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A STUDY ON METALLURGICAL AND MECHANICAL PROPERTIES ON AI 2618 BASED MMC'S WITH BN AND GR

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Abstract : Due to their improved corrosion resistance along with wear compared to conventional metals and alloys, as well as their good mechanical qualities, low density, and low coefficient of the thermal expansion, Aluminium alloys continue to be an increasingly popular option in the automobile, naval construction, and aviation sectors. Composites were highly regarded for their adaptability in a variety of technical applications, in addition to their decreased manufacturing expenses and enhanced mechanical qualities. Researchers have incorporated various amounts of particles in the mixture to produce an Aluminium-based metal matrix composite. The production of 2618 Aluminium-based metal matrix composites augmented with boron nitride and graphite utilizing stir casting processes is the particular goal of the present investigation. In order to assess the characteristics of the metal matrix, the specimens generated were examined for hardness, compressive and tensile strengths, XRD, SEM, and optical microscope tests.

***IndexTerms* -** Metal matrix composites, Strength analysis, boron Nitride and Graphite Powder.

I. INTRODUCTION

Aluminium alloys have attracted designers and manufacturers in many different uses in the past few decades because of their outstanding properties, which include low density, cheap cost, with a high strength-to-weight ratio [1]. Furthermore, they have become recognized for their broad range of engineering applications such as automotive, aerospace, and biomedical [2]. While Aluminium alloys have excellent properties, they're ineffective in corrosion and wear uses. Since the wear as well as corrosion characteristics of materials used in engineering possess a significant impact on component operability and durability, they must be considered in the development of engineering components [3]. Metal matrix composites (MMCs) possess lately gained prominence for improving the mechanical as well as wear properties of Aluminium alloys by establishing a homogeneous structure using refining grains [4, 5]. MMCs are highly hard, abrasion resistant, and generally light [6]. These composites have extremely high strength, resistance to corrosion, wear resistance, resistance to fatigue, stiffness, and other properties [7]. MMCs are a mixture of multiple materials (which includes metal or alloyed) that provide certain qualities that cannot be attained in metals in their pure form or alloys [8]. MMCs are often made up of fibres, whiskers, or particles distributed over a metallic matrix [9]. Stir casting, centrifugal moulding [10, 11], powder metallurgy, compensation-casting, infiltration, squeeze casting [12], as well as additional processes are used to create MMCs [13, 14]. Although there are numerous manufacturing methods, powder metallurgy as well as stir casting have been the most common [15]. Several studies in Aluminium matrix composites (AMCs) and several tests with magnesium matrix composites (Mg-MMCs) have been conducted lately [16-19].

II. Methodology

The purpose of this research was to create a metal matrix composites utilizing Aluminium 2618 (Al2618) for the basis material. Boron Nitride as well as graphite powder were employed as reinforcements. To make melting easier, the aluminum alloy was chopped into little ingots which were able to be easily put in the furnace.

Aluminum 2618

Because of its desirable qualities such as superior resistance to corrosion, high electric as well as thermal resistance, a low density, and acceptable the ability to be machine Al2618 is a prominent matrix component employed in metal matrix composites. The mechanical qualities of the aforementioned alloy can be improved by reinforcing it with additional particles. Aluminium oxide, carbide of silicon, silicon dioxide, graphite, the boron nitride, as well as boron carbide constitute typical reinforcements for this alloy.

Boron Nitride (BN)

Boron nitride has a high hardness and great thermal and chemical durability. Nitride of boron particles having a particle size between 7-11 microns were used in this investigation. The type in boron nitride used was HCV, which is an essential grade for the fabrication of several sophisticated materials.

Graphite (Gr)

Because of its lamellar structure, graphite serves as a self-lubricating reinforcing that improves the antifriction qualities of the composite. Adding graphite within the matrix also increases the composite's precision. Graphite particles having a particle size in 260 microns have been employed in this investigation.

Composite Preparation

The stir casting method serves to prepare the metal matrix elements. A vortex condition is formed in the molten metal to achieve equal dispersion of the reinforcement in the metal matrix when utilizing the stir casting process. To generate a hybrid metal matrix composite, the reinforced particles Bn and Gr are combined with the basic material A2618. 600 grammes of Aluminium alloy are placed in a graphite crucible and cooked in an elevated temperature electric furnace. For an entire hour, the Aluminium alloy gets heated over the melting the temperature (650o) in an electric furnace. The reinforcing particles Bn and Gr are warmed to 450-550o. This procedure serves to eliminate the particle's moisture. Once the Aluminium alloy has been melted, it is then stirred with a mechanical stirrer at a speed ranging from 550 RPM to 1100 RPM. Bn and Gr are gently added into the molten metal and swirled constantly throughout the vortex phase to produce the reinforced particles, and the pace of the stirring is raised while a time frame of 5 minutes remains the same. The hot metal is allowed to cool and solidify in the prepared mould, resulting in casting material.

Figure 1. Stir casting process.

The casting as well as composite ingots undergo heating using a muffle furnace. The ingots are heated to achieve an accuracy of ±1° to a temperature of 529°, and the composite material undergoes treatment with water to conclude the process before being aged for 8 hours with a temperature of 159°C. When the heat treatment procedure is finished, the casting material gets machined to be tested and then processed to the required dimensions.

The using the above presented process, four samples of specimens are prepared. The samples related Al2618 Bn and Gr content are presented in weight percentage.

	AL2618	Bn	Gr
0% Reinforcement	100%	0%	0%
4% Reinforcement	95%	4%	1%
6% Reinforcement	93%	6%	1%
8% Reinforcement	91%	8%	1%

Table1. Samples with percentages in composition

III. Results

Testing Methods

The composite specimen is tested using five different procedures. Hardness testing, testing for tensile strength, compressive testing, as well as XRD, SEM, and optical microscope tests constitute the four types.

Tensile testing

For testing tensile specimen, the specimen is prepared by using EDM cutting machine. The tensile test was prepared according to ASTM E8 and the length of the specimen is 100mm, the thickness of the specimen is 5mm, and the detailed drawing of the specimen are presented below.

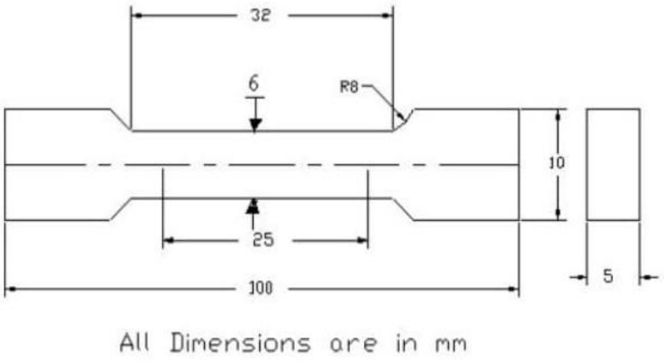


Figure 2. Specimen dimension

Once the dimensions are selected, the rectangular specimen is cut into dumbbell shape using EDM cutting machine. The cutting machine is shown below.

Figure 3. EDM cutting machine

Tensile specimen cutting with an EDM cutting machine entails designing the specimen with a CAD programme, preparing the material along with placing it on the EDM machine, configuring the machine based on the design requirements, cutting the specimen with electrical discharges, as well as completing the specimen through removing it off the machine along with cleaning it. This procedure is rapid, accurate, and enables the cutting of complicated forms, which makes it popular in the testing of materials to evaluate mechanical characteristics under strain.

The specimen is measured to be 100mm long in accordance with ASTM E 08 norms. The sample's ultimate tensile strength (UTS) has been calculated employing a computerized universal testing instrument.

The final tensile specimens are presented below.

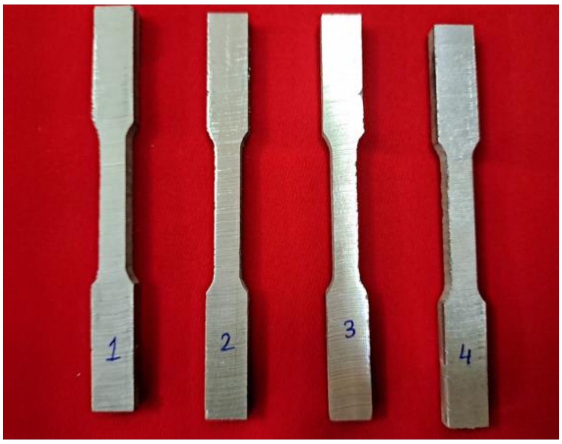
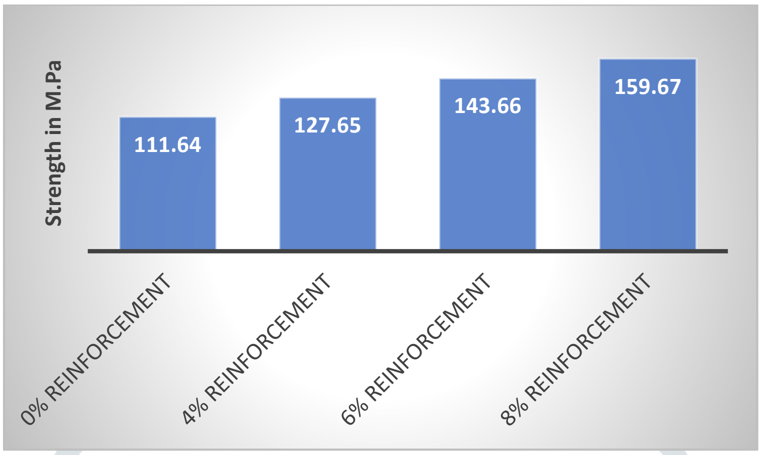


Figure 4. Tensile testing specimens.

The samples have been polished using different types for emery paper, Aluminium paste, which is and diamond paste before being etched with Keller's reagents under an optical microscope. The density of the base metals and various composite compositions were determined through the method of water displacement technique. The hardness for the base metal along with composites was measured using Vickers hardness testing. Tensile testing and compressive testing using a Universal Testing Machine (UTM) was performed in accordance with the ASTM standards to evaluate tensile strength as well as % elongation.



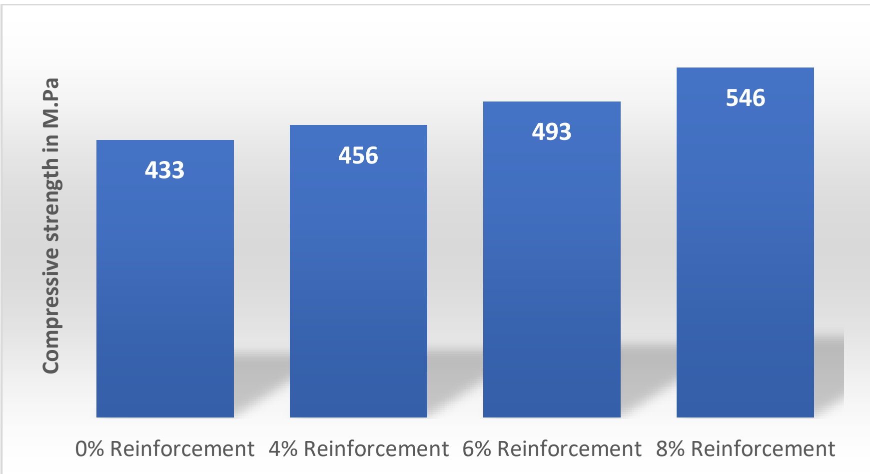
Graph 1. Effect of Bn and Gr on Ultimate tensile strength

The above displayed graph shows what the effect of reinforcements in samples over prepared HMMC samples based on testing which were conducted using UTM testing device, results were recorded as well as graph was plotted that illustrates that the increase in reinforcement will results in strength, which is at 8% if reinforcement, 159.67 MPa strength have been developed.

Compressive testing

Compressive testing is done on UTM. For this, samples are prepared in the form of cylindrical shape. The height is 20mm and has diameter of 8mm. The specimens are prepared using lathe machine. The specimen standard is ASTM E9 and the specimens were shown below.

Figure 5. compressive testing specimens.

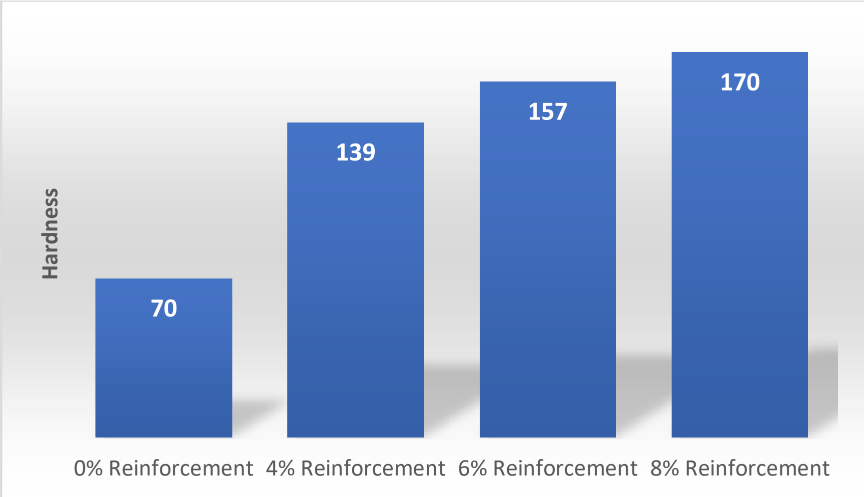


Graph 2. Compressive strength

The graph shown above shows the compressive strength for different samples. For 0% the compressive strength is 433 MPa and for 8% of reinforcement, the compressive strength is 546 MPa. Which indicates that the increase in reinforcement will increase in compressive strength.

Hardness test

Vickers micro-hardness testing was performed as per ASTM E384 on cast composite samples having different weight fractions. The HXD-1000TM/LCD digital hardness testing device was used using an indenter made of diamonds at a force applied of 100gf in addition to a dwell length of 15 seconds. Ten hardness measures were chosen to get the average values.



Graph 3. Hardness test

The above graph illustrates the results of the Hardness test conducted on various percentages of reinforcement. From the graph, higher the percentage of reinforcement will tend to increase the hardness of the specimens.

XRD analysis

The process of X-ray diffraction (XRD) examination has been employed to analyse the crystal structure in materials. In this study, an X-ray beam is aimed regarding a material that scattered the X-rays in different directions based upon its atomic arrangement. Information regarding the structure of the crystal, including lattice spacing as well as orientation, may be retrieved through determining the angles as well as the intensity of the scattered X-rays. XRD analysis is widely used to detect and characterise the crystalline structure of diverse materials in domains such as material science, geological sciences, chemistry, and physics.

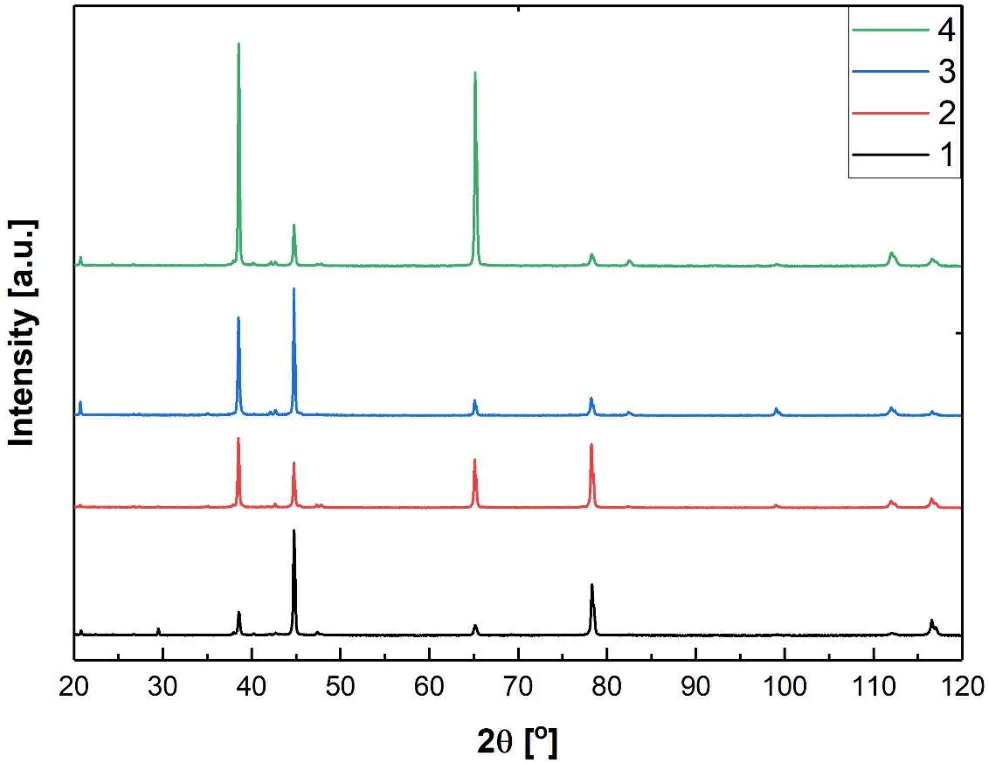


Figure 6. XRD analysis of Aluminium and composite.

The XRD spectrum representing the primary peak areas of hybrid metal matrix composites using Bn and Gr is shown in Figure. With varying reinforcements, different peak levels increases with Bn and Gr content can be observed in the image. The roughly comparable values of 2ϴ for as- HMMC peak position were 38, 45, 65 and 78 accordingly. Xpert Highscore was used to establish the analyses for each of these phases. After adding Bn and Gr to the Aluminium matrix, there was a slight change in 2 ϴ values. This is evidenced by a change in 2ϴ from 38 to 36 in a composite reinforced with Bn. This is evidenced by a change in 2ϴ from 38 to 34 in a composite reinforced with Gr.

Micro Structural Studies

The spatial arrangement of reinforcing particles within the matrix stage was observed using microstructural analysis. Grain size was additionally visible in the microstructure, which was divided with thin black boundaries for grains. The homogeneity of particle dispersion is critical to the efficiency of composites. For the microstructural examinations, metallurgy microscope samples were made and studied at magnification levels of 250X. The microstructure of an Aluminium metal matrix containing reinforcement particles is depicted in image below.

Scanning Electron Microscopy (SEM)

A scanning electron microscope, or SEM, creates pictures of the specimen by using a strong stream of electrons which communicate via the atoms and produce different signals conveying data regarding the sample. The morphology of a produced MMC having a composition comprising graphite as well as boron nitride on weight is shown in Figure, whereby the particles are evenly spread within the matrix material. Each composite has particles that are firmly packed and have a uniform spatial distribution.

Figure depicts the particle dispersion, with white particles recognized is boron nitride and little black particles classified as graphite. The SEM may be used to detect porosity that may lead to mechanical faults and failure. SEM was used to analyse the microstructure for cast Al-Gr, Boron nitride particle composites, revealing a balanced distribution of graphite along with boron nitride particles within the Al2618 matrix at weight fractions that were as high as 6% and as low as 2%. The micrographs also show how the reinforcing particles are round and rectangular in form and are evenly distributed across every specimen. Reinforcements can cause uneven distribution and blunts, especially in greater volume percentage specimens, as well as greater mechanical faults in the composite. The particulate reinforcement distribution is quite consistent, with the Aluminium matrix looking as a continuous material while the reinforcement particles observed in tiny sizes with grain boundaries. Increased reinforcement addition can result in structural variations, bigger and oval grains, as well as a rise in porosity as well as mechanical flaws.

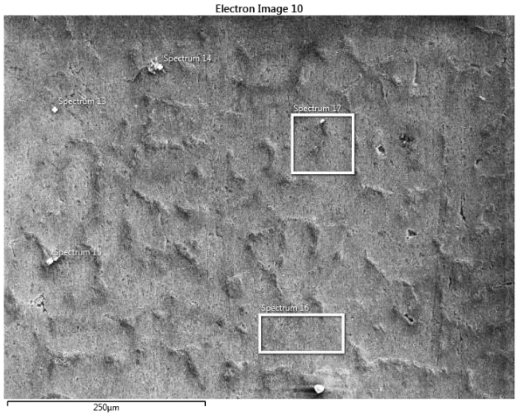


Figure 7. Specimen 1 SEM micrographs of MMC's

The figure above illustrates Al2618, revealing an intricate and interconnected boundary structure accompanied by a coarse grain structure.

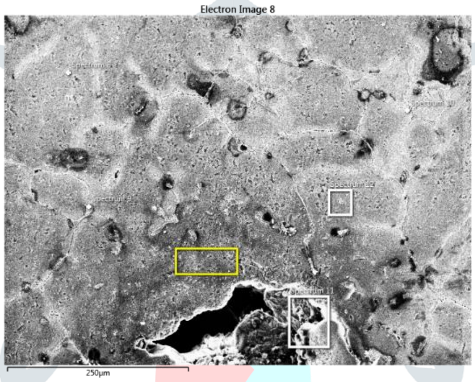


Figure 8. Specimen 2 SEM micrographs of MMC's

The above image exhibits non-refined grain structures, along with a non-uniform distribution observed between Bn and Gr particles in the base Al2618.

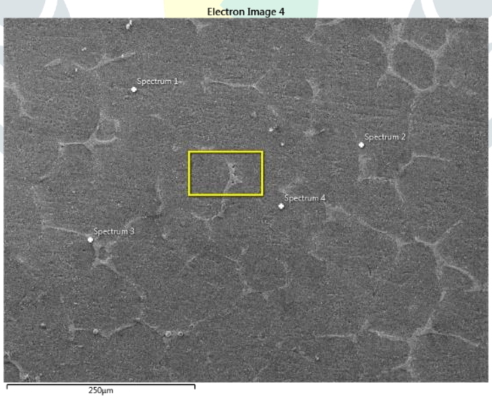


Figure 9. Specimen 3 SEM micrographs of MMC's

The image above reveals a uniform distribution of the reinforcement particles, Bn and Gr, observed in the base Al2618.

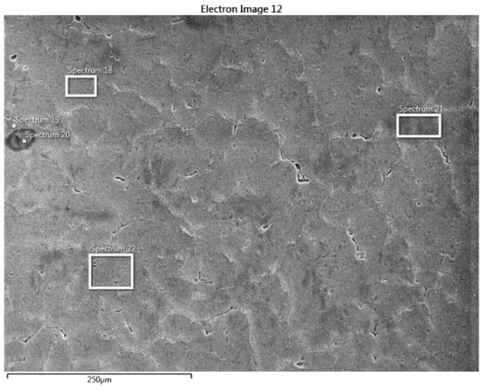


Figure 10. Specimen 4 SEM micrographs of MMC's

From the above image Bn and Gr particles are fine grain and uniform distributed in base Al2618.

Optical microscopic structure

In general, an optical microscopic picture of an MMC can give useful information regarding distribution, orientation, as well as other features of its reinforcing materials, in addition to the matrix-reinforcement bonding. This information is crucial for understanding the material's mechanical and physical characteristics and optimizing its performance for various industries which include aerospace, automotive, and defense. The optical microscopic structure is gained for different metal matrix structure. These are presented below for 20 µm.

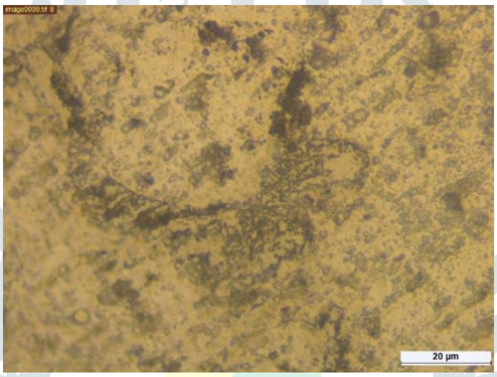


Figure 11. Microscopic structure for 0% reinforcement

The above figure depicts the microstructure of Aluminium 2618.

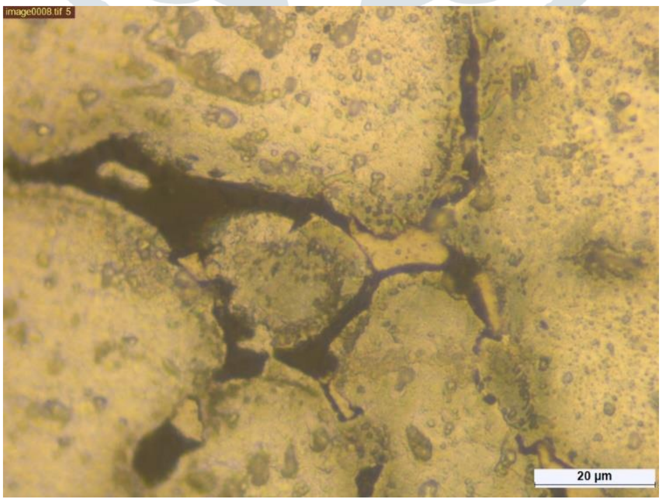


Figure 12. Microscopic structure for 4% reinforcement

The figure above shows a partial homogenous distribution within the composite that results from Bn and Gr reinforcement (4% as well as 1% by weight) in a 2618-Aluminium matrix.

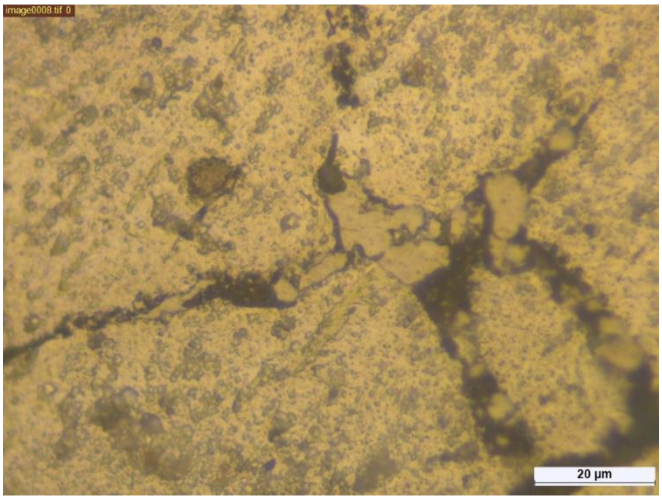


Figure 13. Microscopic structure for 6% reinforcement.

The distribution within the composite that results from Bn and Gr reinforcement (6% & 1% by weight) in a 2618-Aluminium matrix is shown in below figure.

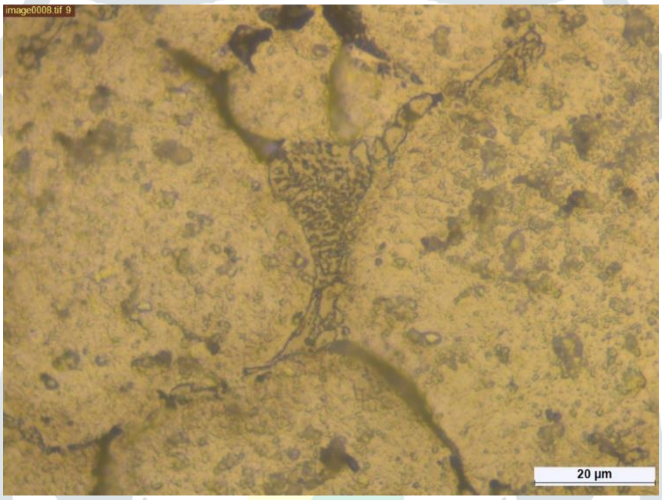


Figure 14. Microscopic structure for 8% reinforcement

The composite reinforced with Bn and Gr (8% & 1% in weight) in a 2618-Aluminum matrix is shown in above figure to have a homogenous distribution.

IV. Conclusion

The following findings have been drawn from the experimental findings of Al2618 reinforced using Boron Nitride with Graphite Hybrid metal matrix composites:

The stir casting technique produces samples with a homogenous microstructure and favorable mechanical characteristics. Adding the Bn, yield strength, hardness and compressive strength of the specimen increases when compared to pure aluminum. The maximum tensile strength observed is 159 MPa, the maximum compressive strength is 546 M.pa and hardness value is 170 is observed for 8% reinforcement. In this work, XRD analysis is studied in this work in which sample 4 has high intensity. Microstructural study has also been done to study the aluminum, Boron nitrite and graphite compositions. For 8% of reinforcement sample, homogenous distribution is observed. Finally, it is concluded that, 8% reinforcement sample has an optimum composition to have good strength.

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