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Study of Microstructure and Mechanical Behavior of Aluminum Composite reinforced with Boron Nitride

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Abstract.
Metal Matrix Composites (MMCs) have garnered significant attention due to their superior mechanical properties, making them ideal for advanced engineering applications. This work focuses on the development and tensile testing of a composite material consisting of Aluminium 1050 as the matrix and Boron Nitride (BN) as the reinforcement. Aluminium 1050, known for its excellent corrosion resistance, ductility, and lightweight properties, was selected as the base material. Boron Nitride, a ceramic material with high thermal stability, exceptional wear resistance, and low density, was chosen to enhance the mechanical characteristics of the composite.

INTRODUCTION

1050 aluminium alloy is an Aluminium-based alloy in the "commercially pure" wrought family (1000 or 1xxx series). As a wrought alloy, it is not used in castings. Instead, it is usually formed by extrusion or rolling. It is commonly used in the electrical and chemical industries, on account of having high electrical conductivity, corrosion resistance, and workability. 1050 alloy is also sometimes used for the manufacture of heat sinks, since it has a higher thermal conductivity than other alloys. It has low mechanical strength compared to more significantly alloyed metals. It can be strengthened by cold working, but not by heat treatment

Boron nitride is a thermally and chemically resistant refractory compound of boron and nitrogen with the chemical formula BN. It exists in various crystalline forms that are isoelectronic to a similarly structured carbon lattice. The hexagonal form corresponding to graphite is the most stable and soft among BN polymorphs, and is therefore used as a lubricant and an additive to cosmetic products. The cubic (zincblende aka sphalerite structure) variety analogous to diamond is called c-BN; it is softer than diamond, but its thermal and chemical stability is superior. The rare wurtzite BN modification is similar to lonsdaleite but slightly softer than the cubic form.

OBJECTIVES

The evaluation of the tensile, compressive, and microstructural properties of Aluminium 1050 metal matrix composite (MMC) reinforced with boron nitride (BN) powder is a critical step in understanding its potential for advanced engineering applications. The detailed objectives for such an evaluation are as follows.

Understanding Mechanical Property Enhancement

To quantify the improvement in tensile strength and compressive strength of Aluminium 1050 when reinforced with BN powder compared to the unreinforced alloy.

To evaluate the composite's performance under both elastic and plastic deformation regimes, ensuring it can withstand high stresses without failure.

To determine the effects of varying the weight percentage of BN reinforcement on the mechanical properties, establishing an optimal reinforcement level for maximum strength.

Evaluation of Material Behavior

To analyze the material's stress-strain response under tensile and compressive loading conditions, providing insights into its ductility, yield strength, and ultimate strength.

To identify the failure modes, such as brittle fracture, ductile fracture, or delamination, resulting from the inclusion of BN particles.

Methodology

Matrix Material: Aluminium 1050 (AL 1050) – High-purity aluminium with excellent ductility and corrosion resistance.

Reinforcement Material: Hexagonal Boron Nitride (h-BN) – Known for its thermal stability, lubricity, and mechanical enhancement properties.

Melting Aluminium:
Place aluminium in a crucible and heat in the furnace to a temperature of 750– 800°C (above its melting point, ~660°C).
Add a fluxing agent (e.g., KCl-NaCl) to prevent oxidation and remove impurities.
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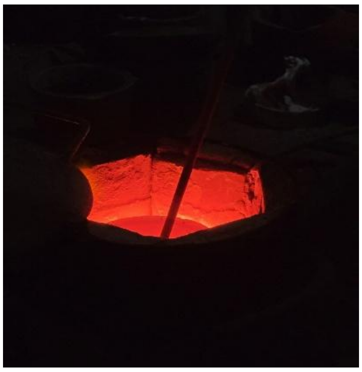


Fig 1: Melting of Alumnium
Inert Gas Purging:
Purge the melt with argon or nitrogen to minimize oxidation and remove dissolved gases.
Pre-Heating of BN:
Preheat BN particles to 200–300°C to match the melt temperature and reduce thermal shock during addition.

Figure 2: Pre-Heating BN powder
Stirring:
Insert the mechanical stirrer into the molten aluminium and stir at 400–600 RPM to create a vortex.
Gradually add preheated BN particles into the vortex to ensure uniform dispersion.
Continue stirring for 5–10 minutes to achieve homogeneity.


Fig 3: Mechanical Stirring process

Degassing:Allow the mixture to settle briefly and remove any slag or impurities floating on the surface.
Pouring:
Pour the molten composite into a preheated mold to prevent solidification defects.
Allow it to cool naturally or use controlled cooling (e.g., in a furnace) to avoid residual stresses

Machining

Fig 4: Machined Ingots.

5.0 Testing

Tensile Testing

Perform tensile tests using a universal testing machine (UTM).

Record stress-strain curves and evaluate tensile strength, yield strength, and elongation at break.

Compare the results with pure Al-1050 and assess the effect of BN reinforcement.

Fig 5: Tensile testing specimen.

RESULTS & DISCUSSIONS

Aluminium 1050, being a relatively soft aluminium alloy, likely has a lower UTS on its own. However, adding BN as a reinforcing phase helps to increase the strength

2. The 2% BN reinforcement can help in reinforcing the aluminium matrix by improving its load-bearing capabilities. This is because BN is a ceramic material, known for its high thermal conductivity, high strength, and low friction.

3. The slight increase in UTS with 2% BN indicates that small amounts of BN (typically in the range of 1-3%) can improve the tensile properties without negatively affecting the overall ductility and formability of the material.

4. BN is inherently a hard material, and when incorporated into the aluminium matrix, it contributes to the overall hardness of the composite. The 3% BN reinforcement leads to a more noticeable increase in hardness compared to the 2% BN.

5. A BH value of 32 suggests that the material becomes significantly more resistant to indentation, indicating that the BN reinforcement not only strengthens the material in terms of tensile properties but also improves its surface resistance to wear and deformation.

Material	Ultimate tensile strength (MPa)	Ultimate yield strength (MPa)	Hardness (BHN)
Aluminium-1050	75.66	48.37	30
AMC-BN 1%	77.06	55.50	31
AMC-BN 2%	79.89	57.66	30
AMC-BN 3%	77.29	52.90	32

CONCLUSION

In conclusion, the incorporation of Boron Nitride (BN) as a reinforcement material in Aluminium Matrix Composites (MMCs) significantly enhances both tensile strength and hardness, as demonstrated by the results of this study. The addition of BN particles leads to a marked improvement in the mechanical properties of the composite, making it a promising candidate for applications requiring high strength, wear resistance, and thermal stability. The increased tensile strength can be attributed to the reinforcement provided by the BN particles, which serve to resist deformation under stress. Similarly, the enhanced hardness is likely a result