Study on Enhancing Mechanical Properties of Al 6061- Based Aluminium Metal Matrix Composites Reinforced with SiC and B_4C through Stir Casting

Mr. Pavan Chaudhary
Assistant Professor,
M.Tech, Engineering Department,
Maharishi University of Information Technology

Mr. Sanjaya Kumar
Research Scholar, M.Tech.
Production Engineering
Maharishi University of Information Technology

ABSTRACT

The development of materials has been essential in advancing humankind from the Stone Age to the modern civilization we live in today. In today's world, materials are essential to everyday life, especially in industries like aerospace, automotive, military, and marine. New materials have been created as a result of continuing material science research, such as the third generation of aluminum metal matrix composites (AMMCs). These AMMCs have better mechanical qualities, low thermal expansion coefficients, remarkable strength-to-weight ratios, and are lightweight.

This review of the literature examines many research on AMMCs focusing on how they are made and how different reinforcing materials affect their mechanical characteristics. The inclusion of B_4C, silicon nitride, zirconium dioxide, boron nitride, and titanium carbide in aluminum matrices are among the notable studies. Increases in reinforcing percentages been shown to improve mechanical properties such as hardness, compressive strength, and tensile strength.

Through the use of stir casting, the present work aims to improve the mechanical characteristics of AMMCs by adding silicon carbide (SiC) and boron carbide (B_4C). Because of its superior mechanical qualities, Al6061 is used as the matrix material, while SiC and B_4C are chosen as reinforcements because of their high levels of strength, hardness, and thermal stability.

In order to see how the weight fractions of SiC and B_4C affect mechanical characteristics, the experimental approach entails altering them. A consistent dispersion of reinforcing particles *throughout the aluminum matrix is guaranteed by the stir casting process. The goal of the project is to provide new information on how AMMCs are made and optimized for better mechanical performance.*

Keywords:*Aluminum Metal Matrix Composites (AMMCs), Stir Casting, Silicon Carbide (SiC), Boron Carbide (B_4C), Lightweight Materials, Automotive Components.*

INTRODUCTION

A composite material is a "material system" made up of two or more micro- or macro-components that are largely insoluble in one another and vary in shape and chemical makeup. The terms "matrix phase" and "reinforcing phase" refer to the two constituents.

Engineered or naturally occurring materials that combine two or more component elements with notably differing physical or chemical characteristics yet maintain their individuality within the completed structure are called composites. The bulk material such as metals or polymers, forms the continuous phase known as the matrix, while the other such as ceramics, fibers, whiskers, or particles, functions as the discontinuous phase known as the reinforcement.While the matrix permits the transmission of weight by keeping them together, the reinforcing material often bears the majority of the load. The widespread popularity of composite materials may be attributed to their high strength to weight ratio and unique behavior.

A series of materials known as aluminum-matrix composites allows for customizable stiffness, strength, density, and electrical and thermal characteristics. One reason for the recent success of AMCs in both commercial and military applications is the creative modifications made to the component design. Compared to most other MMCs, aluminum composites have the benefit of being less expensive. Al6061 is one of the most widely used aluminum alloys as a matrix material. It is mostly because of its improved formability properties and ability to adjust the composite's strength by using the best possible heat treatment.

The objective of this article is to examine the stir-cast aluminum metal matrix composites' mechanical characteristics and microstructure development.

LITERATURE REVIEW

PravinVyavahare examined the mechanical characteristics of a recently developed composite that was produced using a stir casting method with B_4C reinforcement and an Al 356 matrix. B_4C particles have been used as reinforcing materials in composite manufacturing, with varying weight percentages (3, 6, 9, and 12). Tensile strength, compressive strength, density, and hardness were evaluated as mechanical qualities. It was discovered that as the weight percentages of the B_4C particles grow, so do the metal matrix composite's tensile strength, compressive strength, and hardness.

S. Krishna Prasad have produced the composite by stir casting using titanium carbide with weight percentages of 0, 3, and 6% as the reinforcement and aluminum 7075 as the matrix material. In-depth research is done on aluminum matrix composites to discover more about their mechanical characteristics and microstructures. The result demonstrates that the material's mechanical qualities, such as ultimate tensile strength and hardness, improve at the price of ductility as the number of particles in the aluminum matrix rises.

G.B.Veeresh Kumar examined the impact of adding different amounts of zirconium dioxide particles to Al 6061. Step 2 involves the fabrication of four castings with varying levels of reinforcement (0–6% weight percentage) utilizing the liquid metallurgical process. The produced composites underwent a battery of mechanical and physical testing. The percentage elongation was found to decrease as the proportion of reinforcement in the matrix alloy rose, while the density, hardness, and tensile strength all increased considerably.

Akshay B R fabricated By using friction stir processing, aluminum 6061-boron nitride surface composite was created, and its mechanical characteristics were examined. In increments of three weight percent, the proportion of boron nitride was changed from 0% to 6%. Comparing the composite to unreinforced ones, the results indicate that the former had greater hardness and tensile strength.

Bharath V synthesized Al6061-Al_2O_3 MMCs are interpreted mechanically using the traditional metal casting procedure. Al6061 is used as the base metal matrix in this investigation, and 125μm-sized Al_2O_3 particles are employed as reinforcement. Composites are prepared at 6, 9, and 12 W% variable percentage of Al_2O_3 particles for the experimental studies. The melt's highest temperature was 8000^0C. Three steps were involved in the substitution of Al_2O_3 particles, each including mechanical agitation at 200 rpm for ten minutes.

M. Krishnaa and A. Xaviorb synthesized SiC and hybrid MMC based on Al6061 reinforced with graphite for the metal casting technique's mechanical behavior investigation. In order to construct a hybrid composite for the current investigation, they employed graphite and SiC in addition to aluminum as the basis matrix. Prior to adding reinforcement, magnesium was used to increase the wettability. The melt had a temperature of around 760^0C. For ten to twenty minutes, the stirrer was positioned up to two thirds of the smelted metal's elevation from the basement and agitated at 200 to 400 rpm. Then they disclosed that the treated hybrid composite's mechanical responsiveness had improved.

Pardeep Sharma examined the impact of adding silicon nitride (Si_3N_4) particles in different ratios—0%, 3%, 6%, 9%, and 12%—to aluminum (Al6082-T6). The produced aluminum matrix composites' mechanical characteristics are examined. They reported that although the percentage of elongation was observed to decrease, the tensile strength and hardness rose as the proportion of reinforcement in the matrix alloy increased.

I. RESEARCH METHODOLOGY

STIR CASTING PROCESS:

Through mechanical stirring, the reinforcing components are dispersed throughout the molten matrix during the stir casting process. Stir casting of metal matrix composites began in 1968 when S. Ray stirred molten aluminum alloys containing ceramic powders to incorporate alumina particles into the aluminum melt. An essential part of this procedure is the furnace's mechanical stirring. Sand casting, permanent mold casting, or die casting may all be done using the molten alloy that is left behind after incorporating ceramic particles. Composites with up to 30% volume percentage of reinforcement may be made using stir casting.

Fig 1:Stir casting setup

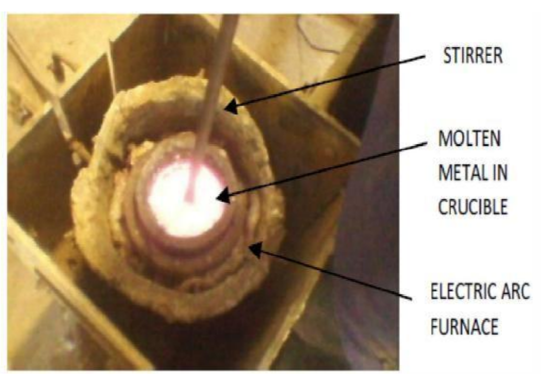

Fig 2:Stirring of molten metal

Fig 3:Pouring the liquid metal into the casting

Fig 4: Casted components

In order to minimize porosity, improve the microstructure and level out the reinforcement distribution, the cast composites are sometimes subjected to further extrusion. The segregation of reinforcing particles, which results from the surfacing or settling of the reinforcement particles during the melting and casting processes, is a significant issue related to the stir casting process. The ultimate distribution of the particles is an intriguing new discovery in stir casting is a two-step mixing technique. In order to completely melt the metal, the matrix material is heated beyond its liquid temperature throughout this process. After that, the melt is maintained in a semi-solid form by cooling it to a temperature that is between that of liquids and solidus points. The heated particles are now introduced and combined. Once again the slurry is heated to a completely liquid condition and well combined. Aluminum has been fabricated using this two-step mixing procedure. Stir casting is the most cost-effective of all the proven metal matrix composite production techniques. Because of this, stir casting is now the most widely used commercial technique for creating composites made of aluminum.

II. SPECIMEN PREPARATION

The specimens are made as metal matrix composites using aluminum 6061 as the base metal and boron carbide reinforcement in the following percentages: 1, 2, 2.5, 3, 4, 5, 7.5, 10, 15, and 20%.

MATRIX	REINFORCEMENT	PERCENTAGE OFWEIGHT
Al6061	B_4C	1,2, 2.5, 3, 4,5, 7.5, 10,15, 20 %

The specimens to be tested in this study are produced in compliance with the relevant ASTM standards. SS 304 is the basic material that is utilized. Following tests are conducted on the raw and welded specimens.

1. **Tension Test**: In accordance with ASTM standard E8/E8M-11, the specimens are produced. Figure 1 shows the geometry's size and form.

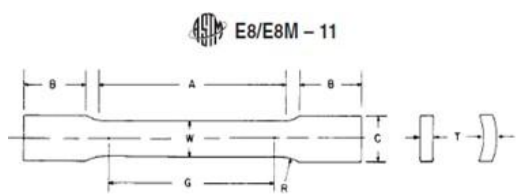

Fig.5 Tension test specimen

The E8/E8M-11 Specimen-5 dimensions are taken into consideration in this study.

Fig.6: ASTM standard specimens

2. Hardness Test: Measured by hardness tests like Brinell, Knoop, Rockwell, or Vickers, a material's resistance to deformation, indentation, or penetration by methods including abrasion, drilling, impact, scratching, and/or wear.

The Vickers hardness test involves applying a force ranging from 1 to 100 kgf while indenting the test material using a diamond indenter shaped like a right pyramid with a square base and an angle of 136 degrees between opposing sides. Usually, the whole load is applied for ten to fifteen seconds. Using a microscope, the two diagonals of the indentation left in the material's surface after the load has been removed are measured, and their average is computed. It is computed how big the indentation's sloping surface is. The ratio produced by dividing the kgf load by the square mm area of indentation is known as the Vickers hardness.

Fig. 7: Vickers hardness testing machine

3. Microstructure: The structure of a material's prepared surface as seen under a microscope at magnifications more than 25 is known as the microstructure, which is the small-scale structure of the material. We distinguish clearly between a material's microstructure and crystal structure when discussing its structure. The average atomic locations inside the unit cell are referred to as "crystal structure," which is entirely defined by the lattice type and the fractional coordinates of the atoms (as found, for instance, by X-ray diffraction).

III. TESTING OF SPECIMENS

Using a universal testing machine, each specimen is machined in accordance with ASTM standards before being tested for tensile strength. In a similar vein, the specimens are shaped to the specifications needed to determine their hardness and impact strength.

IV. RESULTS AND DISCUSSION

(i) Hardness

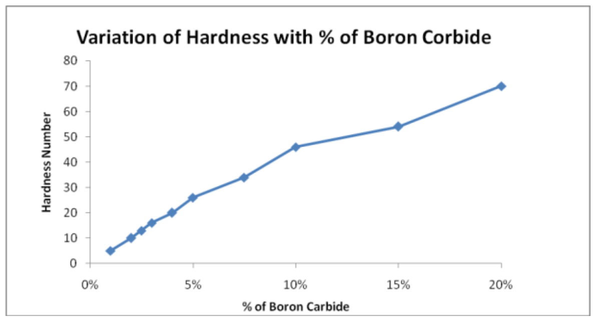

Fig. 8.Variation of Hardness with percentage of boron carbide (B_4C)

Figure 7 illustrates how hardness increases in tandem with an increase in boron carbide %.

(ii) Micro Structures :

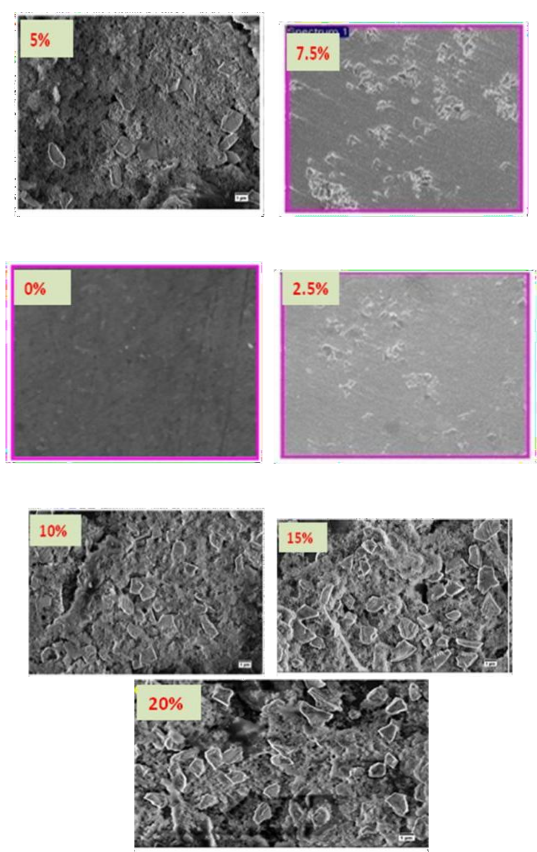

Fig.9. Microstructures of composites for various percentages

As shown in fig. 8, the base material and reinforcing material are blended equally. The aluminum matrix's particle dispersion was comparatively uniform and homogenous. At greater weight percentages of B_4C, there was agglomeration and small-scale clustering of particles between the dendritic borders. There was no sign of reaction products at the particle-matrix interface, which was shown to be distinct and clean.

(iii) Ultimate Tensile Strength:

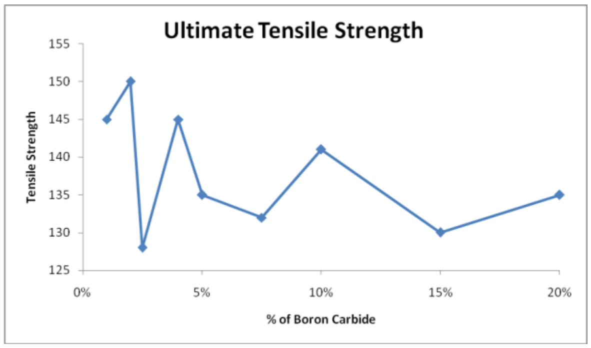

Fig.10. Ultimate Tensile Strength

Variation in the ultimate tensile strength of the boron carbide reinforcement is shown in Fig. 9.

V. CONCLUSION

- Stir casting was used to create the Al 6061-B_4C composites in different percentage combinations of 0%, 2.5%, 5%, 7.5%, 10%, 15%, and 20%.
- The distribution of reinforcement material is consistent; the ultimate tensile strength is highest at 2.5 percent of reinforcement, or 153 MPa.
- Through the use of stir casting, the present work aims to improve the mechanical characteristics of AMMCs by adding silicon carbide (SiC) and boron carbide (B_4C).
- Because of its superior mechanical qualities, Al6061 is used as the matrix material, while SiC and B_4C are chosen as reinforcements because of their high levels of strength, hardness, and thermal stability.
- In order to see how the weight fractions of SiC and B_4C affect mechanical characteristics, the experimental approach entails altering them.

References:

1. Kumar Lingaraj Patil, Mousil Ali, Madeva Nagaral ," Studies on Al8081-B_4C Metal Matrix Composites Fabricated by Stir Casting Method", IJMER, ISSN: 2249–6645, Vol. 4 | Iss.7| July. 2014.
2. ShivrajKoti1, S B Halesh, Madeva Nagaral, V Auradi, " Microstructure and tensile behavior of AA7475-B_4C composites", IJER, Volume No.5 Issue: Special 6, pp: 1129 – 1254.
3. E.Subba Rao, N.Ramanaiah, "Intermetallic- reinforced boron carbide (B_4C) composites produced through stir casting processing", CMAIJ, 1(2) 2016.
4. T.Raviteja, N.Radhika, R.Raghu, " fabrication and mechanical properties of stir cast al-si12cu/B_4C composites", IJRET, Volume: 03 Issue: 07 | Jul-2014.
5. S. Rama Rao , G. Padmanabhan ," Fabrication and mechanical properties of aluminium-boron carbide composites", URP, ISSN 2249–9679, 09 August 2012.
6. S Thirumalai Kumaran, M Uthayakumar, S Aravindan and S Rajesh," Dry sliding wear behavior of SiC and B_4C-reinforced AA6351 metal matrix composite produced by stir castingprocess", Journal of MATERIALS: DESIGN AND APPLICATIONS, 7 March 2015.
7. Ritesh Raj, Dineshsingh G. Thakur ," Qualitative and quantitative assessment of microstructure in Al-B_4C metal matrix composite processed by modified stir casting technique", ELSEVIER, 10 July 2016.
8. T. M. Chenthil Jegan, D. Ravindran, and M.Dev Anand, "material characterization study on aluminium metal matrix composites by enhanced stir casting method", Advanced Materials Research Vols. 984-985 (2014) pp 326-330.
9. D.B. Miracle, Metal matrix composites – From science to technologicalsignificance, Compos. Sci. Technol. 65 (2005) 2526–2540, https://doi.org/10.1016/j.compscitech.2005.05.027.
10. C. Nikhilesh, K.C. Krishan, Metal Matrix Composites, Springer Science Business Media, New York, 2006, p. 266.
11. P. Mukhopadhyay, Alloy designation, processing, and use of AA6XXX, ISRN Metall. 165082 (2012), https://doi.org/10.5402/2012/165082.

12. C. Baron, H. Springer, Properties of particle phases for metal-matrix-composite design, Data Br. 12 (2017) 692–708, https://doi.org/10.1016/j.dib.2017.04.038.
13. J.C. Viala, J. Bouix, G. Gonzalez, C. Esnouf, Chemical reactivity of aluminium with boron carbide, J. Mater. Sci. 32 (1997) 4559–4573, https://doi.org/10.1023/A:1018625402103.
14. J.N. Fridlyander, Metal Matrix Composites, Chapman & Hall, Russian Academy of Sciences, Moscow, Russia, 1995.
15. A.V. Pozdniakov, A. Lotfy, A. Qadir, E. Shalaby, M.G. Khomutov, A.Y. Churyumov, V.S. Zolotorevskiy, Development of Al-5Cu/B_4C composites with low coefficient of thermal expansion for automotive application, Mater. Sci. Eng., A 688 (2017) 1–8, https://doi.org/10.1016/j.msea.2017.01.075.
16. A. Akkas, A.B. Tugrula, O. Addemira, M. Marso?lub, B. A?acanb, B. Büyüka, Radiation shielding effect of boron carbide aluminum metal matrix composite, Acta Phys. Pol. A. 127 (2015) 947–949, https://doi.org/10.12693/APhysPolA.127.947.
17. J.J. Park, S.M. Hong, M.K. Lee, C.K. Rhee, W.H. Rhee, Enhancement in the microstructure and neutron shielding efficiency of sandwich type of Al-6061 B_4C composite material via hot isostatic pressing, Nucl. Eng. Des. 282 (2015) 1–7. doi:10.1016/j.nucengdes.2014.10.020.
18. J.B. Wierschke, L. Wang, Evaluation of aluminum-boron carbide neutron absorbing materials for interim storage of used nuclear Fuel, A Dissertation of Doctor of Philosophy (2015)1–159.
http://deepblue.lib.umich.edu/bitstream/2027.42/111438/1/jonbrett_1.pdf.2015..
19. A.V. Pozdniakov, V.S. Zolotorevskiy, R.Y. Barkov, A. Lotfy, A.I. Bazlov, Microstructure and material characterization of 6063/B_4C and 1545K / B_4C composites produced by two stir casting techniques for nuclear applications, J. Alloys Compd. 664 (2016) 317–320. doi: 10.1016/j.jallcom.2015.12.228.
20. F.Toptan, A.Kilicarslan, M. Cigdem, I.Kerti. Processing and microstructural characterization of Al1070 and Al6063 matrix B_4C reinforced composites. Mater Des 31 (2010) s87-s91.