**IOSR Journal of Engineering (IOSRJEN)** **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 08, Issue 2 (February. 2018), ||V1|| PP 20-27

# Influence of 40 Micron Size $B_4C$ Particulates Addition on Mechanical Behavior of LM29 Alloy Composites

G Pathalinga Prasad[1], H C Chittappa[2], Madeva Nagaral[3], V Auradi[4]
*[1]Research Scholar, Department Of Mechanical Engineering, UVCE, Bangalore-560001 And Assistant Professor, Department Of Mechanical Engineering, AMC College Of Engineering, Bangalore-560083*
*[2]Associate Professor, Department Of Mechanical Engineering, UVCE, Bangalore-560001*
*[3]Design Engineer, Aircraft Research and Design Centre, Hindustan Aeronautics Limited, Bangalore-560037*
*[4]Associate Professor, Department Of Mechanical Engineering, SIT, Tumkur-587102*
*Corresponding Author: G Pathalinga Prasad[1]*

**Abstract:** In the present investigation synthesis, microstructure study and mechanical behavior of micro $B_4C$ particulate reinforced LM29 alloy composites have been reported. LM29 alloy matrix composites containing micro $B_4C$ particulates were fabricated by conventional stir casting method. The microstructures of the composites were examined by scanning electron microscopy and energy dispersive spectrographs. Further, mechanical behavior of as cast LM29 alloy, LM29 – 3, 6 and 9 wt. % micro $B_4C$ composites were studied. Mechanical properties like hardness, ultimate tensile strength; yield strength, percentage elongation and compression strength were evaluated as per ASTM standards. Microstructural observations revealed the uniform distribution of particles in the LM29 alloy matrix. From the analysis, it was found that the hardness, ultimate tensile strength, yield strength and compression strength of composites were increased due to addition of micro $B_4C$ particle in the LM29 alloy matrix. Percentage elongation of the composites decreased due to $B_4C$ reinforced composites.

**Keywords: -** LM29 Alloy, $B_4C$, Microstructure, Stir Casting, Mechanical Behavior

---

Date of Submission: 09-02-2018 Date of acceptance: 24-02-2018

---

## I. INTRODUCTION

Aluminum matrix composites reinforced with micro-particles are widely used in automotive, military and aerospace industries because of their improved mechanical properties, such as high-temperature creep resistance, greater durability under fatigue life and good wear resistance. In the recent years, much of composites research has been focused on the dispersion and distribution of ceramic-particles in a matrix, which significantly affects microstructure and properties of the composites [1, 2]. It is of interest to note that the particles with different sizes are distributed at different regions of the matrix. The aggregates are located along grain boundaries and the large aggregates are distributed in the grain and last freezing inter dendrite region, which suggests that the distribution of particles is related to the solidification behavior. When alloy melts containing suspended particles solidify, interactions between the solidification front and the remaining suspended particles take place, resulting in changed particle distribution.

The particles are either engulfed by the solidification front, and thus distributed within the grain, or pushed by the solid–liquid interface toward the grain boundaries and eutectic regions. Therefore, in order to design the microstructure of composites, interaction of nano-particles with an advancing solid–liquid interface needs to be studied in composites.

For a given particle size, some research [3, 4] calculated a critical velocity of the solidification front to push the particles by the solid–liquid interface, which is the solidification velocity above which particles are engulfed by the interface and below which they are pushed. It is clear that particle expulsion or engulfment is a complicated phenomenon.

During the past four decades, the emergence of a wealth of literature concerned with the processing, microstructure, and properties of discontinuously reinforced metal matrix composites (MMCs). Reinforcements such as silicon carbides (SiC), alumina ($Al_2O_3$), and graphite are regularly used in combination with a matrix needing an enhanced property or a set of properties. A less commonly used reinforcement is a boron carbide ($B_4C$) [6]. Improvements of matrix materials by $B_4C$ in terms of strength [5-7] as well as functional properties [8] have been demonstrated. These materials have yet to be commercialized.

Traditionally, particle-reinforced metal matrix composites have been fabricated by several processing routes such as powder metallurgy, deformation processing and various solidification processing techniques including spray deposition [9]. The cheapest technique for the synthesis of composites is by stir-casting where reinforcing particles or powders are stirred into molten alloy and the resulting slurry is cast to obtain ingots of composite [10]. Metal matrix composites containing particle reinforcements of size of tens of microns generally show poor ductility, often lower than 5% as strain incompatibility results in larger shear stresses across the interface leading to debonding at the interface at relatively lower strain. Decreasing particle size of reinforcement results in difficulty in particle transfer during stir-casting. But if the reinforcement particles are generated by reaction of externally added particles with the melt then there is no difficulty in particle transfer due to wetting.

Hence, in the present research ceramic $B_4C$ particles with 40 micron size is used to fabricate the composites. LM29 alloy- $B_4C$ composites were processed by stir casting in steps of 3, 6 and 9 wt. %. Further, investigations made on mechanical behavior of LM29 alloy and its $B_4C$ reinforced composites.

## II. EXPERIMENTAL DETAILS

**Materials Involved**

Aluminium has been the choice of material for most of the researchers as it finds suitable in most of the applications due to its light weight and good corrosion resistance. The moderate strength of the aluminium can be enhanced by incorporating hard particles and that has made aluminium composites to attain higher stiffness modulus at lower densities. From the detailed literature survey, it was understood that LM29 has not been much focused by the researchers and there is ample scope to use this material as matrix material due to its inherent good properties. Therefore, in the present investigation LM29 casting alloy is been selected as the matrix material. The chemical composition of LM29 alloy is shown in table 1.

**Table 1:** Chemical Composition of LM29 Alloy

| Elements | Si | Cu | Mg | Ni | Al |
|---|---|---|---|---|---|
| Wt. % | 24.0 | 1.0 | 1.0 | 1.0 | Bal |

**Table 2:** Physical Properties of Boron Carbide

| Physical Property | Specification |
|---|---|
| Crystallography | Rhombo-Hedral |
| Color | Black |
| Specific Gravity | 2.52 |
| Knoop100 Hardness | 2800 |
| Shape | Blocky – Angular |
| Melting Point | 2350º C |

Boron carbide is one of the hardest man-made materials available in commercial quantities. Boron carbide ceramics have excellent physical and mechanical properties, such as a high melting point, hardness, good abrasion resistance, high impact resistance and excellent resistance towards corrosion. As an outstanding in borne mechanical property, the boron carbide as a ceramic material have attracted attention over wide variety of applications that comprises light-weight armour plating, blasting nozzles, mechanical seal faces, grinding tools, cutting tools and neutron absorption materials. The physical and mechanical properties of boron carbide are shown in tables 2 and 3 respectively.

**Table 3:** Mechanical Properties of Boron Carbide

| | |
|---|---|
| Density (gm /$Cm^3$) | 2.52 |
| Melting Point (°C) | 2445 |
| Young's Modulus (GPa) | 450 – 470 |
| Thermal Conductivity (At 25°C - W/M-K) | 30 – 42 |
| Hardness (Knoop 100g) (Kg/$Mm^2$) | 2900 – 3580 |

**Composites Fabrication**

The Manufacture of LM29 -$B_4C$ composites were prepared by liquid stir casting method. Boron carbide particles (40 microns) were preheated to 600ºC for 45 minutes to ensure their surfaces are completely oxidized. LM29 al alloy ingots are cut in to small pieces of about 0.5kg each and calculated quantity of it is taken in a graphite crucible and placed in the electric melting furnace. The furnace is heated to the required temperature where melting of the ingots starts to happen and the solid ingots completely melt and liquidifies with period of time.

**Figure 1:** Prepared LM29-$B_4C$ composites

The preheated 3 wt. % boron carbide particulates were added and mixed with stirrer at rated speed. The heating is continued for longer periods to maintain the slurry in the molten state. The uniform distribution of the particles in the slurry is ensured by mechanical mixing through a stirrer at an average mixing speed of 300 rpm for about 15 minutes. Complete melting of the alloy takes place at a temperature of around 750ºC.

The melt embedded with $b_4c$ reinforcement is shifted using graphite crucible in to the specially prepared die that possess pockets of diameter15mm and length 120mm. The composites in the molten state were allowed to solidify to obtain the desired pencil die castings. The entire process is repeated for different weight percentages of $B_4C$ such as 6 and 9 wt. %. Figure1 show the prepared composites castings.

## III. RESULTS AND DISCUSSION

**Microstructural Analysis**

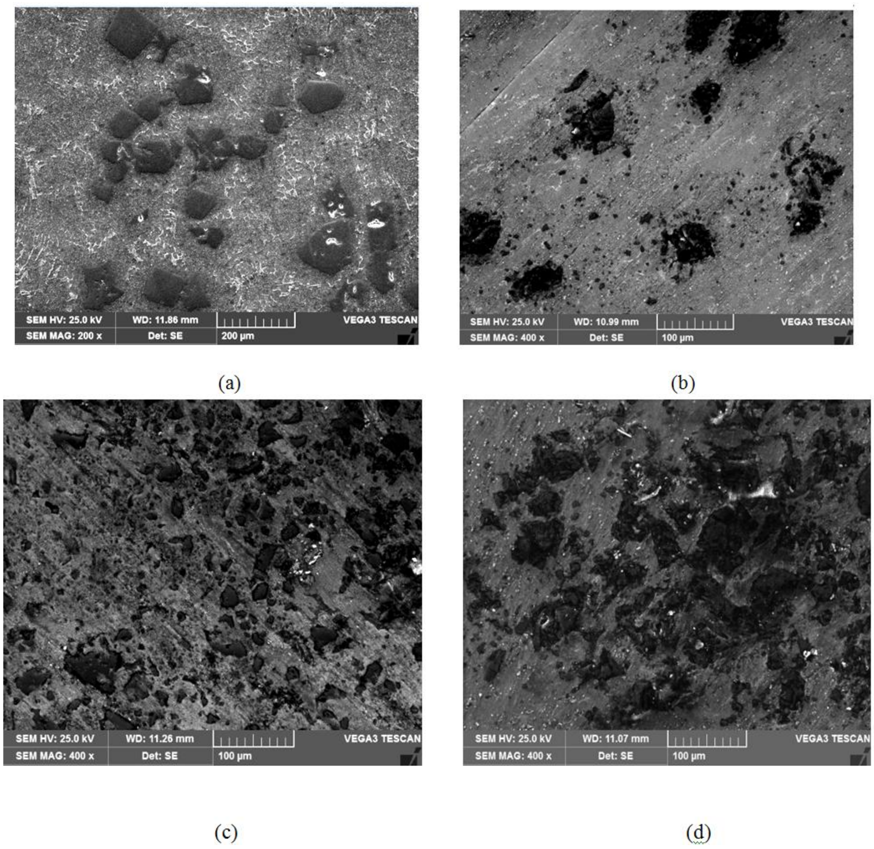
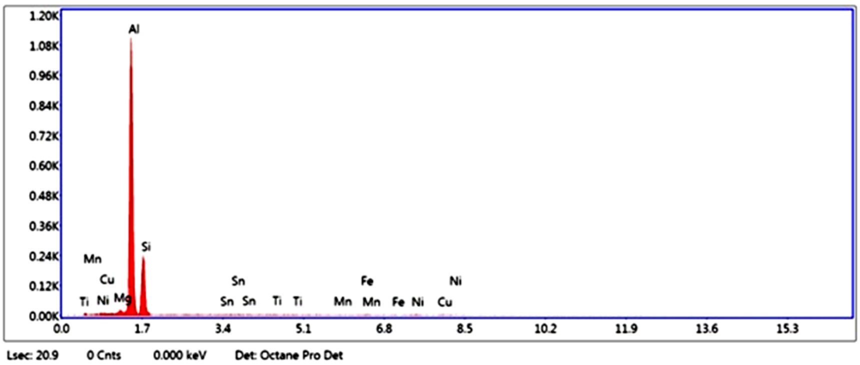


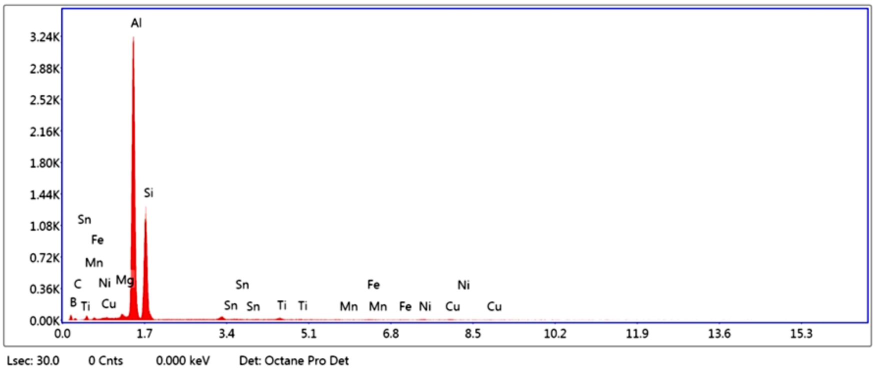

**Figure 2:** Scanning Electron Microphotographs of (a) As cast LM29 Alloy (b) LM29-3% $B_4C$ (c) LM29-6% $B_4C$ (d) LM29-9% $B_4C$ with 40 micron $B_4C$ particles

Figure 2 (a-d) shows the SEM microphotographs of LM29 alloy as cast and LM29 with 3, 6 and 9 wt. % of $B_4C$ particulate composites. This reveals the uniform distribution of $B_4$ particles and very low agglomeration and segregation of particles, and porosity.

Fig. 1 b-c clearly show and even distribution of $B_4C$ particles in the LM29 alloy matrix. In other words, no clustering of $b_4c$ particle is evident. There is no evidence of casting defects such as porosity, shrinkages, slag inclusion and cracks which is indicative of sound castings. In this, wetting effect between particles and molten LM29 alloy matrix also retards the movement of the $b_4c$ particles, thus, the particles can remain suspended for a long time in the melt leading to uniform distribution.




(a)




(b)

**Figure 3:** Energy Dispersive Spectrum of (a) as cast LM29 Alloy (B) LM29-9% $B_4C$ with 40 micron $B_4C$ particles

In order to confirm the presence of $B_4C$ energy dispersive spectroscope analysis was carried out at the edge of the $B_4C$ particle and al alloy matrix. The EDS spectrum reveals the presence of AL and Si elements in the as cast LM29 alloy. In the LM29 alloy major element is silicon which is evident from the graph figure 3a. Further, figure 3b confirms the presence of $B_4C$ particles in the LM29 alloy along with LM29 alloy in the form of B and C elements.

**Hardness**

**Table 4:** Hardness of LM29-$B_4C$ composites

| Sl. No. | Material | Hardness (BHN) |
|---|---|---|
| 1 | LM29 Alloy | 61.9 |
| 2 | LM29-3 Wt.% $B_4C$ | 73.5 |
| 3 | LM29-6 Wt.% $B_4C$ | 86.2 |
| 4 | LM29-9 Wt.% $B_4C$ | 99.4 |

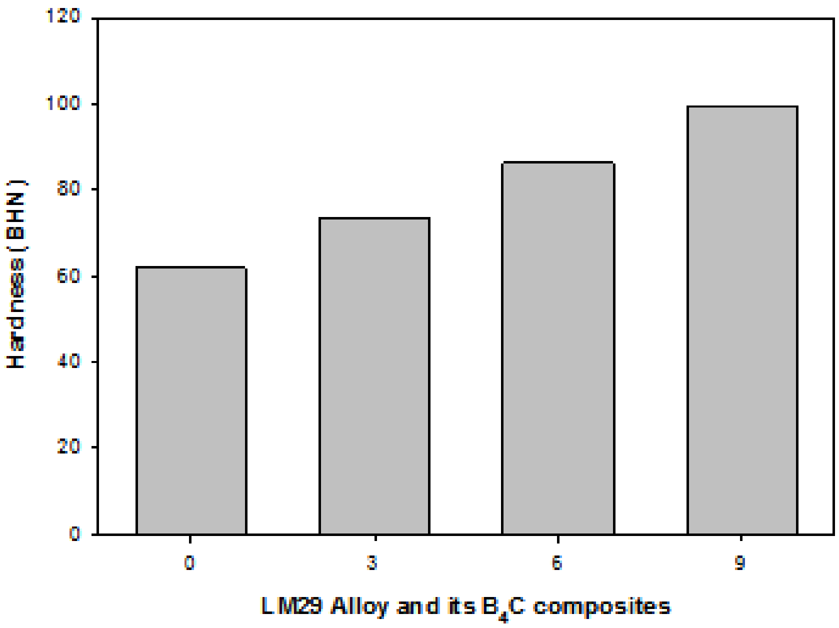



**Figure 4:** Hardness of LM29 alloy and its $B_4C$ composites

Brinell hardness test was conducted on the specimens of LM29 alloy, 3, 6 and 9% $B_4C$ composites, with ball diameter 5mm, load 250kg and the values obtained are in the range 61.9 to 99.4 BHN evident from the graph 4 and table 4. The values indicate that there is gradual increase in the hardness because of the hard boron carbide inclusion. As the percentage of particulates increased the hardness also increased parallel.

In the hardness test, severe plastic flow has been concentrated in the localized region directly below the indentation, outside of which material still behaves elastically. Directly below the indentation the density of the particles increased locally, compared to regions away from the depression [11]. Although plastic deformation itself has not been responsible for volume change, the existence of very large hydrostatic pressure under the indentation can contribute to volumetric contraction of the metal matrix. As the indenter moves downward during the test, the pressure has been accompanied by non uniform matrix flow along with localized increase in particle concentration, which tends to increase the resistance to deformation.

**Tensile Properties**

**Table 5:** Tensile property of LM29-$B_4C$ composites

| Sl. No. | Material | Ultimate Tensile Strength (MPa) | Yield Strength (MPa) | Elongation (%) |
|---|---|---|---|---|
| 1 | LM29 Alloy | 165.3 | 142.1 | 13.2 |
| 2 | LM29-3 Wt.% $B_4C$ | 192.2 | 170.3 | 11.4 |
| 3 | LM29-6 Wt.% $B_4C$ | 207.8 | 186.3 | 10.3 |
| 4 | LM29-9 Wt.% $B_4C$ | 234.6 | 202.9 | 8.5 |

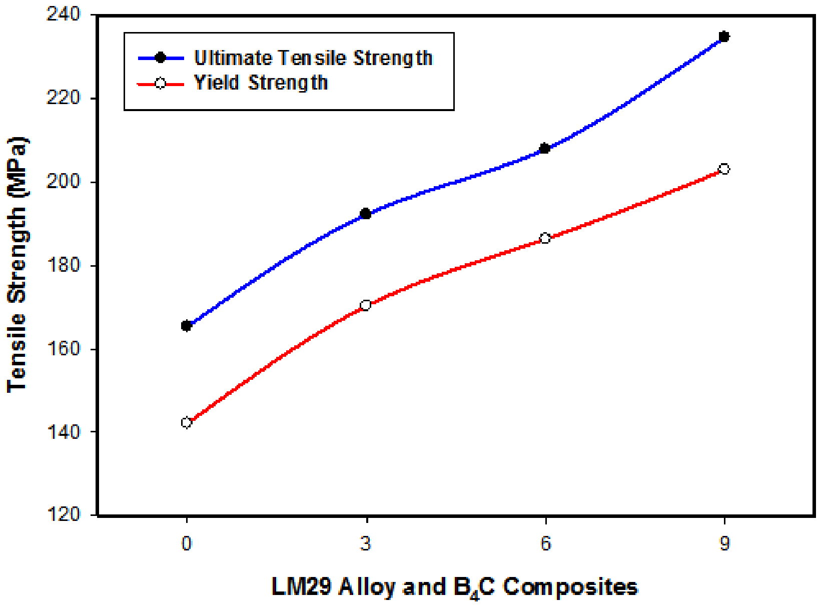



**Figure 5:** Tensile strength of LM29 alloy and its $B_4C$ composites

Figure 5 and table 5, shows there is gradual increase in the UTS with 3, 6 and 9 % wt. Addition of $B_4C$ due to the fact that the properties of $B_4C$ particulates control the mechanical properties of the composite showing the intense tensile strength. The variation in the UTS is may be because of matrix fortifying with increase in reinforcement size.

Figure 5 indicates yield strength improved from 142.1 MPa to 202.9 MPa with addition of $B_4C$ from 3% to 9% wt. The enhancement in the yield strength is due to the close packing of $B_4C$ particles providing molecule strength with the aluminum lattice in turn composite [12, 13].

Figure 6 illustrates the impact of $B_4C$ with reference to malleability of the composite. It can be observed that the graph is falling down with addition of 3, 6 and 9 wt.% of $B_4C$ particulates but the rate of diminishing is less, between 3 – 9 % wt addition. This is due to the strength acquired by the composite with addition of $B_4C$ owing to its properties.

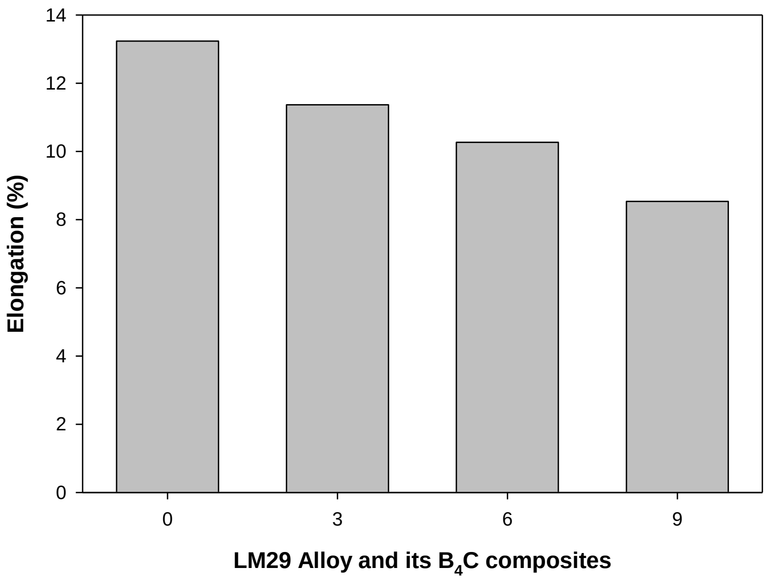



**Figure 6:** Percentage elongation of LM29 alloy and its $B_4C$ composites

**Compression Strength**

**Table 6** Compression strength of LM29-$B_4C$ composites

| Sl. No. | Material | Comp Strength (MPa) |
|---|---|---|
| 1 | LM29 Alloy | 567.4 |
| 2 | LM29-3 Wt.% $B_4C$ | 620.4 |
| 3 | LM29-6 Wt.% $B_4C$ | 704.4 |
| 4 | LM29-9 Wt.% $B_4C$ | 798.0 |

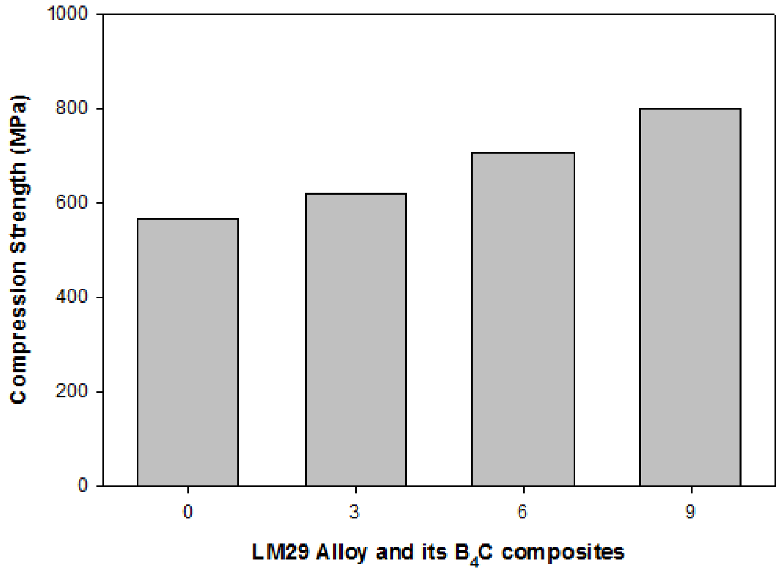



**Figure 7:** Compression strength of LM29 alloy and its $B_4C$ composites

Figure 7 indicates the compression strength of the test specimens with 3, 6 and 9 wt. % of $B_4C$ in LM29 alloy. It is clearly evident that the compression strength is varied from 567.4 to 798 MPa. This increase in compression strength is mainly due to high hardness and the compression strength of $B_4C$ particulates. This ceramic particulate acts as the barrier for the deformation when the compression load is applied [14, 15].

## IV. CONCLUSION

LM29 alloy- $B_4C$ composites are fabricated by reinforcing 3, 6 and 9 wt. % of 40 micron boron carbide in al matrix using stir casting method and their microstructure and mechanical behaviors are investigated. Scanning electron microscope photographs and energy dispersive spectrum revealed the uniform distribution and presence of $B_4C$ particles in the LM29 alloy matrix. Mechanical behaviors like hardness, ultimate, yield strength and compression strength were enhanced with the addition of reinforcement particles with decrement in elongation.

## REFERENCES

[1]. Xiao-Hui Chen, Hong Yan, Solid-Liquid Interface Dynamics During Solidification Of Al 7075-$Al_2O_3$ Based Metal Matrix Composites, *Materials And Design*, 94, 2016, Pp. 148-158.

[2]. J. Hashim, L. Looney, M. S. J. Hashim, The Wettability Of Sic Particles By Molten Aluminium Alloy, *Journal Material Processing Technology*, Vol. 119, 2001.

[3]. Jayasheel I Harti, T. B. Prasad, Madeva Nagaral, Pankaj Jadhav And V. Auradi, Microstructure And Dry Sliding Wear Behavior Of Al2219-Tic Composites, *Materials Today Proceedings*, 4, 10, 2017, Pp. 11004-11009.

[4]. H. H. Kim, J. S. S. Babu And C. G. Kang, Fabrication Of A356 Aluminium Alloy Matrix Composite With Cnts-$Al_2O_3$ Hybrid Reinforcements, *Materials Science And Engineering A*, 573, 2013, Pp. 92-99.

[5]. G. Rama Rao And Padmanabhan, Fabrication And Mechanical Properties Of Aluminium-Boron Carbide Composites, *International Journal Of Materials And Biomaterials Applications*, Vol. 2, No. 3, 2012, Pp. 15-18.

[6]. C. S. Ramesh, R. Keshavamurthy, B. H. Channabasappa, S. Promod, Friction And Wear Behaviour Of Ni-P Coated $Si_3N_4$ Reinforced 6061-Al Composites, *Tribiology Int.*, 43, 2010, 623-624.

[7]. Madeva Nagaral, V. Auradi, K. I. Parashivamurthy And S. A. Kori, Wear Behaviour Of $Al_2O_3$ And Graphite Particulates Reinforced Al6061 Alloy Hybrid Composites, *American Journal Of Materials Science*, 5 (3C), 2015, Pp. 25-29.

[8]. R.Vijay, C. Elanchezhian, M. Jaivignesh, S. Rajesh And C. Parswajinan, Evaluation Of Mechanical Properties Of Aluminium Alloy Alumina Boron Carbide Metal Matrix Composites, *Materials And Design*, Vol. 58, 2014, Pp. 332-338.

[9]. P. Dora Siva And S. Chintada, Hybrid Composites A Better Choice For High Wear Resistant Materials, *Journal Of Materials Research And Technology*, Vol. 3, No. 2, 2014, Pp. 172-178.

[10]. Jaswinder Singh And Amit Chauhan, Overview Of Wear Performance Of Aluminium Matrix Composites Reinforced With Ceramic Materials Under The Influence Of Controllable Variable, *Ceramics International*, 42, 2016, Pp. 56-81.

[11]. S. Ghanaraja, Subrata Ray And S. K. Nath, Synthesis And Mechanical Properties Of Cast Alumina Nano Particle Reinforced Metal Matrix Composites, *Materials Today Proceedings*, 2, 2015, Pp. 3656-3665.

[12]. Dinesh Patidar And R S Rans, Effect Of $B_4C$ Particle Reinforcement On The Various Properties Of Aluminium Matrix Composites: A Survey Paper, *Materials Today Proceedings*, 4, 2017, Pp. 2981-2988.

[13]. Madeva Nagaral, B. K. Shivananda, V. Auradi, K. I. Parashivamurthy And S. A. Kori, Mechanical Behavior Of Al6061-$Al_2O_3$ And Al6061-Graphite Composites, *Materials Today Proceedings*, 4, 10, 2017, Pp. 10978-10986.

[14]. M. Nagaral, S. Attar, H. N. Reddappa And V. Auradi, Suresh Kumar And Raghu, S.: Mechanical Behavior Of Al7025-$B_4C$ Particulate Reinforced Composites, *Journal Of Applied Mechanical Engineering*, 4:6, 2015.

[15]. Madeva Nagaral, R. Pavan, P. S. Shilpa And V. Auradi, Tensile Behavior Of B4C Particulate Reinforced Al2024 Alloy Metal Matrix Composites, FME Transactions, 45, 2017, 93-96.

G Pathalinga Prasad "Influence of 40 Micron Size $B_4C$ Particulates Addition On Mechanical Behavior Of Lm29 Alloy Composites. " IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 2, 2018, pp 20-27.