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Research paper

Synthesis and Mechanical Characterization of Micro B_4C Particulates Reinforced AA2124 alloy Composites

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Abstract

In the current era of aerospace, automobile and other various industries, light weighed aluminium metal matrix composites plays a very major role. Metal matrix composites are composed of base material as metallic which is reinforced with ceramic particulate as reinforcement material. This paper consists of the preparation of micro composites by two step stir casting process by the addition of B_4C particulates (80-90μm) into the AA2124 matrix by varying different weight percentages of 3% and 6% at a temperature of 730-750°C. Further once the composites are prepared are subjected to characterization, the SEM revealed that there is good uniform distribution of micro particles in the aluminum by exhibiting a good bonding with matrix and EDS confirmed the presence of B and C elements. Different properties were evaluated like density, hardness, ultimate tensile strength and yield strength which revealed that there is an increase in the mechanical properties than compared to the base metal.

Keywords:*AA2124 Alloy; B_4C; Stir Casting; Microstructure; Hardness; Tensile Properties*

1. Introduction

Aluminum alloys as a matrix phase are widely used in aerospace, automobile and marine industries due to their various properties like low density, good mechanical properties, better corrosion resistance, and low thermal coefficient of expansion as compared to other conventional metals and alloys and also the cost of production is relatively low [1-2]. Because of these characters they form a very strong and good contender in many of the applications [4].However, the mechanical properties such as strength, elastic modulus and wear resistance are not enough for industrial applications; therefore, these are reinforced by various ceramic reinforcements such as Al_2O_3, SiC, graphite etc. But micro B_4C ceramic particles as reinforcement made a remarkable trend and have recently been used for the better improvement of the mechanical and wear properties in Aluminum matrix composites by offering extremely high hardness, better strength, chemical stability and increase in thermal stability [5, 7]. In addition, a limited work has been done on aluminum matrix composites by reinforcing with micro B_4C because of its high cost of raw material and poor wetting. B_4C is the third hardest material and it possesses an excellent hardness, low specific gravity, and high melting point therefore, which is a best suitable reinforcement material for metal matrix composites having density less than aluminum [8]. The Al–B_4C composites are used in different applications like bicycle frame, armor tanks, containment of nuclear waste, bullet proof vests, neutron absorber in nuclear power plant, Because the absorption of thermal neutrons produces heat and therefore the temperature of the material increases such that the Al–B_4C composites may experience long-term exposure for estimated temperatures [9].

Many different fabrication techniques are generally available for the fabrication of metal matrix composites, such as powder metallurgy, mechanical alloying, high-energy ball milling, nano-sintering, spray deposition, and variety of casting techniques [10]. Nevertheless mechanical stir casting process by the formation of vortex method is one of the best technique because, it is relatively inexpensive and it can be used to disperse micro sized B_4C particles in molten aluminium without forming agglomeration and clustering by the addition of ceramic particles in steps of two stages into the molten matrix and obtaining a good wetting by the proper selection of parameters like stirring speed, time, temperature of molten metal, preheating temperature of the mould and ceramic particle along with uniform feed rate of the reinforcement [11]. Even though stir casting allows producing components in bulk at a low cost of production with different complex geometries, but there are some disadvantages with it such as porosity, blowholes and proper distribution of the ceramic reinforcing particles between the metal matrixes. Due to this the mechanical properties often leads to degradation. However this problem occurs when the volume fraction of the reinforcement is high in the ratio of composites [12].

The present research work is done by the preparation of micro metal matrix composites by the addition of B_4C in AA2124 melt at a temperature of 730-750˚C by two step stir casting process. During the composite preparation the pre-heated mix containing of micro B_4C particles and K_2TiF_6 flux was added by two stages into the melt to enhance wetting and incorporation of B4C particles into molten melt of AA2124. Further the prepared composites were subjected to evaluation of mechanical properties for the better enhancement compared to base metal.

2. Experimental Details

2.1 Matrix and Reinforcements

Table 1 Chemical composition of AA2124 Alloy

Element	Element
Magnesium	1.80
Silicon	0.20
Iron	0.30
Copper	4.90
Zinc	0.25
Manganese	0.90
Titanium	0.15
Cromium	0.10
Aluminium	Bal

AA2124 is a 2000 series aluminum alloy which as major content of copper along with magnesium and it is formulated as wrought product and used a primary matrix material. Among aluminium alloys, AA2124 is chosen because it as a low density of 2.8 g/cm^3 and used in various applications like jet engines, structural and tubing due to its excellent machiniabality characteristics. Because of high content of copper and magnesium the materials becomes age hardenable with good strength, corrosion resistance and has good weldability. Table 1 illustrates the chemical composition of AA2124 alloy.

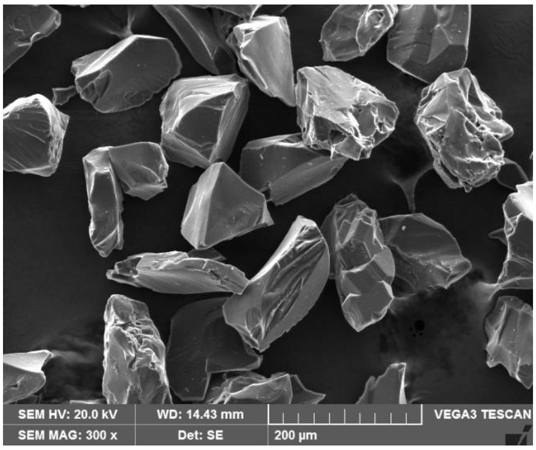


Fig.1: Showing the scanning electron microphotographs of B_4C particles

For the present work micro B_4C is used as secondary reinforcement particle which was procured from Speedfam Pvt. Ltd., Chennai having a particle size of 80 - 90 µm. The different physical characteristics like hard strength, catalyst support and as neutron absorber makes B_4C as a researchers and engineers choice for various applications by increasing mechanical and tribological properties. Aluminum is reinforced with B_4C because it a low density (2.52 g/cm^3) which is less than the matrix material which contributes to weight saving and as high melting point up to 2350°C along with excellent chemical and thermal stability. Hence, B_4C reinforced aluminum matrix composite has expanded more attraction towards stir casting method with low cost.

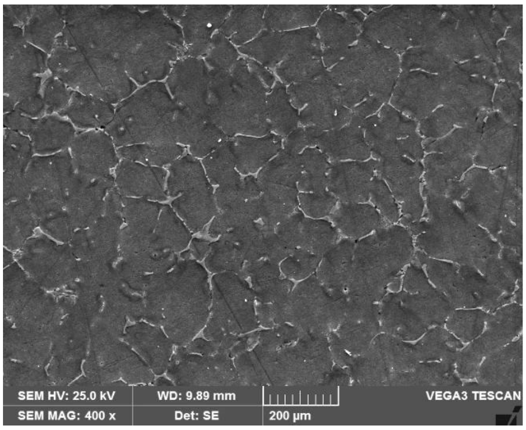
2.2 Preparation of AA2124-B_4C Composites

For the preparation of Metal Matrix Nano Composites stir casting technique is chosen because of less expensive and suitable for bulk production of components. The micro composites containing 3 and 6 wt. % of B_4C particulates were prepared from two step stir casting process technique. Initially the required amount of B_4C and the cast iron die were preheated to a temperature of 400°C. On the other part, the calculated amount of AA2124 was weighed and placed in a graphite crucible inside an electric furnace and heated to temperature of 750°C, so that the entire raw materials coverts into molten phase at above melting temperature. After the complete melting of AA2124, the degassing powder known as Solid Hexa Chloro Ethane (C_2Cl_6) [13] is introduced into the molten melt so that the unwanted adsorbed gases are forced out from the melt. The molten melt is disturbed by dipping a zirconium coated mechanical stirrer to form a clear vortex by stirring mechanism at a speed of 300rpm. Once the vortex is formed then the preheated ceramic particles along with the proper proportion ratio of K_2TiF_6 is introduced into the molten melt in steps of two stages by a constant feed rate, which involves in dividing the entire weight mixture of B_4C and K_2TiF_6 in two equal weights. At every each stage the continues stirring process was carried out before and after the pouring of mixture of B_4C and K_2TiF_6 to avoid clustering of particulates and to have uniform homogenous distribution of micro particulates in the melt. After continues stirring, the entire molten metal was poured into preheated cast iron die. The prepared composites were machined as per the standards for characterization purpose.

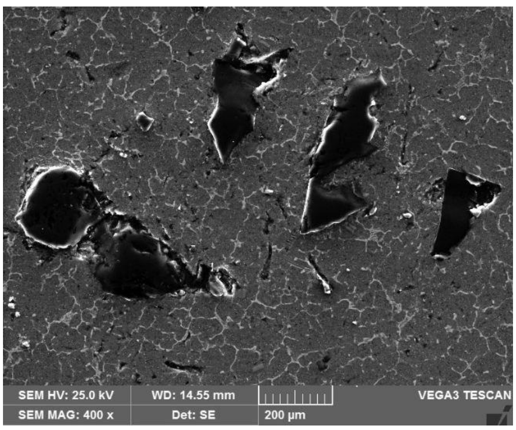
After confirming the uniform homogenous distribution of micro particles in the matrix by SEM and the presence of B and C elements by EDS, the mechanical behavior of as cast Al2124 alloy and its composites were further evaluated as per ASTM standards.

3. Results and Discussions

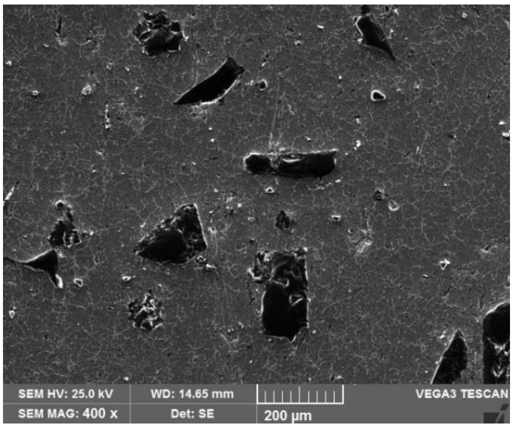
3.1 Characterization by SEM and EDS



(a)



(b)

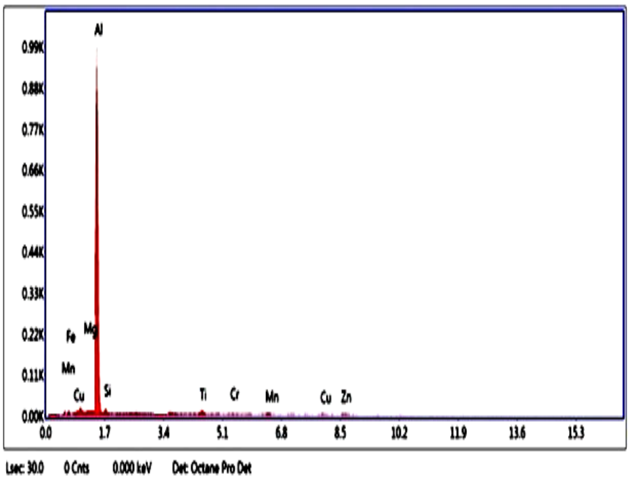


(c)

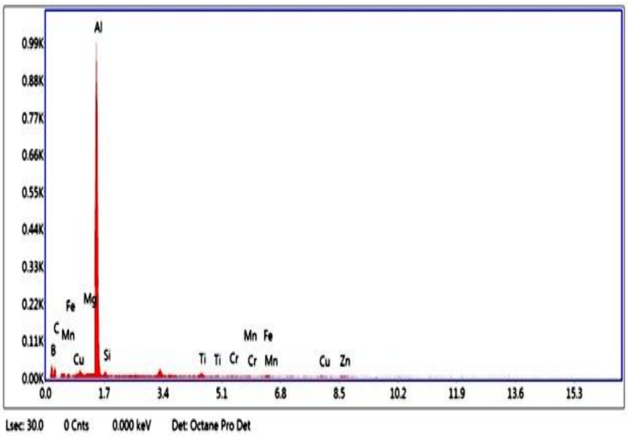
Fig. 2: Showing SEM microphotographs of (a) as cast AA2124 alloy (b) AA2124-3wt. % B_4C (c) AA2124-6 wt. % B_4Ccomposites

The Scanning Electron Microscope is used to examine the reinforcement pattern and the proper distribution of micro particles from the prepared composite. A piece of cut section was taken from the casted specimen and grinded using 220 grit SiC paper followed by 400, 600, 800 and 1000 grades of emery paper. Then the samples were mechanically polished and etched by Keller's reagent (HCL+ HNO_3+HF+Water) to obtain the better contrast of the microstructure.

Figure 2a shows the scanning electron photographs of as cast AA2124 alloy. Similarly figure 3b showing 3 wt. % of B_4C reinforced composites and figure 3c showing scanning electron photographs of 6 wt. % of micro B_4C particulates reinforced composites. From the scanning electron photographs, it is revealed that there is uniform homogenous distribution of secondary phase of particulates in the AA2214 alloy matrix without any agglomeration. It is also observed that there is an excellent interfacial bonding between the B_4C and AA2214 alloy matrix, which further enhances the properties of AA2124 alloy. In the case of AA2214-6 wt. % of B_4C composites, there are more particulates in the AA2124 matrix, which shows good castability and wettability of AA2214 alloy with ceramic reinforcements.



(a)



(b)

Fig. 3: Showing energy dispersive spectrum (a) as cast AA2124 alloy (b) AA2124-6 wt. % B_4C composites

Figure 3a and 3b are the EDS spectrographs of as cast AA2124 alloy and AA2124-6 wt. % B_4C micro composites. From the spectrum 3a it is evident that as cast AA2124 alloy contains major alloying elements like Cu, Mg, Mn and Fe in Al alloy. Further, spectrum 3b contains B and C along with the all other alloying elements in AA2124, which reveals the presence of micro B_4C particulates in the matrix.

3.2 Density Measurements

Table 1: Theoretical and experimental densities of AA2124-B_4C composites

Sl. No.	Material	Theoretical Density (g/cm^3)	Experimental Density(g/cm^3)
1	AA2124 Alloy	2.800	2.740
2	AA2124-3 wt.% B_4C	2.790	2.720
3	AA2124-6 wt.% B_4C	2.781	2.710

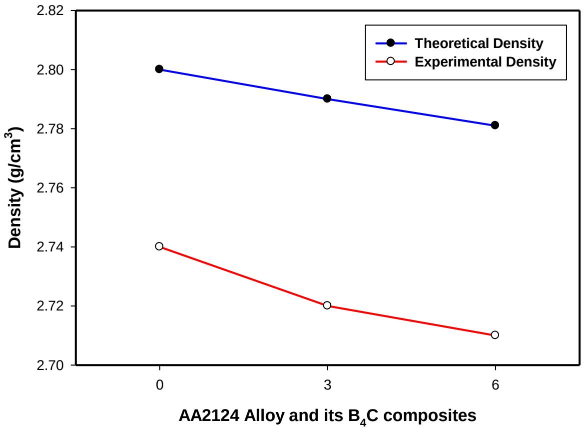


Fig. 4: Theoretical and experimental densities of AA2124 alloy and its B_4C composites

Figure 4 is the theoretical and experimental densities of AA2124 alloy and B_4C particulates reinforced metal matrix composites and Table 1. Theoretical density of AA2124 alloy is 2.8 g/cm3, further theoretical densities of 3 and 6 wt. % B_4C composites are estimated by using rule of mixture. From the plot these densities are decreasing after addition of ceramic particulates in the matrix. This is due to lesser density of B_4C particulates. Experimental densities are calculated by weight method. Both the theoretical and experimental densities are in line with each other, which show the sound fabrication technique to prepare the composites.

3.3 Hardness Measurements

Table 2: Hardness of AA2124-B_4C composites

Sl. No.	Material	Hardness (BHN)
1	AA2124 Alloy	65.7
2	AA2124-3 wt.% B_4C	73.9
3	AA2124-6 wt.% B_4C	85.6

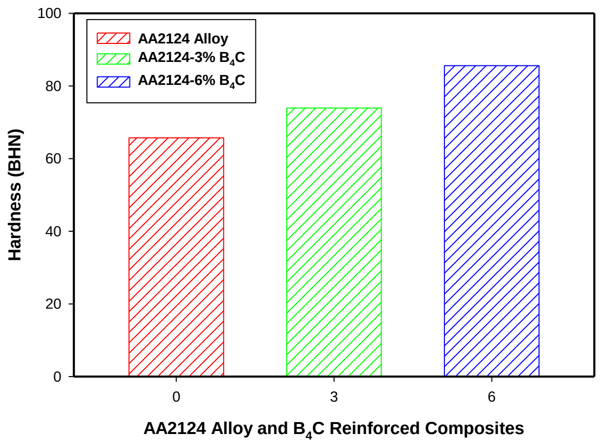


Fig.5: Hardness of AA2124 alloy and its B_4C composites

Figure 5 is the plot showing the hardness of AA2124 alloy, AA2124-3 wt. % B_4C and AA2124-6 wt. % B_4C composites (Table 2). Brinell hardness test was conducted using a Brinell hardness tester under a load of 250 kgf and ball indenter of diameter 5mm. Table 2 show the hardness of AA2124 alloy and its composites obtained by taking average value of three readings. The hardness of as cast AA2124 alloy is 65.7 BHN and for 6 wt. % B_4C composite is 85.6 BHN. From the plot and the table as the B_4C percentage increases from 3 to 6 wt. %, hardness increased, since B_4C is inherently harder than Al matrix and fairly well distribution of reinforcements improves the ability of the soft matrix to resist deformation [14].

3.4 Tensile Properties

Table 3: Tensile properties of AA2124-B_4C composites

Sl. No.	Material	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
1	AA2124 Alloy	187.08	150.33	12.70
2	AA2124-3 wt.% B_4C	204.01	160.61	11.40
3	AA2124-6 wt.% B_4C	226.97	179.80	10.30

Table 3 and figure 6 illustrates the variation of tensile strength of AA2124 alloy, 3 and 6 wt. % of B_4C composites. It is clear that when the amount of reinforcement increases, the ultimate and yield strength of AA2124 alloy composites increases. The ultimate tensile strength of AA2124 alloy improved from 187.08 MPa to 226.97 for 6 wt. % B_4C composites. Similarly, yield strength of composites increased from 150 to 179 MPa. This increase in strength might be ascribed to the fact that during plastic deformation, the restraining effect of B_4C particles on the surrounding matrix highly depends on the properties of interface. It has also been shown that particle matrix interface acts as a sink for dislocations during tensile test. Therefore, dislocation pileup behind the particles in the composite materials becomes less pronounced and hardening rate increases [15]. It is expected that due to the thermal mismatch stress between ceramic and aluminium matrix, there is a possibility of increased dislocation density within the matrix which might lead to generating local stress and also could improve the strength of the matrix and thus that of the composite.

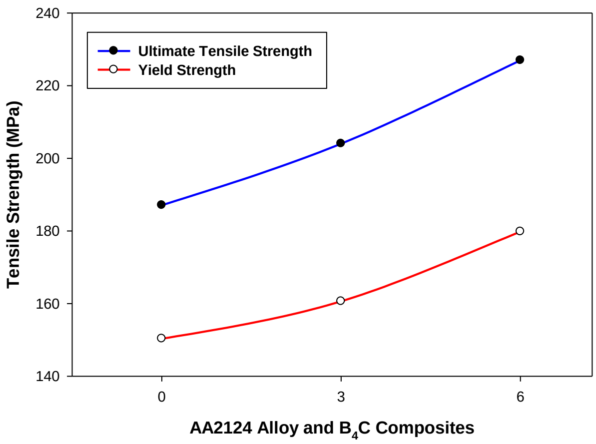


Fig. 6: Ultimate tensile strength and yield strength of AA2124 alloy and its B_4C composites

Figure 7 demonstrates the variation of elongation of AA2124 alloy and its B_4C composites. As seen, the elongation value remarkably decreased from 12.7 % to 10.3 %. When the hard B_4C phase in the matrix increases, the dislocations movement is hindered as a result. This is considered to be one of the most important factors in decreasing the elongation.

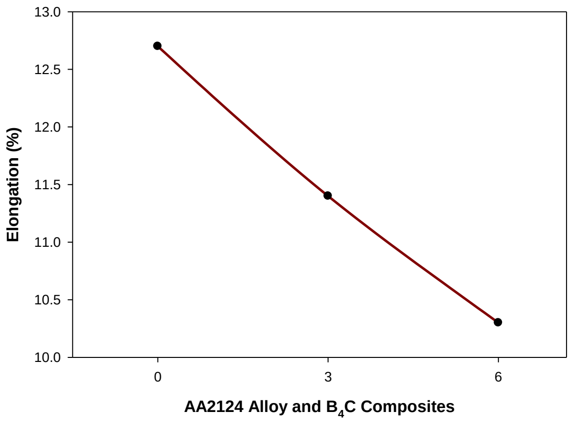


Fig.7: Percentage elongation of AA2124 alloy and its B_4C composites

4. Conclusion

AA2124-B_4C composites are fabricated by reinforcing 3 and 6 wt. % boron carbide in Al matrix using stir casting method and their microstructure and mechanical behaviors are investigated. The composites produced by using two steps stir casting method using K_2TiF_6 flux demonstrated strong bonding and homogeneous distribution of boron carbide particulates. Scanning electron microscope photographs and energy dispersive spectrum revealed the uniform distribution and presence of B_4C particles in the AA2124 alloy matrix. Densities of composites decreased with the addition of low density boron carbide particulates. Both the theoretical and the experimental densities are in line, which indicates the sound casting process. Mechanical behaviors like hardness, ultimate and yield strength were enhanced with the addition of reinforcement particles with decrement in elongation.

References

[1] Xiao-Hui Chen and Hong Yan (2016), Solid-liquid interface dynamics during solidification of Al 7075-Al_2O_3 based metal matrix composites. *Materials and Design*, 94, 148-158.

[2] Hassan Zare, Mohammad Zahedi, Mohammad Reza Toroghinejad, Mahmoud Meratian and Marko Knezevic (2016), Compressive, shear, and fracture behavior of CNT reinforced Al matrix composites manufactured by severe plastic deformation. *Materials and Design*, 106, 112-119.

[3] Biao Chen, Shufeng Li, Hisashi Imai, Lei Jia, Junko Umeda, Makoto Takahashi, and Katsuyoshi Kondoh (2015), Load transfer strengthening in carbon nanotubes reinforced metal matrix composites via in situ tensile tests. *Composites Science and Technology*, 113, 1-8.

[4] Jaswinder Singh and Amit Chauhan (2016), Overview of wear performance of aluminium matrix composites reinforced with ceramic materials under the influence of controllable variable. *Ceramics International*, 42,56-81.

[5] Meijuan Li, Kaka Ma, Lin Jiang, Hanry Yang, Enrique J Lavernia, Lianmeng Zhang and Julie M Schoenung (2016), "Synthesis and mechanical behavior of nanostructured Al 5083-TiB_2 metal matrix composites. *Materials Science and Engineering A*, 656, 241-248.

[6] Barbera D, Chen HF and Liu YH (2015), "On the creep fatigue behavior of metal matrix composites," Procedia Engineering, 130, 1121-1136.

[7] Ghanaraja S, Subrata Ray and Nath SK (2015), Synthesis and mechanical properties of cast alumina nano particle reinforced metal matrix composites. *Materials Today Proceedings*, 2, 3656-3665.

[8] Dinesh Patidar and Rans RS (2017), Effect of B_4C particle reinforcement on the various properties of aluminium matrix composites: a survey paper. *Materials Today Proceedings*, 4, 2981-2988.

[9] Yu-Li Li, Wen-Xian Wang, Jun Jhou and Hing-Sheng Chen (2017), Hot deformation behaviors and processing maps of B_4C-Al6061 neutron absorber composites. *Materials Characterization*, 124, 107-116.

[10] Madeva Nagaral, Shivananda BK, Auradi V, Parashivamurthy KI and Kori SA(2017), Mechanical *behavior of Al6061-Al_2O_3 and Al6061-Graphite composites," Materials* Today Proceedings, 4, 10,10978-10986.

[11] Adaveesh B, Halesh GM, Madeva Nagaral and Mohankumar TS (2016), Microstructure and tensile behavior of B_4C reinforced ZA43 alloy composites. *IOP Conf. Series: Materials Science and Engineering*, 149, 012115.

[12] Jayasheel I Harti, Prasad TB, Madeva Nagaral, Pankaj Jadhav and Auradi V (2017), Microstructure and dry sliding wear behavior of Al2219-TiC composites. *Materials Today Proceedings*, 4, 10, 11004-11009.

[13] Pankaj R Jadhav, Sridhar BR, Madeva Nagaral and Jayasheel Harti (2017), Evaluation of mechanical properties of B_4C and graphite particulates reinforced A356 alloy hybrid composites. *Materials Today Proceedings*, 4, 9, 9972-9976.

[14] Madeva Nagaral, Auradi V, Kori SA, Reddappa HN, Jayachandran and Veena Shivaprasad (2017), Studies on 3 and 9 wt.% B4C particulates reinforced Al7025 alloy composites. *American Institute of Physics Proceedings*, Vol. 1859, 020019.

[15] Madeva Nagaral, Pavan R, Shilpa PS and Auradi V (2017), Tensile behavior of B4C particulate reinforced Al2024 alloy metal matrix composites. *FME Transactions*, 45, 93-96.