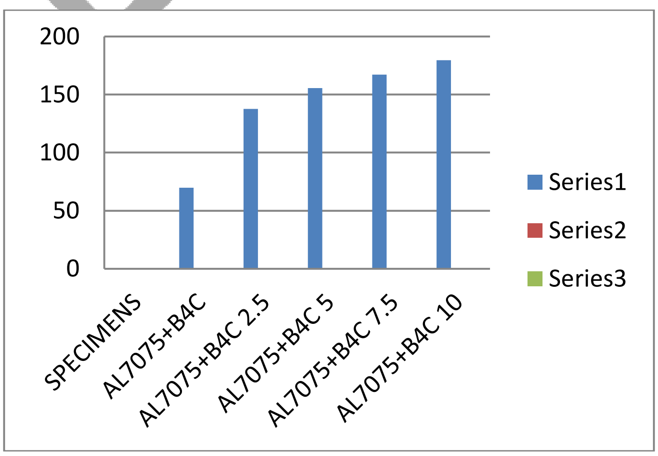


FIG 6.5 SEM IMAGES OF AL7075-B4C 10% MMC AT DIFFERENT MICRON

TENSILE STRENGTH

Specimen	Tensile Strength(Mpa)
Al7075	69.8
Al7075+ B4C 2.5%	137.6
Al7075+ B4C 5%	155.6
Al7075+ B4C 7.5%	167.1
Al7075+ B4C 10%	179.6

Table 6.1 Tensile Test Results of AL7075 – B4C Composite



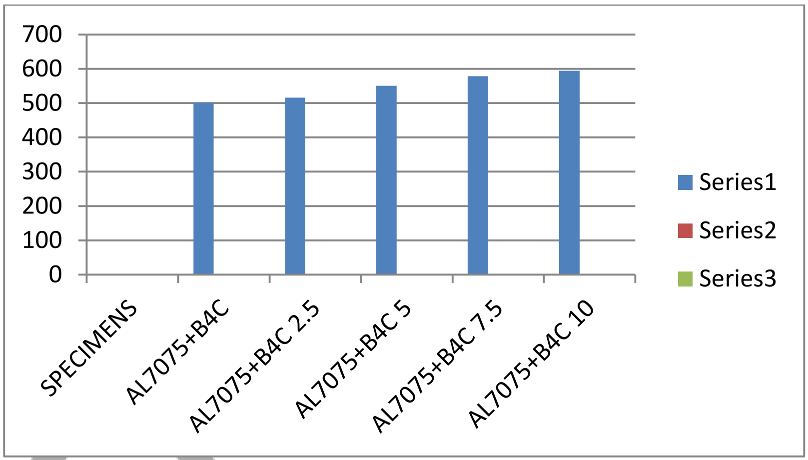
Graph 6.1 Tensile test results graph (Al 7075-B4C)

From the above graph we can know that pure Al7075 Having Tensile Strength of 179.6Mpa. As the reinforcement percentage increased the Tensile strength also increased and it acquires the maximum value observed in Pure Al7075-B4C10% MMC.

COMPRESSIVE STRENGTH

Specimen	compressive Strength(Mpa)
Al7075	88
Al7075+ B4C 2.5%	112
Al7075+ B4C 5%	137
Al7075+ B4C 7.5%	142
Al7075+ B4C 10%	145

Table 6.2 Compressive Test Results of AL 7075 – B4C Composites



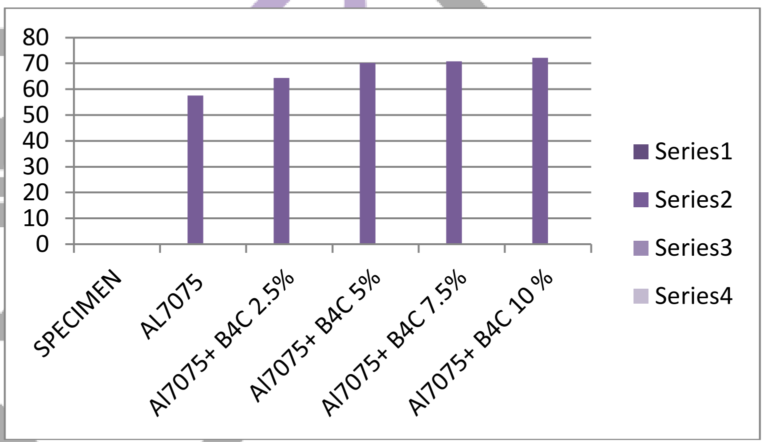
Graph 6.2 Compressive Test Results graph (AL 7075- B4C)

From the above graph we can know that pure Al7075 Having Compressive Strength of 84 Mpa. As the reinforcement percentage increased the Tensile strength also increased and it acquires the maximum value observed in Al7075-B4C 10% MMC.

HARDNESS TESTING

Specimen	Hardness number
Al7075	57.6
Al7075+ B4C 2.5%	64.3
Al7075+ B4C 5%	70.2
Al7075+ B4C 7.5%	70.8
Al7075+ B4C 10%	72.1

Table 6.3 Hardness Test Results of AL 7075 – B4C Composites.



Graph 6.3 Hardness Test Results (AL 7075- B4C).

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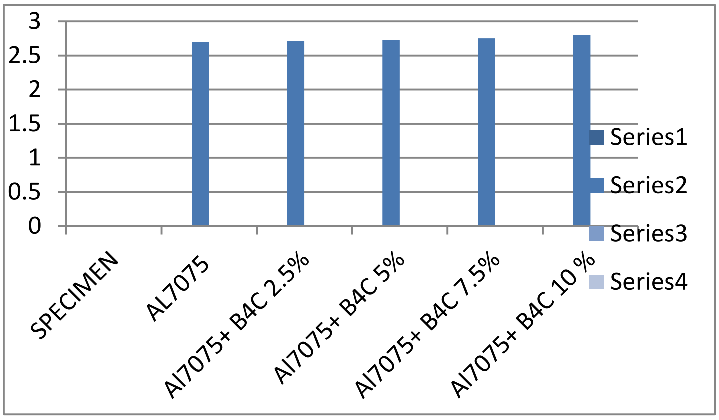
From the above graph we can know that pure Al7075 Having Hardness of 57.6.As the reinforcement percentage increased the Hardness also increased and it acquires the maximum value observed in Al7075-B4C 10% MMC.

IMPACT TEST (IZOD)

Specimen	Hardness number
Al7075	2.7
Al7075+ B4C 2.5%	2.71
Al7075+ B4C 5%	2.725
Al7075+ B4C 7.5%	2.75
Al7075+ B4C 10%	2.8

Table 5.5 IZOID Test Results Of AL7075-B4C Composites



Graph.6.4 Izod Test Results (AL 7075- B4C)

From the above graph we can know that pure Al7075 Having Impact Strength of 2.7N-M.As the reinforcement percentage increased the Tensile strength also increased and it acquires the maximum value observed in Al7075-B4C 10% MMC.

VII.CONCLUSIONS

I. Successfully fabricated Al 7075 - B4CMetal matrix composites by stir casting.
II.After that specimens were prepared for different mechanical tests as per ASTM standards.
III.In this investigation the composites are developed with the help of stir casting technique, the fabricated samples are prepared As per ASTM standards to conduct the Mechanical behavior, from the test it is noticed the tensile strength of the composite are increases up to 61% for 10wt.% as compared to parent material. Similarly the compressive strength increases for developed composite with 39.3% for 10wt. % of B4C in to a matrix material. Similarly the Hardness value increases for developed composite with 14.5% for 10wt. % of B4C in to a matrix material. Similarly the impact strength increases for developed composite with 3.5% for 10wt. % of B4C in to a matrix material.

REFERENCES

1. Jillellavadla mohanachari et al. (2018) developed the Al-Sic metal matrix composites by varying the Sic percentage in steps of 0%, 4%,8% and 16% and after that they found from their experimental results as Sic percentage increases the hardness was also increased.
2. Ravendra Singh et al. (2012) used grey relational analysis in optimization of control parameters for the betterment of mechanical and wear properties of carburized mild steel, and they reported that A3 (960°C Carburization Temperature), B3 (4 hours Carburization Sock Time), C2 (260°C Tempering Temperature), D3 (1.5 hours Tempering Sock Time) is an optimal process parameters combination for the carburization process.
3. Sozhamannan et al. (2012) fabricated Al-SiC composites by stir casting process, and reported that SiC particles uniformly distributed at the processing temperature in the range of 750°C and 800°C.
4. SeyedAbdolkarimSajjadi et al. (2011) performed Taguchi design to study the effects of Sn/Gr lubricants on the cold extrudability of FeTiCnano composites, and investigated that milling time is most useful parameter to get the quality extrusion product. Increase in milling time, decreases the degree of crystallinity unlike surface energy of particles.
5. Das et al. (2010) studied hardness and forge ability characteristics of Aluminium reinforced composites with 5, 10, 15 and 20 Wt% of Sic, and reported that hardness increaseswith the increase of weight % of SiC in the metal matrix composite. Forge ability of metal matrix composite decreases with an increase in weight % of SiC.
6.Chauhan et al. (2010) used Taguchi's design of experiments method for to investigate the dry sliding wear and coefficient of friction of the polymer matrix composites reinforced with fly ash. From the investigations, it was reported that 10 Wt%-20 Wt% of fly ash has the highest physical and statistical significance on the responses.
7. ManojSingla et al. (2009) Produced Al-SiC MMC's, from this work hey reported that the increase in SiC weight percentage increases the strength of the base material .
8.YucelBirol (2008) reported that salts generated while the formation of Al3Ti particles will clean the surface oxides of the aluminium powders, and Al3Ti particles are gradually replaced by a fine dispersion of TiC particles as soon and as long as solute Ti is made available via the solutionizing of Al3Ti particles over a range of temperatures starting at 800^{0}C.