Study of Microstructure and Mechanical Behaviour of Aluminium (1050) Metal Matrix Composite Reinforced with Boron Nitride

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Abstract - This project focuses on the fabrication and analysis of an aluminium metal matrix composite (AMMC) reinforced with varying percentages of boron nitride (BN) particles—specifically 1%, 2%, and 3% by weight. The primary aim is to understand how these different reinforcement levels influence the composite's microstructure and mechanical properties. Aluminium is chosen for its lightweight and corrosion-resistant characteristics, while BN is selected for its excellent thermal stability, lubricating properties, and high hardness.

The composites were produced using a stir casting method to ensure uniform distribution of BN particles within the aluminium matrix. Microstructural analysis using optical microscopy and scanning electron microscopy (SEM) was conducted to observe the dispersion of BN particles and any changes in grain structure. Mechanical testing, including hardness (Brinell test) and tensile strength measurements, was carried out to evaluate the material's performance.

The results showed that as the BN content increased, there was a notable improvement in hardness and tensile strength up to a certain point, with the 2% BN-reinforced composite exhibiting the most balanced mechanical properties. However, at 3% BN, slight agglomeration of particles was observed, which affected the uniformity of the matrix and slightly reduced mechanical efficiency.

Overall, this study demonstrates that controlled addition of BN can significantly enhance the performance of aluminium composites, making them suitable for applications in aerospace, automotive, and structural industries where strength, wear resistance, and weight are critical factors.

***Key Words*: Aluminium metal matrix composite, boron nitride reinforcement, stir casting, microstructure analysis, mechanical properties, hardness, tensile strength, particle dispersion, composite materials, wear resistance.**

1.INTRODUCTION

In recent years, the demand for lightweight, high-strength materials has grown significantly, especially in aerospace, automotive, and structural engineering sectors. MetalMatrix Composites (MMCs) have emerged as promising materialsto meet these requirements by combining the beneficial properties of metals with the enhanced mechanical characteristics of reinforcements. Among various metals, aluminium has gained substantial attention due to its low density, good corrosion resistance, and ease of fabrication.

Aluminium 1050, a commercially pure grade of aluminium, is widely used for its excellent ductility, high thermal conductivity, and corrosion resistance. However, its relatively low mechanical strength limits its use in load-bearing applications. To overcome this limitation, reinforcing aluminium with ceramic particles such as boron nitride (BN) offers a viable solution. BN is known for its high thermal stability, low density, and excellent lubricating properties, making it a suitable reinforcement to improve both the structural and functional properties of aluminium.

This project focuses on the development and evaluation of Aluminium 1050 metal matrix composites reinforced with 1%, 2%, and 3% boron nitride particles using the stir casting process. The objective is to understand how BN content influences the microstructure and mechanical behavior of the composite, with the ultimate goal of optimizing the material for real-world applications where highperformance and reduced weight are critical.

2.METHODOLOGY

In this project, we aimed to develop aluminium metal matrix composites using Aluminium 1050 as the base material and boron nitride (BN) powder as the reinforcement. We added BN in different amounts—1%, 2%, and 3% by weight—to see how it affects the material's strength, hardness, and internal structure. The entire process was carried out in a series of steps: preparing the materials, mixing them usinga method called stir casting, and then testing the finalproducts to study their properties.

We started by selecting **Aluminium 1050**, which is a very pure form of aluminium. It's lightweight, corrosion-resistant, and easy to work with. However, its natural strength is relatively low, which is why we added **boron nitride(BN)**—a ceramic material known for being hard, stable at high temperatures, and very smooth, like graphite. The BN powder we used was very fine, with a particle size of less than 50 microns.

The composite was made using the **stir casting** method. First, we melted the aluminium in a furnace, heating it up to around **750°C to 800°C**. While that was happening, we preheated the BN powder to around **300°C to 400°C** to remove moisture and help it mix better with the molten aluminium. Once the aluminium was fully melted, we stirred it with a mechanical stirrer at about **500–600 rpm** to create a whirlpool-like motion. Then we slowly added the BN powder into the molten metal while it was being stirred. In some batches, we also added a small amount of **magnesium** to help the BN mix better with the aluminium. After mixing for around 10 minutes, we poured the molten compositeinto **preheated moulds** and let it cool down at room temperature. Once solidified, the cast blocks were taken out and **machined into specific shapes and sizes** for testing.

To check how strong and hard the material was, we performed two main mechanical tests: the **Brinell Hardness Test** and the **Tensile Strength Test.** In the Brinell test, we used a ball-shaped tool to press into the surface of the sample under a fixed load and measured the size of the indentation. This gave us the **Brinell Hardness Number (BHN)**, which tells us how hard the material is. We did this test at three different spots on each sample to get an accurate average.

For the **tensile test**, we used a **Universal Testing Machine (UTM)** to pull the samples until they broke. This test helped us understand how much load the material can handle before stretching or breaking. From this, we recorded values like **Ultimate Tensile Strength (UTS)**, **Yield Strength**, and **Elongation (% stretch before breaking)**.

Next, we studied the **microstructure**, or what the inside of the material looks like under a microscope. We cut small pieces from each sample and carefully **polished** them to make the surface smooth. Then we used a special chemical called **Keller's reagent** to etch the surface and make the grain boundaries visible. These etched samples were first examined under an **optical microscope** to observe how evenly the BN particles were spread out and to look for defects like pores or clumps.

For a more detailed view, we also used a **Scanning Electron Microscope (SEM).** This powerful microscope gave us high-resolution images so we could clearly see how well the BN particles bonded with the aluminium and whether they were evenly distributed. In some cases, we also used **EDS (Energy Dispersive Spectroscopy)** to confirm that the reinforcement particles were indeed BN.

Overall, this methodology helped us understand how different amounts of BN affected the hardness, strength, and internal structure of Aluminium 1050. It gave us a clear picture of how the composite behaves and which composition might be best for real-world applications like automotive or aerospace components.

Fig 1 – Casting Process.

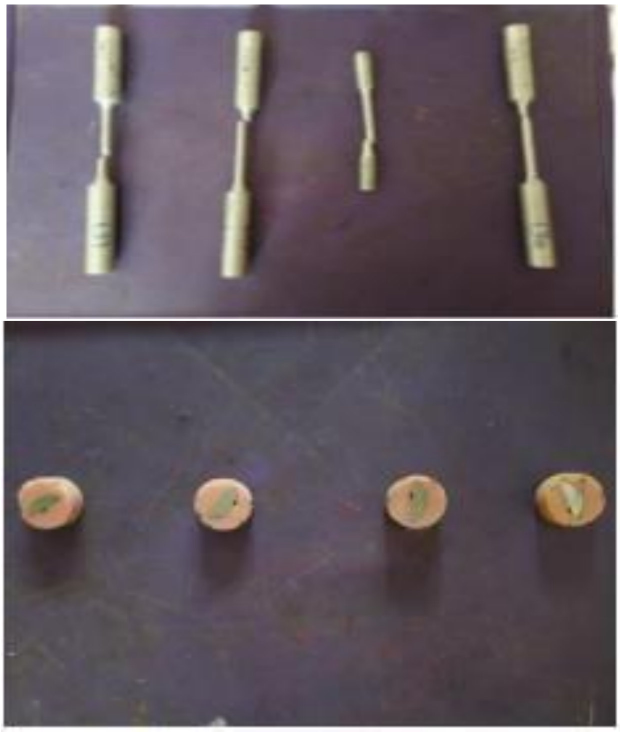

Fig 2 – Tested Specimens.

3. RESULTS AND DISCUSSIONS.

TEST PARAMETERS	RESULTS	TEST METHOD
Yield Strength, N/mm^2	48.37	ASTM E8:2022
Ultimate Tensile Strength, N/mm^2	75.66	
% Elongation	33.72	
% Reduction in Area	52.41	

Table 1: Tensile Test results for 0% BN

TEST PARAMETERS	RESULTS	TEST METHOD
Yield Strength, N/mm^2	55.50	ASTM E8:2022
Ultimate Tensile Strength, N/mm^2	77.06	
% Elongation	31.70	
% Reduction in Area	53.77	

Table 2: Tensile Test results for 1% BN

TEST PARAMETERS	RESULTS	TEST METHOD
Yield Strength, N/mm^2	57.66	ASTM E8:2022
Ultimate Tensile Strength, N/mm^2	79.89	
% Elongation	38.24	
% Reduction in Area	72.69	

Table 3: Tensile Test Results of 2% BN

TEST PARAMETERS	RESULTS	TEST METHOD
Yield Strength, N/mm^2	52.90	ASTM E8:2022
Ultimate Tensile Strength, N/mm^2	77.29	
% Elongation	34.82	
% Reduction in Area	34.72	

Table 4: Tensile Test Results of 3% BN

TEST	TRIAL	RESULTS	TEST METHOD
Hardness (HBW)Ball Dia 10 mm Load @ 500kg	1	30	ASTM E10:23
	2	30	
	3	30	
	Average	30	

Table 5: Brinell Hardness Test Results of 0% BN

TEST	TRIAL	RESULTS	TEST METHOD
Hardness (HBW)Ball Dia 10 mm Load @ 500kg	1	30	ASTM E10:23
	2	30	
	3	30	
	Average	30	

Table 6: Brinell Hardness Test Results of 1% BN

TEST	TRIAL	RESULTS	TEST METHOD
Hardness (HBW)Ball Dia 10 mm Load @ 500kg	1	30	ASTM E10:23
	2	30	
	3	30	
	Average	30	

Table 7: Brinell Hardness Test Results of 2% BN

TEST	TRIAL	RESULTS	TEST METHOD
Hardness (HBW)Ball Dia 10 mm Load @ 500kg	1	30	ASTM E10:23
	2	30	
	3	30	
	Average	30	

Table 8: Brinell Hardness Test Results of 3% BN

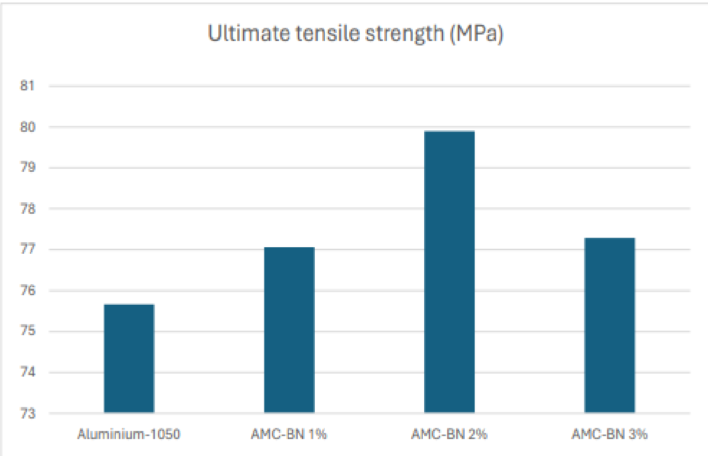

Fig 4 – Bar Graph for Tensile Strength

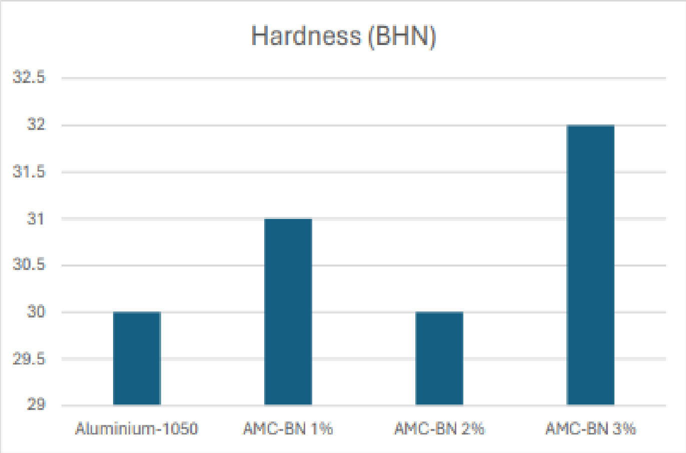

Fig 5– Bar Graph For Brinell Hardness Test

4.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 highstrength, 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 of BN's high intrinsic hardness and its ability to distribute stress more effectively throughout the composite. These improvements in material properties could makeAluminium MMCs with BN suitable for demanding applications, including in the aerospace, automotive, and electronics industries, where materials are subjected to high mechanical stress and wear. While the results are promising, the full potential of these composites will be realized only through continued research and optimization. Future studies should focus on refining the fabrication techniques and reinforcement strategies to further enhance theperformance of these composites. Moreover, exploring the impact of BN reinforcement on other properties such as thermal conductivity, fatigue resistance, and corrosion resistancewill provide a more comprehensive understanding of the material's potential for real-world applications. Overall, this study paves the way for the development of advanced composite materials that combine the advantages of both aluminium and Boron Nitride, offering a balanced performance in terms of strength, hardness, and durability. With continued research and development, Aluminium MMCs with BN reinforcement could become a versatile and reliable material solution for a wide range of industrial applications.

5.REFERENCES

1. Kumar, A., & Sood, D. (2011). "Tensile and Hardness Properties of Aluminium Matrix Composites Reinforcedwith Boron Nitride." Journal of Materials Science & Technology, 27(9), 854-858.

2. Ravi, V., & Sathish, T. (2017). "Effect of Boron Nitride Reinforcement on the Mechanical Properties of Aluminium Matrix Composites." Materials Science and Engineering A, 686, 243-253.

3. Madhusudhan, N., & Suresh, S. (2015). "Microstructural and Mechanical Characterization of Boron NitrideReinforced Aluminium Matrix Composites." Journal of Materials Science, 50(5), 2312-2321.

4. Mishra, R. K., & Pradhan, A. (2013). "Mechanical Properties and Wear Resistance of Aluminium-Based Boron Nitride Composites." Wear, 303, 187-194.

5. Sakthivel, P., & Prakash, M. (2017). "Microstructure and Tensile Behavior of Boron Nitride Reinforced Aluminium Matrix Composites." Materials Science and Engineering B, 223, 13-20.

6. Saha, P., & Ghosh, S. (2019). "Microstructural Evolution and Mechanical Properties of BN Reinforced Aluminium Matrix Composites." Materials Characterization, 155, 47-55.

7. Chawla, K. K., & Kewalramani, S. (2014). "Tensile Properties and Microstructural Characterization of Aluminium-Boron Nitride Composites." Journal of Alloysand Compounds, 592, 62-69.

8. Wang, X., & Li, W. (2018). "Influence of Boron Nitride on the Hardness and Wear Resistance of Aluminium Matrix Composites." Journal of Materials Engineering and Performance, 27(6), 2751-2757

9. Ghosh, S., & Kothari, A. (2015). "Microstructural and Mechanical Properties of AMMCs Reinforced with Boron Nitride: A Review." Materials and Design, 65, 120- 137

10. Banu, M. S., & Jayaraman, V. (2017). "Mechanical Properties and Microstructure of Boron Nitride Reinforced Aluminium Matrix Composites: A Comprehensive Review." Composites Part B: Engineering, 124, 132-145.

11. Sivakumar, D., & Kumar, S. (2016). "Effect of Boron Nitride Particles on the Microstructure and Tensile Strength of Aluminium Matrix Composites." Materials Research Express, 3(6), 065306.