

Evaluation of mechanical properties of Al-Bn metal matrix composites

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Abstract— Although several processing methods were used to produce particulate reinforced AMCs stir casting is a viable low-cost method. Even though there are some studies carried out on effect of BN fillers in polymer matrix composites. AA6061 is chosen as the matrix material. As boron nitride has higher thermal conductivity than aluminium alloys to enhance the thermal conductivity by decreasing thermal contact resistance at the filler matrix interface. The preparation of Aluminium Boron Nitride composites for heat transfer applications to replace conventional Aluminium alloy material. This also includes preliminary characterization study using optical microscope, Scanning Electron Microscope (SEM) and Flexural testing the Al/BN composites. The aim of the work is to produce Metal matrix which composite are promising materials for a number of specific applications in aerospace, defense, and automobile, industries.

Index Terms—aluminium, boron nitride reinforcement, metal matrix composites, stir casting,

I. INTRODUCTION

Particulate reinforcement metal matrix composites (PMMC's) are more familiar to serve the different type of applications in Automobile, Marine, Nuclear, Aerospace, electronics and recreational industries. Specifically, the Al6061 based hybrid metal matrix composite are better substituted for conventional aluminium alloys because of their increased strength hardness strength to weight ratio and their better wear resistance. Even powder metallurgy is a powerful technique for mass production of small composite component; liquid melt processing has some unique advantages such as simplicity, relatively inexpensive and manufacturing of intricate components. Stir casting is an attractive processing technique for the fabrication of particulate reinforced AMC's. Now a day the particulate reinforced Al matrix composite have more important because of their isotropic process and low cost. In structural automotive, space application mostly aluminium is used for light weight and good strength. Through various liquid metallurgical process composites were fabricated and their impacts on mechanical properties were investigated.

Composites can be very strong and stiff, yet very light in weight, so ratios of strength-to weight and stiffness-to-weight are several times greater than steel or aluminium. Toughness is often greater too. Composites can be designed that do not corrode like steel.

Possible to achieve combinations of properties not

attainable with metals, ceramics, or polymers alone. This is due to their outstanding properties such as light weight, high strength, high specific modulus, low thermal expansion coefficient, and good wear resistance.

Rama Rao et al [1] examined that aluminium alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). Phase identification was carried out on boron carbide by x-ray diffraction studies microstructure analysis was done with SEM a composite were characterized by hardness and compression tests. The results show increase the amount of the boron carbide. The density of the composites decreased whereas the hardness is increased.

Ravichandran et al [2] synthesized and studied the forming behavior of aluminium-based hybrid powder metallurgic composites. Aluminium-based metal matrix composites were synthesized from Al-TiO₂-Gr powder mixtures using the powder metallurgy technique and their forming characteristics were studied during cold upsetting. Microstructure models under tensile loading conditions. Hence analyses were carried out on the microstructure of random and clustered particles to determine its effect on strength and failure mechanisms

Karunamoorthy et al [3] analyzed that a 2D microstructure based FEA models were developed to study the mechanical behavior of MMC. The model has taken into account the randomness and clustering effects. The particle clustering effects on stress-strain response and the failure behavior were studied from the model. The optimization of properties was carried out from analysis of microstructure of MMC since the properties depend on particles arrangement in microstructure. In order to model the microstructure for finite element analysis (FEA), the micro-structures image converted into vector form from the raster than its conversion push to IGES step and mesh in FEA model in ANSYS 7. The failure such as particle interface de-cohesion and fracture the predicted for particle clustered and non-clustered micro structures. They analyzed that failure mechanisms and effects of particles arrangement.

Sozhamanna et al [4] analyzed that the methodology of microstructure-based elastic-plastic finite element analysis of PRMMC. This model is used to predict the failure of two-dimensional models was generated in ANSYS using SEM images. The percentage of major failures and

stress-strain responses were predicted numerically for each microstructure.

Rohatgi et al [5]. analyzed that A356-fly ash chemosphere composites can be synthesized using gas pressure infiltration technique over a wide range of reinforcement volume fraction from 20 to 65%. The densities of Al356-fly ash chemosphere composites, made under various experimental conditions, are in the range of 1250-2180 kg/m³ corresponding to the volume fraction of chemosphere in the range 20-65%. The density of composites increased for the same chemosphere volume fraction with increasing size of particles, applied pressure and melt temperature. This appears to be related to a decrease in voids present near particles by and enhancement of the melt flow in a bed of chemosphere. The compressive strength Plateau stress and modulus of the composites increased with the composite density

Venkat Prasad et al [6]. investigated that tribological behavior of aluminium alloy reinforced with alumina and graphite this is fabricated by stir casting process. The wear and frictional properties of the hybrid metal matrix composites was studied by performing dry sliding wear test using a pin – on – test wear test. Experiments were conducted based on the plan of experiments generated through taguchi's technique. AL27 orthogonal array was selected for analysis of the data. Investigation to find the influence of wear rate sliding speed applied load sliding distance, as well as the coefficient of friction. The results show that sliding distance has the highest influence followed by load and sliding speed. Finally, confirmation test was carried out to verify the experimental results and scanning electrons microscopic studies were done on the wear surfaces. The incorporation of graphite as primary reinforcement increases the wear resistance of composites by forming a protective layer between pin counter face and the inclusion of alumina as a secondary reinforcement also has a significant effect on the wear behavior. The regression equation generated for the present model was used to predict the wear rate and coefficient of friction of HMMC for intermediate conditions with reasonable accuracy.

Sedat Ozdenet et al. [7] investigated the impact behavior of Al and Si C particle reinforced with AMC under different temperature conditions. The impact behavior of composites was affected by clustering of particles, particle cracking and weak matrix- reinforcement bonding. The effects of the test temperature on the impact behavior of all materials were not very significant.

Mahendra Boopathi et al [8] found that development of hybrid metal matrix composites has become an important area of research interest in materials science. In view of this, the present study was aimed at evaluating the physical properties of aluminium 2024 in the presence of fly ash, silicon carbide and its combinations. Stir casting method was used for the fabrication of aluminium MMC. Structural characterization was carried out on MMC by x-ray diffraction studies and optical microscopy was used for the

micro structural studies

Biennia's et al [9] experimented that microstructure characteristics of aluminium matrix Al 12 composites containing of fly ash particles, obtained by gravity and squeeze costing techniques, pitting corrosion behavior and corrosion kinetics are presented and discussed. It was found that one in the comparison with squeeze casting, gravity casting technology is advantageous for obtaining higher structural homogeneity with minimum possible porosity levels, good interfacial bonding and quite a uniform distribution of reinforcement, second on the fly ash particles lead to an enhanced potting corrosion of the Ak12/9% flyash (75-100 micro meter fraction) composite in comparison with unreinforced matrix (Ak12 alloy), and third one the presence of nobler second phase of fly ash particles, cast defects like pores, and higher silicon content formed as a result of reaction between aluminium and silica in Ak12 alloy and aluminium fly ash composite determine the pitting corrosion behavior and the properties of oxide film forming on the corroding surface.

Anilkumar et al [10]. Investigation that mechanical properties of fly ash reinforced aluminium alloy (Al 6061) composites fabricated by stir casting. They are three sets of composites with fly ash particle sizes of 75-100; 45-50 and 4-25 μ m were used. Each set had three types of composite samples with the reinforcement weight fractions of 10 15 and 20%. The mechanical properties studied were the compressive strength, tensile strength, ductility and hardness. Unreinforced Al6061 samples also tested the mechanical properties. It was found that the compressive strength, tensile strength and hardness of the aluminium alloy composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite. The SEM of the samples indicated uniform distribution of the fly ash particles in the matrix without any voids. Research efforts put in place to resolve these problems are mostly channeled towards selecting the right choice of reinforcing materials. This is an indication that the reinforcing materials play significant role in determining the overall performance of the composites. Considering the number of published articles surveyed while preparing this review, it was observed that three different approaches have been adopted to improve the performance of DRAMCs. The first approach involves finding alternative and cheaper reinforcements in the development of DRAMCs.

Suhail Ahmed.S et al [11] presented the Development and Characterization of Al7075 Based Hybrid Composites. Aluminium based Metal matrix composites have been emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications.

Srinivasa Bakshi et al [12] presented Microstructure and Wear properties of Aluminium/Aluminium-Silicon Composite coatings prepared by cold spraying. Particles impinging on a substrate will either rebound from the substrate or bond with the substrate de- pending on the

material type and particle velocity on impact with the substrate. Cold spraying was used successfully to prepare 350–1200 μ m thick composite coatings containing aluminium and aluminium–silicon. Alloy with a density of 98% or higher. The Al–Si particles were distributed uniformly in the aluminium matrix. Wear volume was found to be similar for Al and Al–Si coatings. Manoj Singla, D.

From the study of literatures and previous investigations, it was found that study on preparation of Aluminium metal matrix composites reinforced with Boron Nitride was very less. Thus, in this paper, using stir casting method Boron Nitride was reinforced with aluminium and the property variations were studied.

II. MATERIALS AND METHODS

A. Base material and reinforcements

In this work for preparing metal matrix composite, aluminium 6061 (Al6061) is used as base material. Boron Nitride in the powder form is used as the reinforcements.

i. Aluminium 6061:

One of the most popular matrix materials that are used in case of metal matrix composites is Al6061. Because of good corrosion resistance, good electrical and thermal conductivity, low density, good machine ability etc. Al6061 is quite attractive. Many mechanical properties of this alloy can be enhanced when it is reinforced by other particles. The common reinforcements used with this alloy are aluminium oxide, silicon carbide, silicon dioxide, graphite, boron nitride, boron carbide etc.

ii. Boron Nitride (BN):

Boron nitride has excellent thermal and chemical stability and also high hardness. The particle size of boron nitride used in this study is 7-11 microns. The grade of boron nitride used is HCV grade. HCV grade is a basic grade of boron nitride and this serves as a starting block for the production of many advanced materials.

B. Composite preparation

Stir casting method is used for the preparation of composite. In this process the Al6061 bars are cut into small ingots using a chisel and hammer. These ingots are placed in clay graphite crucible and the crucible is kept in the electrical resistance furnace. The ingots are melted at the temperature of 8000C. The BN particles are preheated at a temperature of 4000C for to increase the surface reaction. These pre-heated particles are then added into the melt and stirred continuously in order to archive uniform distribution of particles in the matrix. After the mixing of reinforcement with Matrix the crucible is taken out of the furnace and the molten is poured into the metal mould and allowed to solidify. After the solidification the casted specimen is removed from the mold.

- Composition A=Al6061- 5% BN
- Composition B=Al6061-10%BN
- Composition C=Al6061-15%BN

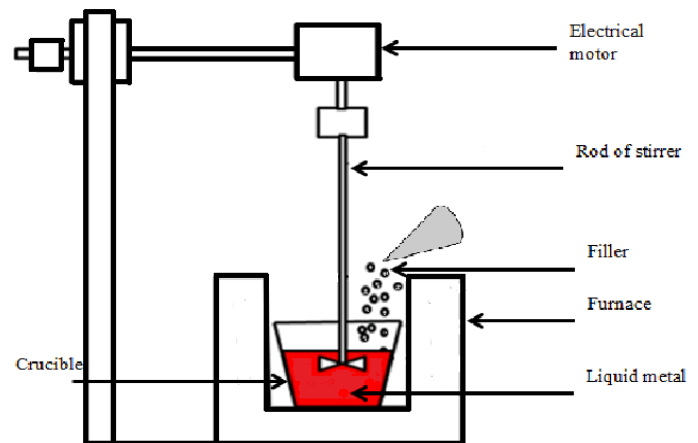


Figure 1. Schematic diagram of stir casting setup

Stir casting process is mainly used for manufacturing of particulate reinforced metal matrix composite (PMMC). It is a primary process of composite production whereby the reinforcement ingredient material is incorporated into the molten metal by stirring. Stir casting is used for low cost composite production. The process parameters are given below,

1) Stirrer Design:

It is very important parameter in stir casting process which is required for vortex formation. The blade angle and number of blades decides the flow pattern of the liquid metal. The stirrer is immersed till two third depth of molten metal.

2) Stirrer Speed:

Stirring speed is an important parameter to improve wettability. Vortex formation depends on Stirring speed which is responsible for dispersion of particulates in liquid metal. In our project stirring speeds are different for different composition.

3) Stirring temperature:

Aluminium melts around 640- 650°C, at this temperature semisolid stage of melt is present. Particle distribution depends on change in viscosity. The viscosity of liquid is decreased by increasing processing temperature with increasing holding time for stirring which also promote binding between matrix and reinforcement.

4) Stirring Time:

As stirring promote uniform distribution of reinforcement partials and interface bond between matrix and reinforcement, stirring time plays a vital role in stir casting method. Stirring times are different for different composition.

5) Preheat temperature:

Reinforcement is heated to 200°C for 180 minutes. It removes moisture as well as gases present in reinforcement.

6) Preheat temperature of mould:

Porosity is the major problem in casting. In order to avoid porosity preheating of mold is good solution. It helps in removing the entrapped gases from the slurry to go into the mold. Mold is heated to 200°C for one hour.

7) Addition of Magnesium:

Addition of Magnesium enhances the wet ability. However, increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution becomes difficult.

8) Reinforcement feed rate:

Non-uniform feed rate promotes clustering of particles at some places which causes the porosity defect and inclusion defect, so to have a good quality of casting the feed rate of powder particles must be uniform. The flow rate of reinforcements measured is 1- 1.2gram per second

III. RESULTS AND DISCUSSION

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. Details of the preparation conducting and conducted affect the test results. The sample placed on two supporting pins a set distance apart.

Calculation of the flexural stress

Stress (flexural) = $3FL/2bd^2$ for a rectangular cross section

Calculation of the flexural strain

Strain (flexural) = $6Dd/L^2$

Calculation of flexure modulus E_f

$E_f = L^3m/4bd$

In this formula the following parameters used,

- E_f = flexure modulus of elasticity
- F = load at a given point on the load deflection curve, (N)
- L = support span, (mm)
- b = width of the test beam, (mm)
- d = depth or thickness of tested beam, (mm)
- D = maximum deflection of the center of the beam, (mm)
- m = the gradient of the initial straight-line portion of the load deflection curve, (N/mm).
- R = radius of the beam, (mm)

The fracture toughness of a specimen can also be determined using a three-point flexural test. Its methodology is used fracture toughness testing. The stress intensity factor at the crack tip of a single edge notch bending specimen is where P is the applied load, B is the thickness of the specimen, 'a' is the crack length, and W is the width of the specimen. In a three-point bend test, fatigue crack is created at the tip of the notch by cyclic loading. The length of the crack is measured. The specimen is then loaded monotonically. A plot of the load versus the crack opening displacement is used to determine the load at which the crack starts growing.

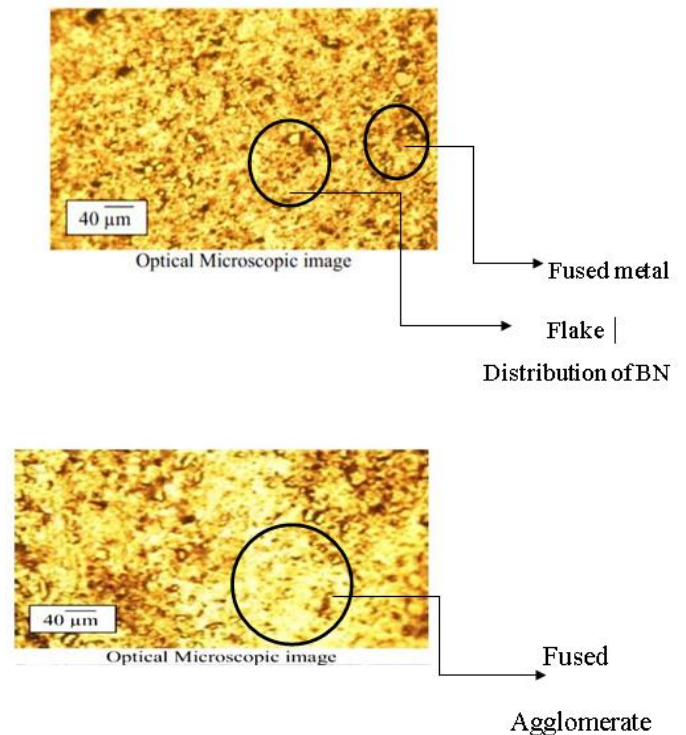


Figure 2 - Optical microscopic images

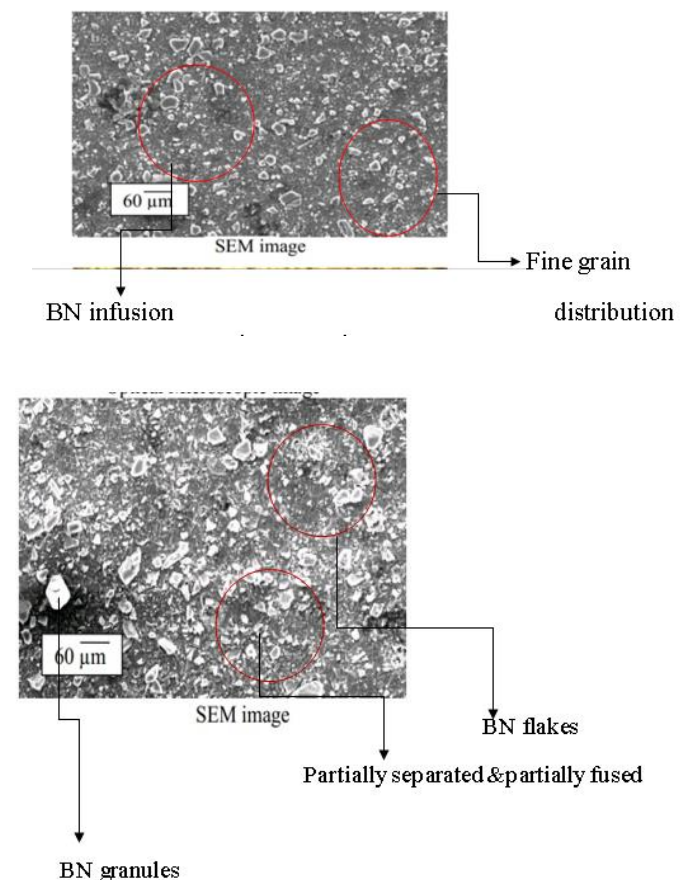


Figure 3 – SEM images

The optical microscope analysis results of metal matrix composite specimen obtained from Al -10%BN powder

sintered at 5500C is shown in fig 2. The observed in metal matrix composites in joined in BN particles was analyzed in image.

The optical micrographs taken at lower magnification (50X) from AA6061 and Al-BN (5%) composite sectioned in latitudinal direction showing distribution of BN particles. It is observed that grain size of aluminium alloy AA6061 is quite large whereas by addition of BN particles decreases aluminium grain size yet there are lot of porous regions in Al/BN composite. Al/BN composite developed with the help of two step mixing method of stir casting. In this first step gas layers present in the reinforcement particles were broken by mechanical stirring in semisolid state. In this phase alpha-Al nucleic exists, hence stirring promotes move forces on BN particles by abrasion and collusion which helps to achieve good weld ability. In second step this semisolid slurry was again heated to liquid temperature and stirred to have good weld ability with reinforcement particles. Due to this reason homogenous dispersion and distribution of particles was achieved. The scanning electron microscopy micrographs of the hybrid composite specimens 3 is analyzed in 5% BN material in presented in BN induction and edge side of the occurred in distribution of the fine grain BN flakes. The 10% BN composite material analyzed in the grooves and BN particles are clearly visible. The clearly visible BN granules and BN flakes in are presented in composite materials. The microstructure of pure AA6061 at 500X to 1000X magnifications respectively. Which indicate 10% BN is displays analyzed in the microstructure of Al- BN composite presented in 5% BN in fine grain distribution and acquired in BN induction in 60 micro meter size of structure. The 10% of BN is specimen testing the material is presented in different places of BN flakes and mainly parts of partially separated and partially fined size of particles of specimen. The 15% BN material is more porosity is presented in composite materials so this combination is neglected in scanning electron microscope testing.

The results of flexural testing have been indicated in Table 1

Table 1 - 3-point bend test results

S No	Specimen	Flexural value MPa
01	Al MMC – 5% BN	283
02	Al MMC – 5% BN	293
03	Al MMC – 5% BN	269

The stress vs strain graph has been indicated in Figure 4. The graph is drawn in stress and strain for composite material in flexural strength. The taken by X axis is strain and Y axis is taken in stress drawing straight line presented in graph

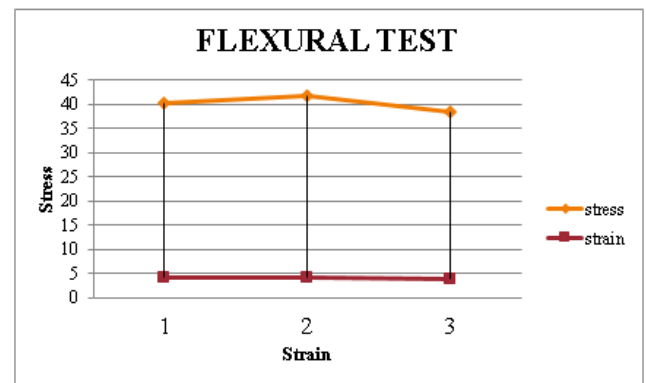


Figure 4 – Stress strain graph for flexural test

IV. CONCLUSION

1. Aluminium based hybrid metal matrix composites have been successfully fabricated by stir casting method by addition of reinforce combined with pre-heating of particles.
2. The micro structural study revealed that there was uniform distribution of the BN in Al6061 matrix.
3. The variation in grain size observed using scanning electron microscope was found to be changing as the reinforcement % was BN of increased.
4. Similarly, with increased in the wt % of reinforcement. The actually aluminium bending stress was 2.75 M Pa. Aluminium-5% BN is 6.7% increase in actually aluminium bending stress. Aluminium-10% BN was 10.5% increase in normal bending stress of the reinforcement materials.
5. Aluminium-15% BN bending stress was 1.5% decreased in normal aluminium bending stress. So, this composite material was neglected in the flexural strength.
6. Metal matrix composites of Al 6061 reinforced with Boron Nitride particulates was founded to have improved in resistance bending stress when compared to Al 6061 alloy alone

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