IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 2, August 2023

Formation of Al-7075 Based Hybrid Composites and Evaluation of their Properties

Shilpa T V[1], Lakshminarayana T H[2], Vinay A N[3], Raghavendra Prasad[4]
Department of Mechanical Engineering[1,2,3,4]
R L Jalappa Institute of Technology, Doddaballapur, India

Abstract: *Metal matrix composites possess significantly improved properties including high tensile strength, toughness, hardness, low density and good wear resistance compared to alloys or any other metal. The Al-7075 matrix can be strengthened by reinforcing with 1%Al_2O_3 and 1%,2%,3% B_4C.Evaluation of mechanical properties like Tensile and Compression Strength, Hardness, Wear Rate, Microstructure Analysis conducted on pure and casted specimens. In this study, we have attempted to examine the microstructures and thermal behavior of Al_2O_3/B_4C reinforced composites with different weight fractions. The microstructure, thermal conductivity, and coefficient of thermal expansion were also examined after adding Al_2O_3/B_4C to Al6061. Al7075 reinforced with Al_2O_3/B_4C particles exhibited better thermal properties than without Al_2O_3/B_4C reinforcement.*

Keywords: Al 7075; Al_2O_3;B_4C; Mechanical properties

I. INTRODUCTION

Due the increasing demand of light-weight materials in the emerging industrial applications, fabrication of aluminium-boron carbide composites is required. In this context aluminium alloy - boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). With the increase the amount of the boron carbide, the density of the composites decreased whereas the hardness is increased.Composite materials do play a great significance and an effective role in many engineering industries applications because of the physical properties that are characterized by thermal properties. Thermal properties are one of prime physical properties of composites, which also include electrical, magnetics and optical properties [1-6]. Thermal property of a material is its physical property related to application of heat energy and explain its response. As a solid body absorbs energy in the form of heat, its temperature increases and its dimensions increase. Thermal properties that are often critical in the practical utilization of solids. In this project we are developing and doing analysis on thermal properties of Al6061 and SiC/Gr hybrid composites. In our daily life, AMMCs have found many applications. AMMCs are composites that only use aluminium as the matrix and incorporate a few reinforced components into the matrix. There are a few benefits such as low Coefficient of Thermal Expansion (CTE), improved stiffness, greater hardness and strength, light weight, high specific modulus, enhanced damping capabilities, enhanced wear-resistance and greater Thermal Conductivity (TC) when the reinforced is used in matrix. The matrix may include reinforcing elements in a manner of continuous fibers, particulates or monofilaments [7-10]. They have been used in the fields of industrial goods, automotive and aeronautics applications. The reinforcement particulates must be robust, flexible and anti-reactive in the specified operating temperature. SiC, Al6061, graphite, are commonly used as reinforcements. In order to gain the optimum properties, selection of good reinforcement and the matrix materials are not only sufficient, processing method also plays a significant role. There are different techniques available to produce AMMCs like powder metallurgy, squeeze casting, stir casting, chemical vapour deposition, pressure infiltration etc. Among these manufacturing techniques stir casting is the prevalent technique which has been used by many investigators since the process is cost-effective, and this process have greater hardness and refined micro structure grains than other techniques. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergies SiC/Gr way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties. The shape of the discontinuous phase (which may by spherical, cylindrical, or rectangular cross-sanctioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix. Composites as engineering materials normally refer to the material with the following characteristics [11-16].

1.1 Matrix Material

Aluminium alloy (Al7075) is an aluminium alloy with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. The Al7075 is widely used for construction of aircraft structures, such as wings and fuselages. Its strength and light weight are also desirable in other fields. Rock climbing equipment and bicycle components are commonly made from 7075 aluminium alloy.Aluminium alloy matrix as shown in figure 4.1 and table 4.1 shows the chemical compositions of Al7075 alloy.

Table 1: Chemical composition of Al7075 alloy

Chemical composition [%]					
Element	wt. %	Element	wt. %	Element	wt. %
Si	0.67	Ti	0.2	Fe	0.6
Mg	1.58	Zn	0.17	Cu	0.27
Cr	0.2	Mn	0.22	Al	Bal.

Al_2O_3/B_4C are polycrystalline composite materials, consisting of Al2O3/B4C (single crystals) embedded in a matrix of amorphous or partially crystallized glassy phase. Their properties are not only determined by the intrinsic properties of Al_2O_3/B_4C crystals, but strongly depend on the size and morphology of Al_2O_3/B_4C grains, as well as the volume fraction and chemistry of glassy phase at the grain boundaries of Al_2O_3/B_4C. In the first part, the article describes the structure, properties and manufacturing routes of Al_2O_3/B_4C single crystals. The last part describes the room temperature mechanical properties (hardness, strength, fracture toughness), high temperature mechanical properties (oxidation and creep resistance), and functional properties (thermal conductivity and biological properties) of Al_2O_3/B_4C.

II. TESTING OF THE HYBRID COMPOSITES

The developed hybrid composites are subjected to microscopic investigation to examine the microstructure. Study of microstructure comprises of optical microscopic study, EDS study, SEM study of tensile fractured surfaces and worn-out surfaces of wear specimen. The uniformity of reinforcement distribution, which is influenced by the manufacturing and processing techniques employed, is the most crucial component in the production of hybrid composites. An optical microscope was used to conduct metallographic investigations of the resulting composite materials in order to study the distribution of reinforcements inside the aluminium matrix. On a typical universal lathe machine, the cast composite specimens were mechanically ground into 10 mm diameter and 10 mm heights. For microstructural analyses, the samples were polished on 200, 400, and 600-grid emery paper. The microstructure test samples received metallographic polishing. The specimen was subjected to micro structural tests after having its surface thoroughly cleaned with hydrogen fluoride as an etchant in order to obtain an equal distribution of reinforcement particles in the aluminium matrix. The experiments were conducted using an inverted optical microscope with a 100X–1000X magnification range.

Optical microscopic examination examined the basic information about the microstructure of developed MMCs. The optical microscope employed for this purpose was Olympus and having following specifications: NIKON- ECLIPSE LV 150 Japan optical metallurgical microscope, magnification range of 100X – 1000X with 360^{o} rotatable analyzer slider for reflected light and objective lens of 5X to 100X. For the microstructural examination, the samples were polished using the standard metallographic method. One end of the specimen underwent polishing with abrasive sheets of different grades from 100 to 120^{o}F. It was then followed by cleaning the specimens by soaking them in kerosene and polish with velvet cloth. Specimens are then polished with diamond paste and then etching is carried out using the Keller's reagent. Polished surfaces of specimens were positioned in the optical microscope for observation.

The wear rate of the developed hybrid composites was evaluated using wear testing. The experimentation followed the recommendations of ASTM G 99-05. Machines were used to form test samples with dimensions of 8mm in diameter and 30mm in length. The computerized testing apparatus pin-on-disc (Version-EV00, WTE 165 model) of disc size 165 mm and thickness 8mm (Material: EN31) was used to test having s speed range of 200 rpm to 2000 rpm, operates at load from 5N to 100N and frictional force up to 100N.

III. RESULTS AND DISCUSSIONS

3.1 Microstructure

Significant improvements in mechanical characteristics was observed mainly due to the restructured grain structure, whereas increased splitting was mainly due to the presence of refurbishing particles that reduced the elongation properties and improved cargo capacity. Studies of particle additions found that with heterogeneous nucleation of the reinforcement grains, mechanical characteristics improved with the development of the precise structure. Composite characterization refers to the wide-ranging and general method by which composite structure and properties are analyzed and evaluated to ensure that materials meet performance criteria for various applications. In scanning electron microscopy, Figure 1 shows the slicked pattern observed systematically, with different magnifications and measurements.Analyses of 100X magnification of the microscopic structure show that the deformation observed can be attributed to the formation of a solid Al_2O_3/B_4C solution. The visible dark grey area is determined to be the solid solution of the reinforcement particles with the rest of the area being the Al alloy matrix. The dark and white part in the image of the microstructure, as shown in Figure 1 a, explains the aggregation of Al_2O_3/B_4C particles.Comparison of microscopic illustrations on Al alloy and divergence breaks was observed in both samples. However, the dendrite arm distance was not as large as the reinforcing-parts inhibition width during solidification, as seen in figure 1 b. Dendrite arm distance in the composite was observed in both samples.

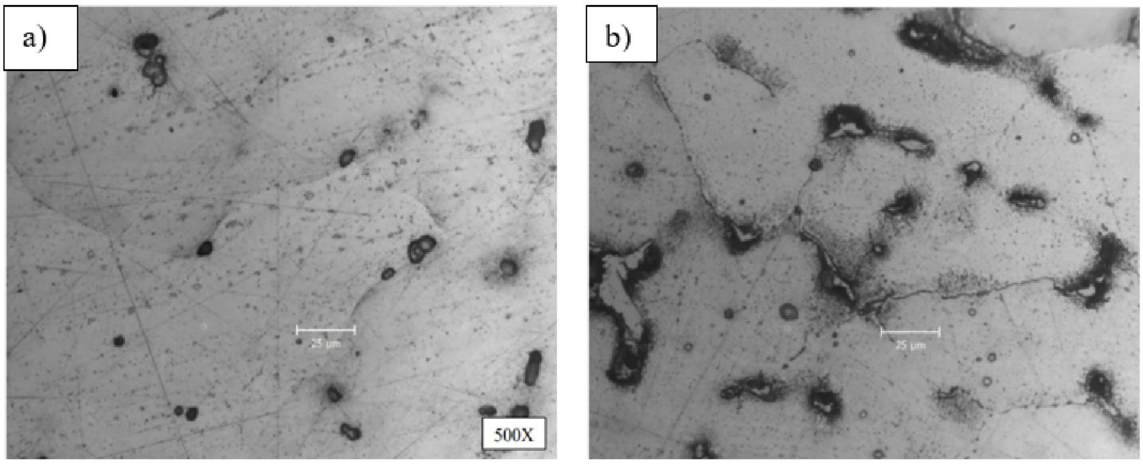
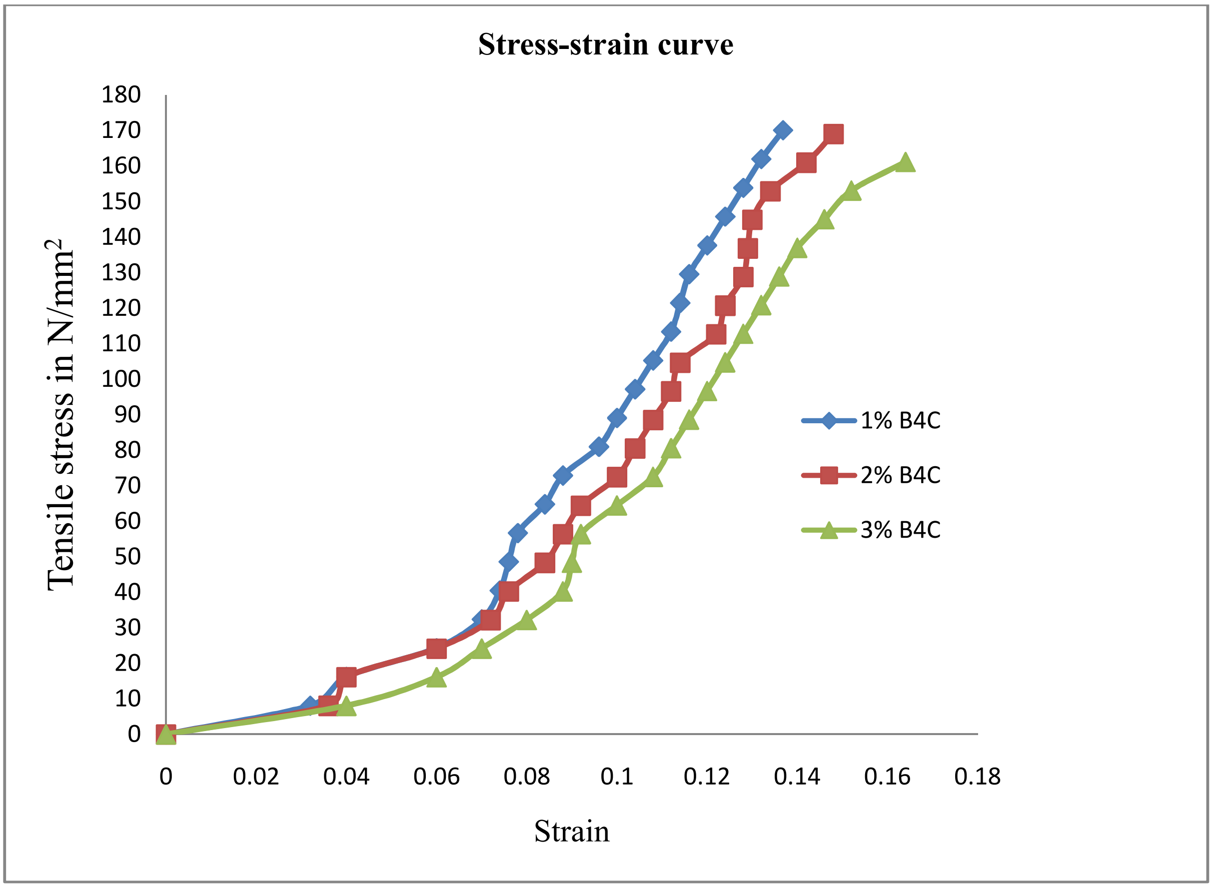


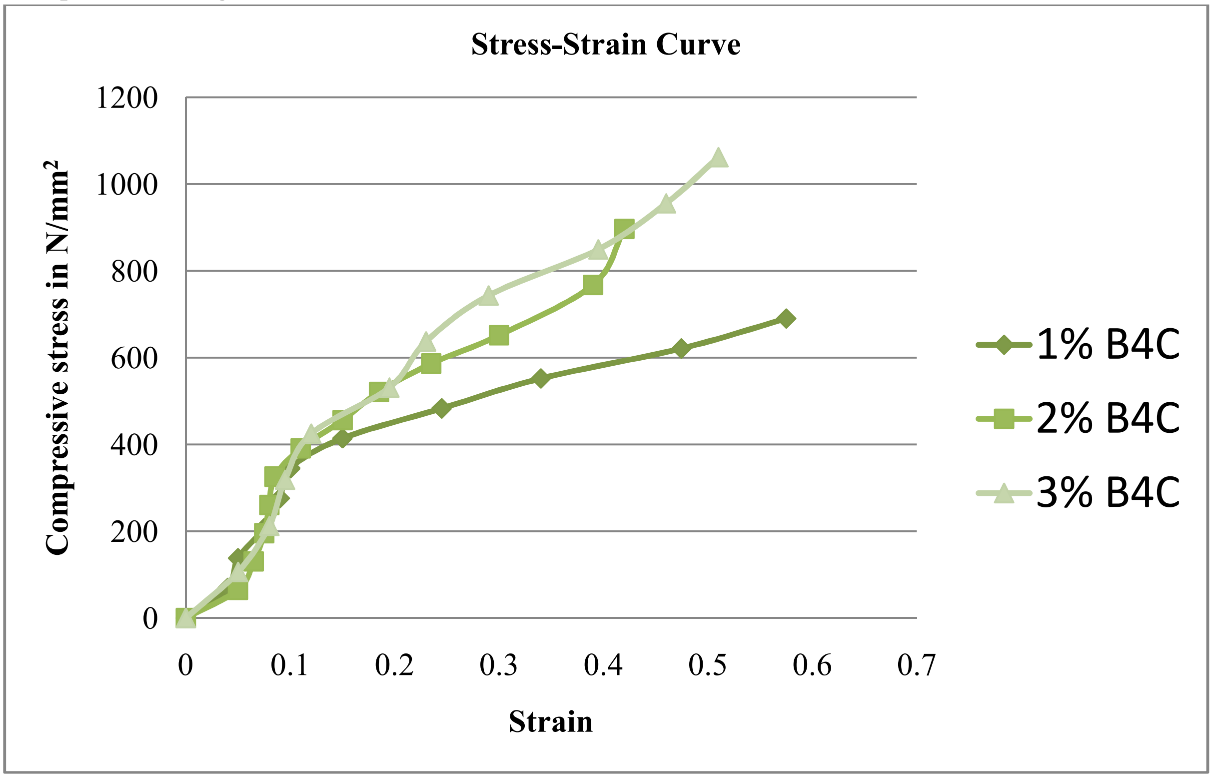
Figure 1: Microstructure of Base alloy and composite

3.2 Tensile strength

Particulate involvement in matrix molecules greatly improves its microstructure, weakening roughness when freezing of the primary dendrites. Ni_3S_4 particles mainly pass through primary dendrite boundaries of the Al alloy though some are found in aluminum slab. Porosity in the cluster region of Al_2O_3/B_4C particles was seen frequently after small scale engraving. Processing of microstructures on the silicon surface throughout the Al_2O_3/B_4C particles occurred. The microstructure had a viscous solution from the Al alloy, with some unspecified non-metallic additions. The combined surface appeared to include small boulders, with the whole dendritic form being clearly visible at 200X. Microstructural qualities of the metal matrix Al combination composites rely basically on the idea of lattice amalgam fortification, their holding, and dissemination. The present discussion relies upon 6 wt. % fortresses since mechanical properties are optimum in the 6 wt. % of Al_2O_3/B_4C. Further augmentation in the stronghold substance (to 8 wt. %) lead to at the care group improvement which self-destructs the mechanical properties due to the distinction between the thickness and higher percentage of reinforcement.



3.3 Compressive strength



VI. CONCLUSIONS

- The main contributions of this project work have been summarized and the scope for future work listed at the end of this chapter.
- Microstructure SEM analysis showed uniform distribution of Al_2O_3/B_4C particulates with the smallest number of porosities and agglomeration was observed. The fine grains dendrite structure was formed by adding Al_2O_3/B_4C particulates.
- Formation of fine dendrite structure was observed in all metal matrix composite specimens due to faster solidification and density change of the composites by metal casting. The same was also observed in thermal conductivity tests.
- Agglomeration of hard ceramic particles was observed in higher composites i.e. 8 wt. % Al_2O_3/B_4C due to higher volume rations and insufficient stirring time and speed.

REFERENCES

[1]. J. Kumaraswamy, V. Kumar and G. Purushotham, A review on mechanical and wear properties of ASTM a 494 M grade nickel-based alloy metal matrix composites, Materials Today: Proceedings, Vol 37, 2021, pp 2027–2032,https://doi.org/10.1016/j.matpr.2020.07.499.

[2]. K. Jayappa, V. Kumar, and G. G. Purushotham, "Effect of reinforcements on mechanical properties of nickel alloy hybrid metal matrix composites processed by sand mold technique," Applied Science and Engineering Progress, Vol. 14, no. 1, pp. 44–51, Jan.–Mar. 2021, http://dx.doi.org/10.14416/j.asep.2020.11.001

[3]. J. Kumaraswamy, V. Kumar and G. Purushotham, Thermal analysis of nickel alloy/Al_2O_3/TiO_2 hybrid metal matrix composite in automotive engine exhaust valve using FEA method,Journal of Thermal Engineering, Vol. 7, No. 3, March, 2021, pp. 415-428. https://dx.doi.org/10.18186/thermal.882965.

[4].J Kumaraswamy, Vijaya Kumar, G Purushotham, Evaluation of the microstructure and thermal properties of (ASTM A 494 M grade) nickel alloy hybrid metal matrix composites processed by sand mold casting, International Journal of Ambient Energy, Vol. 43, pp. 4899–4908.https://www.tandfonline.com/doi/abs/10.1080/01430750.2021.1927836.

[5]. Sandeep Khelge, Vijaya Kumar, Vidyasagar Shetty and Kumaraswamy J,Effect of reinforcement particles on the mechanical and wear properties of aluminium alloy composites: Review, Materials Today: Proceedings, Vol. 52, Part 3, pp. 571-576, 2022. https://doi.org/10.1016/j.matpr.2021.09.525

[6]. Sandeep Khelge, Vijaya Kumar and Kumaraswamy J, Optimization of wear properties on aluminum alloy (LM22) hybrid composite, Materials Today: Proceedings, Vol. 52, Part 3, pp. 565--570, 2022.https://doi.org/10.1016/j.matpr.2021.09.518

[7]. Vidyasagar Shetty, Shabari Shedthi B and Kumaraswamy J, Predicting the thermodynamic stability of perovskite oxides using multiple machine learning techniques, Materials Today: Proceedings, Vol. 52, Part 3, pp. **457-461**, 2022. https://doi.org/10.1016/j.matpr.2021.09.208

[8]. Kumaraswamy J, Anil K. C., Vidyasagar Shetty and C Shashishekar. Wear behaviour of the Ni-Cu alloy hybrid composites processed by sand mold casting,Advances in Materials and Processing Technologies, Vol. 2, pp. 1-17. https://doi.org/10.1080/2374068X.2022.2092684

[9]. Harish R S, Sreenivasa Reddy M, Kumaraswamy J, Wear characterization of Al7075 Alloy hybrid composites, Journal of Metallurgical and Materials Engineering, Vol. 28 (2), pp. 291-303. https://doi.org/10.30544/821.

[10]. K.C. Anil, J. Kumaraswamy, Akash et al., Experimental arrangement for estimation of metal-mold boundary heat flux during gravity chill casting, Materials Today: Proceedings, Volume 72, Part 4, 2023, Pages 2013-2020. https://doi.org/10.1016/j.matpr.2022.07.399

[11]. J. Kumaraswamy et al., "Thermal Analysis of Ni-Cu Alloy Nanocomposites Processed by Sand Mold Casting," Advances in Materials Science and Engineering, vol. 2022, Article ID 2530707, 11 pages, 2022. https://doi.org/10.1155/2022/2530707.

[12] R.S. Harish, M. Sreenivasa Reddy and J. Kumaraswamy, Mechanical behaviour of Al7075 alloy Al2O3/E-Glass hybrid composites for automobile applications, Materials Today: Proceedings, Volume 72, Part 4, 2023, Pages 2186-2192. https://doi.org/10.1016/j.matpr.2022.08.460

[13] J. Kumaraswamy, K.C. Anil and V. Shetty, Development of Ni-Cu based alloy hybrid composites through induction furnace casting, Materials Today: Proceedings, Vol. 72, pp. 2268-2274. https://doi.org/10.1016/j.matpr.2022.09.215

[14] Anil, K.C., Kumarswamy, J., Reddy, M., Prakash, B., Mechanical Behaviour and Fractured Surface Analysis of Bauxite Residue & Graphite Reinforced Aluminium Hybrid Composites, Frattura ed Integrità Strutturale, 16 (62) (2022) 168-179. DOI: 10.3221/IGF-ESIS.62.12

[15] Anil K C, Kumaraswamy J, Mahadeva Reddy, Mamatha K M, Air Jet Erosion studies on Aluminum - Red Mud Composites using Taguchi Design, EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 10, Issue 01, pp130-138, March 2023. https://doi.org/10.5109/6781059

[16] Sharan kumar, Akash, Anil K C, Kumaraswamy J,Solid Particle Erosion Performance of Multi-layered Carbide Coatings (WC-SiC-Cr3C2), EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 10, Issue 02, pp 813-819, June 2023. https://doi.org/10.5109/6792833