Journal of Mines, Metals and Fuels, *73(9): 2865-2870; 2025. DOI: 10.18311/jmmf/2025/49825*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.co.in/index.php/jmmf*

Effect of the Addition of Boron Carbide Particles on the Mechanical Characteristics of AA7050 Composites

Hazari Naresh[1], T.S. Krishna Kumar[2*], Nagasrisaihari Sunkara[1], S. Anilkumar[3] and Nimmagadda Srilatha[1]

[1]Department of Mechanical Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad - 500090, Telangana, India

[2]Department of Automobile Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad - 500090, Telangana, India; krishnakumar_ts@vnrvjiet.in

[3]Department of Mechanical Engineering, T S Srinivasan Centre for Polytechnic College and Advanced Training, Chennai - 600095, Tamil Nadu, India

Abstract

Metal matrix nanocomposites are a newly developed material with promising applications in a wide variety of areas, ranging from medical to aerospace structures, owing to their lightweight, high-strength properties. A light metal like aluminum is usually strengthened by a reinforcing agent of carbides, nitrides, oxides, carbon-based materials, or even elementals to boost the mechanical performance without sacrificing lightweight; however, almost all reinforcing nanomaterials are commonly poorly wetted by metals leading to agglomerations, clusterings, among other problems, with diminished ductility and overall mechanical performance. To tackle the mentioned problems, a number of strategies including coatings, thermal, mechanical, or chemical treatments may be followed. In the present study, mechanical dispersion of varying wt% of nano-boron carbide particles (0 to 2wt %) in a molten AA7050 alloy through applying high-intensity agitations in order to improve dispersibility, wettability, and interfacial affinity. AA 7050 +1%nB_4C shows better mechanical properties.

Major Findings: *Mechanical Characterization of 1 wt% nanocomposites shows better properties compared to all other composites. Hardness of Nanocomposites shows a better hardness value compared to the base alloy*

Keywords: *Impact Strength, Nano Boron Carbide, Stir Casting, Tensile Strength*

1.0 Introduction

Engineers fabricate tailored composites by amalgamating two or more materials with distinct properties that cannot be achieved with a singular substance[1]. Composites, composed of metals, ceramics, polymers, and both naturally and synthetically manufactured materials, have a wide range of applications[2]. A composite consists of two fundamental components as the matrix and the reinforcing substance. The matrix substance—commonly a metal, ceramic, or polymer—is infused with reinforcing agents[3]. The matrix material functions to both encapsulate and protect the reinforcing material from external threats. The attributes of a fabricated composite can be altered[4]. Through the alteration of the matrix and the enhancement of materials. A polymer matrix infused with carbon fiber exhibits a significant increase in strength and rigidity, making it appropriate for aerospace and automotive applications[5]. The incorporation of glass fibers into a polymer matrix enhances the material's

**Author for correspondence*

impact resistance, rendering it appropriate for protective equipment and athletic items[6].

The elevated strength-to-weight ratio of manufactured composites is one of its principal characteristics. Although capable of enduring the requisite weights and pressures, their weight is frequently considerably less than that of traditional materials, such as metals[7]. Composites can be engineered to exhibit resistance to fire and corrosion, alongside superior electrical and thermal properties[8]. A diverse array of products, including aviation components, automotive parts, sporting equipment, building materials, and medical devices, utilize manufactured composites[9]. A particular type of composite material is selected according to the product's specifications and intended application. Low-cost stir casting may effectively make Al6061 matrix composites enhanced with ZrO_2 ceramic particles, exhibiting promising characteristics. The addition of ZrO_2 ceramic reinforcement to an Al matrix, up to 3 wt.% under optimal conditions with uniform dispersion, enhances mechanical characteristics[10].

Powder Metallurgy (PM) to fabricate Al-Fe-Si-Zn-Cu (AA8079) matrix composites with different weight percentages of B_4C (0, 5, 10, and 15). SEM micrographs obtained post-compression testing indicated that the B_4C reinforcement was uniformly dispersed within an AA8079 matrix devoid of voids and grain boundaries. The corrosion resistance of AA8079-B_4C composites is enhanced with an increase in the weight fraction of 10% B_4C reinforcement within the AA8079 matrix[11]. This research uses stir casting to make aluminium (AA6082) matrix composites with different volume percentages of alumina (50nm) particles. Mechanical properties of stir-cast Al-matrix nanocomposites show better strength than the base metal[12].

In this research motorized stir casting is utilized to produce AA7050 reinforced with varying weight % of nB_4C (0,1,2) and the mechanical properties were studied

2.0 Materials and Methods

2.1 Blend of Matrix and Reinforcement

AA7050 procured local shop in Chennai is used as the base material for making aluminium alloy nanocomposites using the Motorized stir casting method. Their chemical combinations are highlighted in Table 1. Reinforcement used in this work is nano-ceramic strengthening powder

Table 1. Chemical combinations of AA7050

Mg	Si	Fe	Mn	Cu	Ti	Al
0.50	0.40	0.15	0.30	0.01	0.01	Balance



Figure 1. AA 7050.

of B_4C (2.28 g/cm^3) with 70nm particle sizes purchased from Merck.

2.2 Stir Casting

Figures 1 and 2 depict an electric resistance furnace that was used to melt the base metal, which was an aluminum alloy with the designation AA 7050.

The melting process took place in a graphite crucible. For the purpose of achieving a fully liquefied state and ensuring a uniform distribution of reinforcement particles once they are put into the thermal head for further operations, the melting process was carried out at a temperature of roughly 850^{O}C, which is much higher than the liquidus temperatures of the alloy, which range from 720 to 850^{O}C.The material was obtained in the shape of rectangular ingots, which were then sliced into smaller pieces and weighed with a high-precision digital weighing equipment. This was done to guarantee that the samples were consistent with one another. The

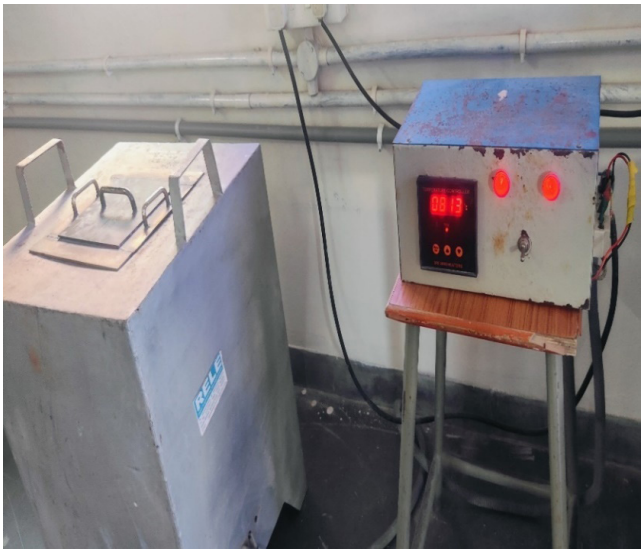


Figure 2. Electronically controlled furnace.



Figure 3. Motorized stirring in furnace.

amount of aluminum that was measured for each batch of composite fabrication was a total of one thousand grams. A mechanical stirrer with a graphite-coated steel impeller was used to mix the reinforcement particles into the molten metal, is shown in Figure 3.

Stirring promotes vortex formation, which improves the wetting of B_4C particles and minimizes particle agglomeration. Creating a stable vortex is essential for

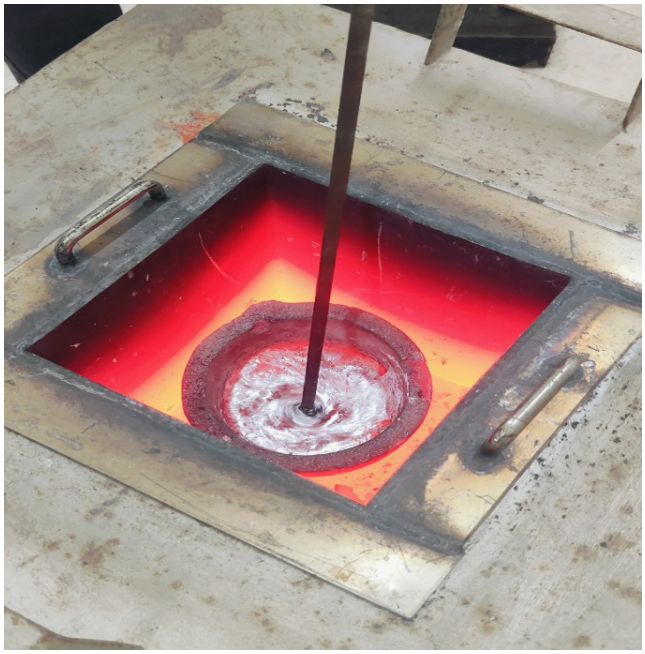


Figure 4. Pouring molten composite material.

pulling the B_4C particles into the molten aluminium. The impeller is placed about 2/3 depth from the top surface to maximize circulation and particle pull-in. Improper vortex geometry can result in poor dispersion or air entrapment. The molten composite was poured into the preheated mold under atmospheric conditions. The process was done manually while maintaining steady pouring to avoid turbulence and air entrapment is shown in Figure 4

3.0 Results and Discussion

3.1 Hardness

The Vickers microhardness test of Wilson MICI is used to determine the hardness of AA7050 alloy nano composites. The test is performed with a load range of 1 kilogram and a dwell length of 10 seconds, by the standards established by ASTM E381[13]. An increase in hard ceramic strengthening particulates, the Orawan strengthening mechanism, interfacial bonding between the base material and strengthening particulates, and an inadequacy of porosity were the factors that contributed to the significant increase in the hardness of the aluminum alloy nano composites in comparison to the parent material, as demonstrated in Figure 5 and the values are shown in Table 2.

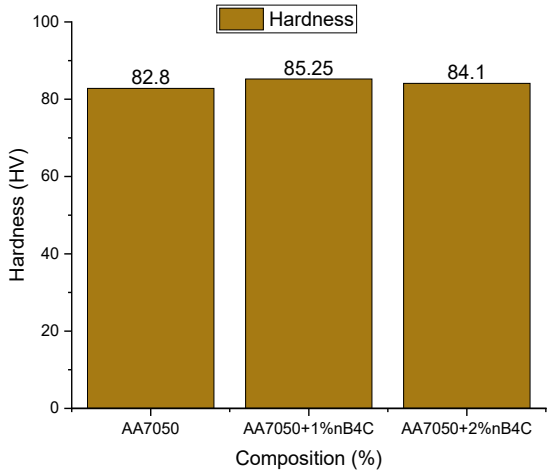


Figure 5. Hardness of AA7050 nanocomposites.

Table 2. Hardness of aluminium nano composites

Sl. No	Composition	HV
1	AA7050	82.80
2	AA7050 +1%nB_4C	85.25
3	AA7050 +2%nB_4C	84.10

Table 3. Ultimate tensile strength of AA7050 nano composites

Sl. No	Composition	N/mm²
1	AA7050	130
2	AA7050 +1%nB_4C	145
3	AA7050 +2%nB_4C	139

3.2 Tensile Strength

Tensile tests were carried out at room temperature with the assistance of a Universal Testing Machine (UTM) in accordance with the ASTM E8[14]. Manufacturing was done using gauge dimensions of 50 millimeters and a thickness of 12.5 millimeters. Following the completion of five different sets of measurements, the tensile strength of the Al7050 +1% nB_4C composites is shown in Figure 6 and the observed values are shown in Table 3.

3.3 Impact Strength

A rectangular bar that features a V-shaped notch and has standard specifications of length 55mm, as well as cross sections of 10 mm x 10 mm, is characterized by ASTM E23 standard[15]. The notch is a V-notch that is

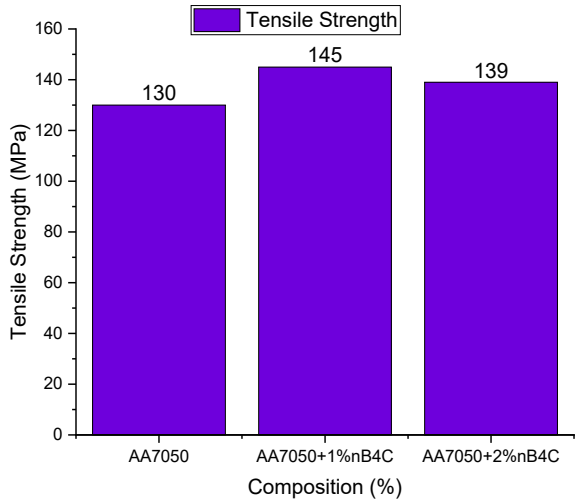


Figure 6. Tensile strength of AA7050 nano composites.

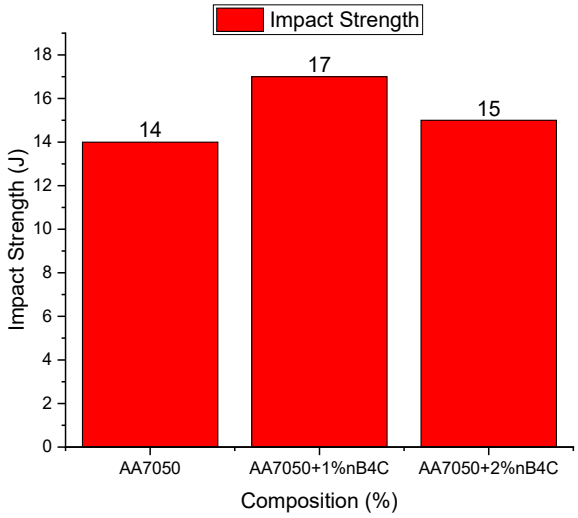


Figure 7. Impact strength of AA7050 nanocomposites.

Table 4. Impact strength of aluminium nanocomposites

Sl. No	Composition	J
1	AA7050	14
2	AA7050 +1%nB_4C	17
3	AA7050 +2%nB_4C	15

2 millimeters deep, has a root radius of 0.25 millimeters, and is machined on one face. Five samples of each composition have been prepared for the Charpy test, and the values are shown in Figure 7.

The readings of nanocomposites are recorded in Table 4.

4.0 Conclusion

- Aluminium alloy 7050 reinforced with nanoparticles with varying weight percentage was successfully fabricated via stir casting.
- AA7050 +1% nB4C gives a better hardness value, which is 2.87% compared to the base alloy.
- AA7050 +1% nB4C gives better Tensile strength and Impact strength, which is 10.34% and 17.64%, respectively, compared to the base alloy.
- At this point, the scope of the investigation is restricted to single nanoparticles. In light of this, there is a significant opportunity to develop hybrid nano composites in order to improve the qualities of a variety of applications in the automotive and related industries.

5.0 Author Contribution

Conceptualization: Hazari Naresh, Methodology: T.S.Krishna Kumar, Writing - Original Draft: T.S.Krishna Kumar, Writing - Review & Editing: Nimmagada Srilatha Formal analysis: S. Anilkumar, Investigation: Nagasrisaihari Sunkara, Resources: S. Anilkumar.

6.0 References

1. Ye T, Xu Y, Ren J. Effects of SiC particle size on mechanical properties of SiC particle reinforced aluminum metal matrix composite. Mater Sci Eng A. 2019; 753(March):146-55. https://doi.org/10.1016/j.msea.2019.03.037
2. Boostani AF, Yazdani S, Mousavian TR, Tahamtan S,Khosroshahi RA, Wei D, *et al.,* Strengthening mechanisms of graphene sheets in aluminium matrix nanocomposites. Mater Des. 2015; 88:983-9. https://doi.org/10.1016/j.matdes.2015.09.063
3. Loganathan T, Kumar VK, Ayyappa K, Mahendran G, Venkatachalam G. Mechanical and vibrational property evaluation of banana fiber epoxy sandwich composite with steel wire mesh core. J Nat Fibers. 2022; 19(11):4024-37. https://doi.org/10.1080/15440478.2020.1848744
4. Swain PTR, Biswas S. Influence of fiber surface treatments on physico-mechanical behaviour of jute/epoxy composites impregnated with aluminium oxide filler. J Compos Mater. 2017; 51(28):3909-22. https://doi.org/10.1177/0021998317695420
5. Hanan F, Jawaid M,Tahir PM. Mechanical performance of oil palm/kenaf fiber-reinforced epoxy-based bilayer hybrid composites. J Nat Fibers. 2020; 17(2):155-67. https://doi.org/10.1080/15440478.2018.1477083
6. Hindi J, Hegde A, Bm G, Sharma S, Kini A, Murthy A A, *et al.* TEM analysis and related mechanical characterization of age hardened aluminium 7075-grey cast iron particle reinforced composites. Cogent Eng. 2022; 9(1). https://doi.org/10.1080/23311916.2022.2114208
7. Talabi HK. Characterization of mechanical properties of aluminium based composites reinforced with copper nanoparticles. J Chem Technol Metall. 2023; 58(4):725-62. https://doi.org/10.59957/jctm.v58i4.109
8. Garg HK, Sharma S, Kumar R, Manna A, Dwivedi SP, Abbas M, *et al.* Mechanical, tribological, and morphological properties of SiC and Gr reinforced Al-0.7Fe-0.6Si-0.375Cr-0.25Zn based stir-casted hybrid metal matrix composites for automotive applications: Fabrication and characterizations. J Mater Res Technol. 2024; 282023:3267-85. https://doi.org/10.1016/j.jmrt.2023.12.171
9. Li SS, Yue X, Li QY, Peng HL, Dong BX, Liu TS, *et al.* Development and applications of aluminum alloys for aerospace industry. J Mater Res Technol. 2023; 27(October):944-83. https://doi.org/10.1016/j.jmrt.2023.09.274
10. Khalili V, Heidarzadeh A, Moslemi S, Fathyunes L. Production of Al6061 matrix composites with ZrO_2 ceramic reinforcement using a low-cost stir casting technique: Microstructure, mechanical properties, and electrochemical behavior. J Mater Res Technol. 2020; 9(6):15072-86. https://doi.org/10.1016/j.jmrt.2020.10.095
11. Meignanamoorthy M, Ravichandran M, Mohanavel V, Afzal A, Sathish T, Alamri S, *et al.* Microstructure, mechanical properties, and corrosion behavior of boron carbide reinforced aluminum alloy (Al-fe-si-zn-cu) matrix composites produced via powder metallurgy route. Materials (Basel). 2021; 14(15). https://doi.org/10.3390/ma14154315 PMid:34361508 PMCid:PMC8347984.
12. Mohanavel V, Suresh Kumar S, Mariyappan K, Ganeshan P, Adithiyaa T. Mechanical behavior of Al-matrix nanocomposites produced by stir casting technique. Mater Today Proc. 2018; 5(13):26873-7. https://doi.org/10.1016/j.matpr.2018.08.170
13. Kumar TSK, Kandavel A. Experimental Investigation of NanoB4C-NanoGr Reinforced AA7075 alloy

hybrid nanocomposites. 2024; 65(8):923-7. https://doi.org/10.2320/matertrans.MT-M2023219

14. Kumar TSK, Kandavel A. Mechanical characterization of B4C-Gr reinforced Al-Zn-Mg alloy hybrid nanocomposites. Mater Trans. 2023; 64(5):955-61. https://doi.org/10.2320/matertrans.MT-M2022168
15. Prasad Somayajula VS,Kumar KTS, Morampudi P, Srilatha N, Siddhardha S. Mechanical and tribological analyses of Al6061-GO/CNT hybrid nanocomposites by combined vacuum-assisted and ultrasonicated stir casting method. J Mech Behav Mater. 2025; 34(1). https://doi.org/10.1515/jmbm-2025-0049