Synthesis, Characterization and Testing of Al Alloy Based Hybrid Composite Materials

S. Suresh Kumar, M. Uthayakumar, S. Thirumalai Kumaran, K. Vinoth Babu

Abstract*: The developments in the area of aerospace, advancing activities in aircraft field and automotive industry emerges the exploit of new materials. In such applications, the role of Metal Matrix Composites (MMCs) is inevitable. In the proposed article, the fabrication of Al (6351) alloy reinforced with SiC and varying weight proportion of Boron Carbide (B_4C) was done through stir casting process. The characterization of prepared composite materials is evaluated to ensure the homogeneous distribution of reinforced particulates in Al matrix. The existence of alloying elements and their mapping is done through EDS. Moreover, the enhancement of physical and mechanical behavior of the fabricated composites is also discussed in detail.

***Keywords*: hybrid composite, stir casting, SEM, microstructure, mechanical properties.**

I. INTRODUCTION

MMCs are fabricated by joining two or more dissimilar materials having varying chemical and physical characteristics. Nowadays, it is been gaining more attention, owing to improved strength with lower density and higher rigidity [1]. Recently, the researchers in this area have shifted towards aluminum based metal matrix composites, due to variety of applications viz. vehicle shafts, pistons, and bicycle frames. [2]. The fabrication and characterization of Al alloy reinforcing with boron carbide particles are examined by Kalaiselvan et al. [3]. Though, metal matrix based composites are produced by ample method viz. powder metallurgy, pressure infiltration, stir casting. Amid the entire techniques, conventional stir casting is fairly cheap, easy one and suitable for variety of materials. Belete Sirahbizu Yigezu et al. [4] have studied the ceramic particle reinforced aluminum composites. They reported that the stir casting route is cost effective and simple and can produce superior dispersion on the metal matrix, as a result of stirring action.

Pozdniakov et al. [5] have examined the characterization of Al-B_4C MMC fabricated through casting route. They have reported that the better interface bonding is produced by the development of AlB_2 and Al_3BC phases. Mahendra and Radhakrishna [6] have examined MMC consists of Al alloy reinforced with fly ash and SiC. The enhanced mechanical property of the prepared composite was reported. Bijay Kumar Show et al. [7] produced Al6351 – (Al_4SiC_4+SiC) hybrid composite and observed the advances in strength and hardness of the composite compared to base alloy. The mechanical properties of A356 composite reinforcing with B_4C was evaluated by Ali Mazahery and Mohsen Ostad Shabani [8]. The experimental result shows the improved strength and hardness than base material and also increased with increase in B_4C content.

Arun Premnath et al. [9] attempted to determine the mechanical properties of aluminum based composites with varying weight fraction of alumina. They observed increased density and the hardness with the increased Al_2O_3 content. Aykut Canakci et al. [10] have fabricated AA2024–B_4C composite by stir casting process with varying volume fraction of 3, 5, 7 and 10 % and with sizes 29 and 71μm. They have concluded that the raise in volume percentage, increases hardness of the composite, although the strength of the material is decreased with an addition of the particle volume percentage. Saba Khoramkhorshid et al. [11] have done an experimental analysis on the mechanical properties of Al composite reinforced with $Al_{84}Gd_6Ni_7Co_3$ powders and concluded that the presence of particles significantly enhances the mechanical properties compared to pure Al. Sajjadi et al. [12] have examined the microstructure and mechanical properties of Al–Al_2O_3 micro and nano composites produced by stir casting techniques. The experimental result reveals that the nano particle incorporation is poor in the aluminum melt prepared by the common condition. In addition, the stirring system also improves the wettability and the distribution of the nano particles is uniform within the aluminum melt.

The most of the researchers have attempted to develop Al alloy based composite and few were produced hybrid composites. However, still there is a scope for analyzing the influence of weight fraction of reinforcing particulates on the mechanical behaviour of hybrid composites. An attempt is completed to analyze the effect of B4C on Al- 5 wt. % SiC metal matrix composite towards influencing the physical and mechanical properties of the prepared composite.

II. FABRICATION OF THE COMPOSITE

An aluminum 6351 alloy is most widely used materials in the structural engineering applications.

Revised Manuscript Received on December 30, 2019.
S. Suresh Kumar*, Faculty of Mechanical Engineering, Kalasalingam Academy of Research and Education, Srivilliputhur, India. Email: sureshme48@gmail.com
M. Uthayakumar, Faculty of Mechanical Engineering, Kalasalingam Academy of Research and Education, Srivilliputhur, India. Email: uthaykumar@gmail.com
S. Thirumalai Kumaran, Faculty of Mechanical Engineering, Kalasalingam Academy of Research and Education, Srivilliputhur, India. Email: thirumalaikumaran@yahoo.com
K. Vinoth Babu, Faculty of Mechanical Engineering, Sri Indu College of Engineering & Technology, Hyderabad, India. Email: vinothbabukr@gmail.com

The chemical compositions of Al6351 alloy is Al – 97.8 %, Si – 1 %, Mn – 0.6 %, Mg – 0.6 %. Owing to its improved competence to aquatic ambiance and higher strength, it is employed in the field of ship production. Moreover, attributable to its high strength and increased mechanical properties, it is used in nuclear industries.

The higher strength and higher thermal conductivity together with less coefficient of thermal expansion enables improved thermal resistant capabilities to SiC. This material is used in thermistor and electric furnaces, due to its low electrical conductivity. SiC has high hardness, high strength, low density and hence, it is employed in various high-performance applications.

The new composite material reinforced with SiC particles is being developed for the usage in the structural engineering and wear applications. B4C has better mechanical properties as similar to those of SiC, but have greater wear resistance and also offer outstanding chemical resistance to acid and base. Some of its unique properties are high neutron absorbing characteristics, high hardness and chemical inertness. It is used in lightweight composite materials, abrasive and wear-resistant products and control rods in nuclear power plant.

The composite consists of aluminum alloy 6351 cast as matrix and SiC and B_4C as reinforcement materials. The Al 6351alloy in the form of cast rods is placed in the hard crucible and heated using resistance furnace. Similarly, reinforcing particles are also preheated in order to oxidize their surface so as to improve the wettability. The average size of the particulates is 69 µm and 149 µm respectively for SiC and B_4C powder. The alloy is melted by heating it above its liquidus temperature. The preheated particulates are gradually mixed by using a motorized stirrer with 500 rpm of rotor speed. The melt is maintained at 750±10°C temperature range and the 720°C is maintained while pouring melt into mold. The uniformly mixed molten state of metal is poured into steel mold and allowed for complete solidification in order to obtain the product. The cast is machined to required shape for further examination.

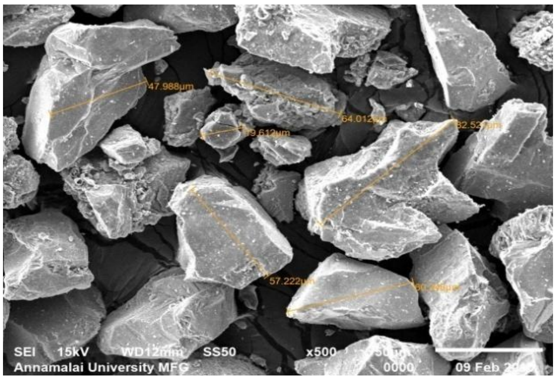
III. RESULTS AND DISCUSSIONS

A. Microstructure analysis

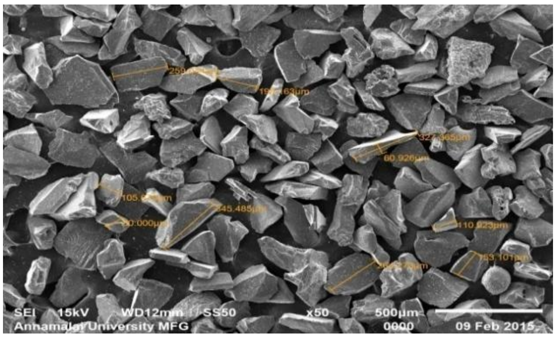
By varying the weight fraction of B_4C (0%, 5% and 10%), three composite specimens were prepared for the analysis. The Scanning Electron Microscopic (SEM) image of the ceramic particulates is presented in Figure 1. The average size of SiC particulates is around 70 µm and B_4C is around 145µm. The microstructure of the three fabricated composites is examined through SEM-EDS mapping which is shown in Figure 2 (a-c). The particle dispersion in the alloy matrix is uniform and the presence of various alloying elements also shown in the image.

B. Physical and Mechanical Properties

The fabricated materials are subjected to testing of their physical and mechanical properties. The ASTM B557M – 10 is used for measuring the tensile strength of the three materials. Table 1 exhibits the mechanical properties of three composites. It is understood that the significant improvement in the hardness, tensile strength is noted which result of inclusion of hard reinforcements in the matrix. Table 2 shows the theoretical density calculated by rule of mixture theory and experimental density measured by using densometer for prepared MMCs. The porosity is calculated from both the densities and is also reported.



a) SiC particle.



b) B_4C particle

Fig. 1. Reinforced particles

Table- I: HARDNESS AND TENSILE STRENGTH

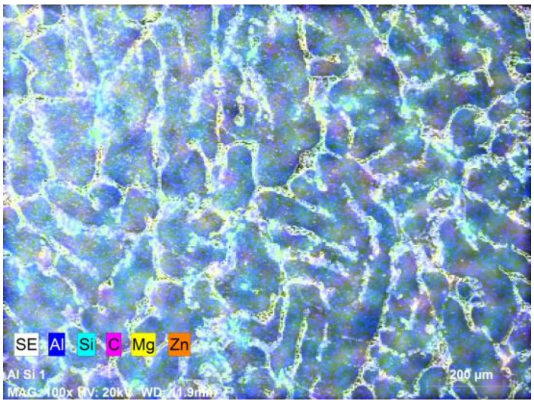
Properties	Al alloy with 5 wt. % SiC	Al alloy with 5 wt. % SiC and 5 wt. % B_4C	Al alloy with 5 wt. % SiC and 10 wt. % B_4C
Brinell's Hardness (HB)	66.81	71.58	76.78
Yield Strength (N/mm^2)	81.37	98.75	107.43
Tensile Strength (N/mm^2)	105.62	120.32	132.48

Table- II: PHYSICAL PROPERTIES

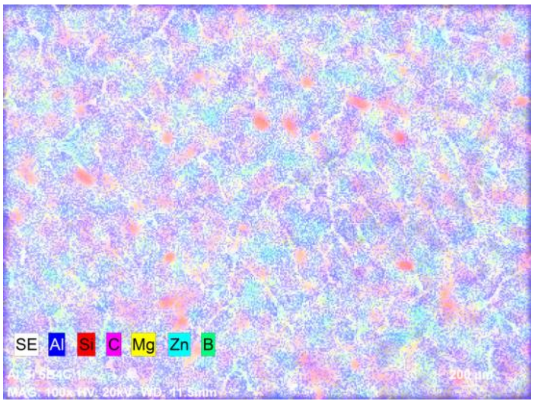
Properties	Al alloy with 5 wt. % SiC	Al alloy with 5 wt. % SiC and 5 wt. % B_4C	Al alloy with 5 wt. % SiC and 10 wt. % B_4C
Experimental Density	66.81	71.58	76.78
Theoretical Density (kg/m^3)	81.37	98.75	107.43
Porosity (%)	3.81	4.46	3.29

Retrieval Number: B10331292S219/2019©BEIESP
DOI: 10.35940/ijitee.B1033.1292S219

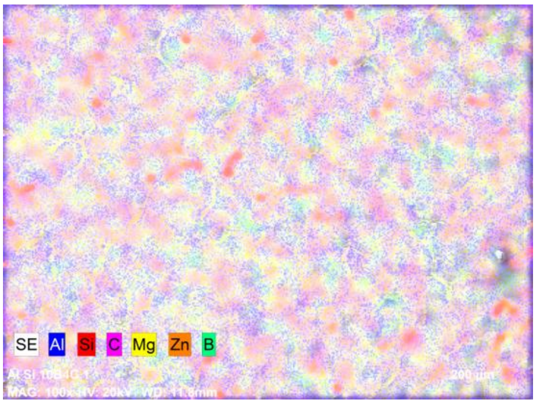
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



a) Al alloy with 5 wt. % SiC.



b) Al alloy with 5 wt. % SiC- 5 wt. % B4C



c) Al alloy 5 wt. % SiC - 10 wt. % B_4C

Fig. 2.Microstructure of the composites

IV. CONCLUSIONS

The Al alloy based hybrid composite with varying weight percentage of B_4C is fabricated through stir casting method. The microstructure is examined for each composite and experimental density, hardness and tensile strength of each composite was determined.

1) The average particle size of the SiC is determined to be around 69µm and B_4C is 149µm approximately through SEM image.
2) The homogeneous dispersion of ceramic particulates in the alloy is ensured from SEM and EDS mapping.
3) The lower porosity is observed in the composite which ensures the quality of production of composite through stir casting route.
4) The improved mechanical properties are witnessed as a result of the existence of rigid ceramic reinforcing particulates.
5) The density of composites is lowered as weight fraction of the B_4C is increases.

REFERENCES

1. N. Valibeygloo, R. Azari Khosroshahi and R. Taherzadeh Mousavian, “Microstructural and mechanical properties of Al-4.5wt% Cu reinforced with alumina nano particles by stir casting method,” *International Journal of Minerals, Metallurgy, and Materials*, 2013, vol. 20 (10), pp. 978-985.
2. Wang Zhenlong, Geng Xuesong, Chi Guanxin and Wang Yukui, “Surface Integrity associated with SiC/Al particulate composite by micro-wire electrical discharge machining,” *Journal of Materials and Manufacturing Process*, 2014, vol. 29, pp. 532-539.
3. K. Kalaiselvan, N. Muruganand and Siva Parameswaran, “Production and characterization of AA6061–B4C stir cast composite,” *Materials and Design*, 2011, vo. 2, pp. 4004–4009.
4. Belete Sirahbizu Yigezu, P.K. Jha, and Mahapatra M.M., “The key attributes of synthesizing ceramic particulate reinforced Al-based matrix composites through stir casting process: A Review,” *Materials and Manufacturing Process*, 2013, vol. 28 (9), pp. 969-979.
5. A.V. Pozdniakov, V.S. Zolotorevskiy, R. Yu. 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,” *Journal of Alloys and Compounds*, 2016, vol. 664, pp. 317-320.
6. [6] K.V. Mahendra and K. Radhakrishna, “Characterization of stir cast Al—Cu—(fly ash + SiC) hybrid metal matrix composites,” *Journal of Composite Materials*, 2010, vol. 44 (8), pp. 989-1005.
7. Bijay Kumar Show, Dipak Kumar Mondal, Koushik Biswas and Joydeep Maity, “Development of a novel 6351 Al–(Al4SiC4+SiC) hybrid composite with enhanced mechanical properties,” *Materials Science and Engineering: A*, 2013, vol. 579, pp. 136-149.
8. Ali Mazahery and Mohsen Ostad Shabani, “Mechanical properties of squeeze-cast A356 composites reinforced with B_4C particulates,” *Journal of Materials Engineering and Performance*, 2012, vol. 21 (2), pp. 247-252.
9. A. Arun Premnath, T. Alwarsamy, T. Rajmohan and R. Prabhu, “The influence of alumina on mechanical and tribological characteristics of graphite particle reinforced hybrid Al-MMC,” *Journal of Mechanical Science and Technology*, 2014, vol. 28 (11), pp. 4737-4744.
10. Aykut Canakci, Fazli Arslan and Temel Varol, “Physical and mechanical properties of stir-casting processed AA2024/B_4Cp composites”, *Science and Engineering of Composite Materials*, 21 (4) (2014), 505-515.
11. Saba Khoramkhorshid, Morteza Alizadeh, Amir Hossein Taghvaei, Sergio Scudino, “Microstructure and mechanical properties of Al-based metal matrix composites reinforced with $Al_{84}Gd_6Ni_7Co_3$ glassy particles produced by accumulative roll bonding, *Materials & Design*, 90 (2016), 137-144.
12. Sajjadi S.A, Ezatpour H.R, Beygi H, Microstructure and mechanical properties of Al–Al_2O_3 micro and nano composites fabricated by stir casting, *Materials Science and Engineering: A*, 528 (29–30) (2011), 8765-8771.

AUTHORS PROFILE

S. Suresh Kumar completed his Ph.D. degree in Mechanical Engineering from Kalasalingam Academy of Research and Education (KARE), India in 2016. He also completed Post-doc from Karadeniz Technical University, Turkey in 2018. Currently, he is doing his research in the area of non-traditional machining on metal matrix composites.

M. Uthayakumar completed his Doctoral work in the area of Precision Machining. He is actively working in the development of high strength light weight composites. His other areas of interest include processing of metal matrix, polymer matrix, ceramic matrix composite and its performance studies.

.

S. Thirumalai Kumaran completed his Ph.D. degree in Mechanical Engineering from Kalasalingam Academy of Research and Education (KARE), India, in 2015. After completing Ph.D., he worked as an Assistant Professor at School of Mechanical Engineering, Yeungnam University, South Korea for a period of one year. He is currently an Associate Professor at School of Automotive and Mechanical Engineering, KARE.

K. Vinothbabu completed his Ph.D. degree in Mechanical Engineering from Kalasalingam Academy of Research and Education (KARE), India, in 2016.

Retrieval Number: B10331292S219/2019©BEIESP
DOI: 10.35940/ijitee.B1033.1292S219

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication