PROCESSING OF Al 6061/SiC/B_4C/MULLITE FUNCTIONALLY GRADED MATERIAL

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Abstract: The present investigation is on the processing of Al (6061) reinforced with SiC (23μ), B_4C (25μ), and mullite (25μ) by functional gradient method. Processing is carried out by synthesis of MMC using a pitt furnace followed by vertical centrifugal casting. A Result based on the analysis of images shows the volume of higher percentages of the ceramic particle is generated at the periphery of the outer casting and inner casting are compared. The high-volume fraction obtained at the periphery based on outer casting may lead to selective improvement in the hardness at the casting based on the outer periphery.

Keywords: Material based on Functionally Graded, Metal matrix composite, centrifugal casting.

1. Introduction

Advanced Material is required with multifunctional behavior and performance in various categories such as Defense, aerospace, bio-medical, electronics, and electricals. To meet these requirements a new concept emerged as “Functionally Graded Material (FGM)”. “Functionally Graded Materials(FGM)” are revolutionary substances that belong to a classification of superior substances that have exceptional houses when altering their dimensions in a specific direction. Functionally graded metal matrix composite having metal and ceramic ingredients is one of the most doable structures for fabricating factors with gradient properties [1].

Aluminum matrix composites have multiplied hardness due to the improved extent fraction of reinforcing particles in contrast to aluminum alloys and are desired for some distinct purposes [2][3]. Much research has been mentioned on his aluminum-based FGM the use of aluminum oxide, silicon carbide, boron carbide, and titanium carbide in terms of reinforcements. However, the fabrication of aluminum-based FGM with SiC, B4C, and mullite as reinforcements have now not been described in the literature.

A Fabricate FGM has been generated with various types of techniques including deposition techniques with Chemical Vapor, Spray techniques using Plasma, metallurgy techniques using powder, and casting techniques with centrifugal **[4].** The best and most economical method which acts as one of the most effective “Functionally Graded Material” is Centrifugal Casting [5]. Development of FGM involves two steps, one is a synthesis of MMC by a conventional foundry setup and another one with the formation of microstructure with gradients based on the centrifugal force applications. The casting which depends upon the density of the particle is Centrifugal Casting. In Centrifugal Casting, the particle with the lighter density moves closer to the axis rotating whereas the particle with denser moves away from the axis rotating. An FGM has three specific zones mainly focused on the rich zone, transition zone, and matrix zone[6].

on the particle density, the lighter particles move closer to the rotating axis and the denser particles move away from the rotating axis. FGM has three specific zones. Specifically, the particle-rich zone, the transition zone, and the matrix-rich zone [6]

2. Experimental setup and materials

Al 6061 alloy was chosen as the matrix phase and green SiC of average particle size

Composition	Al 6061 (%)	SiC (%)	B_4C (%)	Mullite (%)
1	100	0	0	0
2	82	5	10	3
3	79	10	5	6

23µ, B_4C of average particle size 25µ, and Mullite of average particle size 25µ with varying compositions are used as the reinforcement for the development of functionally graded metal matrix composite. The different compositions used for the development of FGM are given in the table1.

Table 1 Percentage of composition

SiC, B4C, and mullite have been preheated to 300°C in the furnace earlier than aluminum melting started. 10 kg of Al 6061 was once melted in a graphite crucible at 800 °C the use of a pit furnace. Meanwhile, degassing agent and pinnacle flux eleven had been brought to eliminate undesirable fuel and ash, respectively. After the aluminum melted, it used to be poured into some other graphite crucible whilst including a preheated combination of SiC, B4C, and mullite to the melt. Mix nicely by hand with a graphite rod earlier than pouring it into the mold. He then poured the MMC into a vertical centrifugal caster mildew preheated to 400°C and spun at 1200 rpm. A schematic graph of the vertical “Centrifugal Casting Machine” is shown in Figure 1.

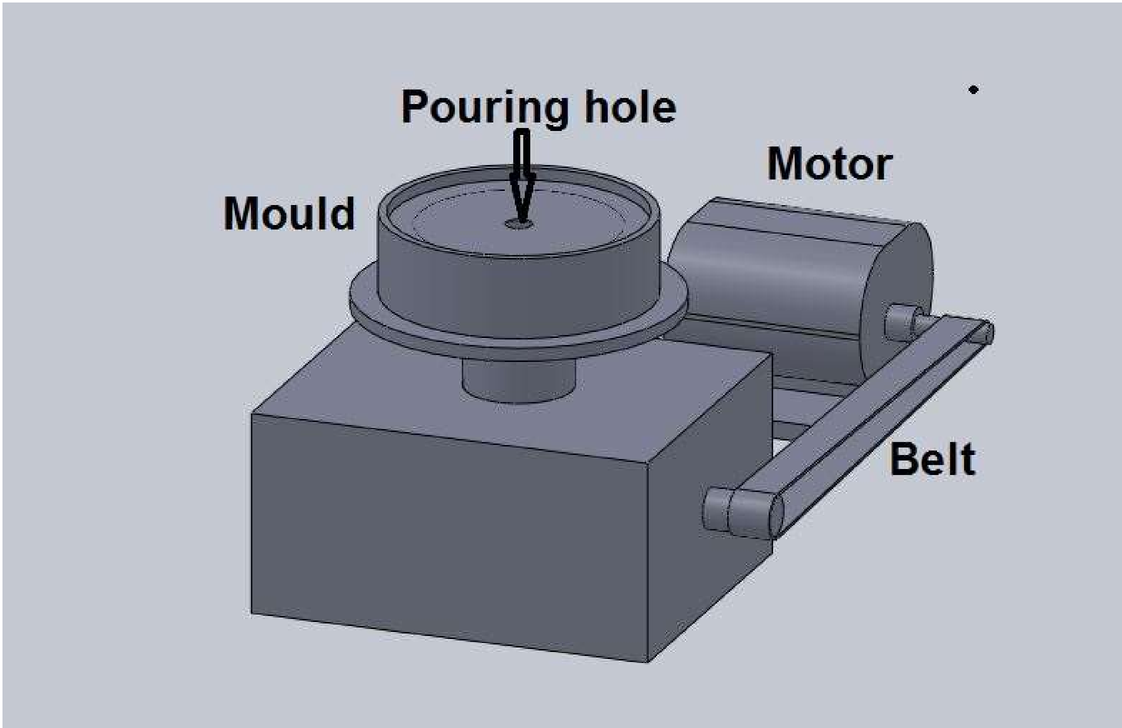


Figure 1. Representation of "Vertical Centrifugal Casting Machine"

1 2 3

Figure 2. Al (6061) as cast and FGMCC rings

Figure 2 represents the cast FGM rings with a thickness of 50mm, a diameter of the fixed outer ring is 210mm, a diameter with an inner ring is 140 mm and a 2.6kg weight. Analysis of the image, SEM Analysis, and test based on hardness were the three specimens used to cut from the cast ring using ASTM Standards.

3. Results and discussion

3.1 Image analysis

The optical micrographs of FIGS. three and four genuinely exhibit the gradient distribution of ceramic particles in three precise zones within the FGMMC ring: matrix-rich zone, transition quarter, and particle-rich zone, respectively. A greater awareness of ceramic particles is bought at the outer circumference of the casting in contrast to the internal circumference of the casting. The extent fractions of ceramic particles in unique zones of the FGMMC ring, i.e. internal zone, transition region, and outer zone, are proven in Fig. 5. Image evaluation effects proven in Fig. four point out that the outer circumference of the Al(6061)-5%SiC-10.C-3% mullite FGMMC ring includes up to 5.283 vol. percent ceramic particles, accompanied using a gradual reduce to decrease values (0 mm to 30 mm). In the transition zone, the ceramic grains are decreased to 1,980 vol%, then the internal circumference of the ceramic grains is decreased to 0.835 vol%. %. Al (6061)- 10% SiC-5.C-6% Mullite FGMMC ring incorporates up to 8.913 vol. percent ceramic particles bought at the perimeter. The transition sector incorporates 4.579 volumes. percent and internal circumference comprise 2,203 vol. percent ceramic particles. Centrifugal pressure maximizes the quantity ratio of the outer circumference in contrast to the internal circumference of the casting.

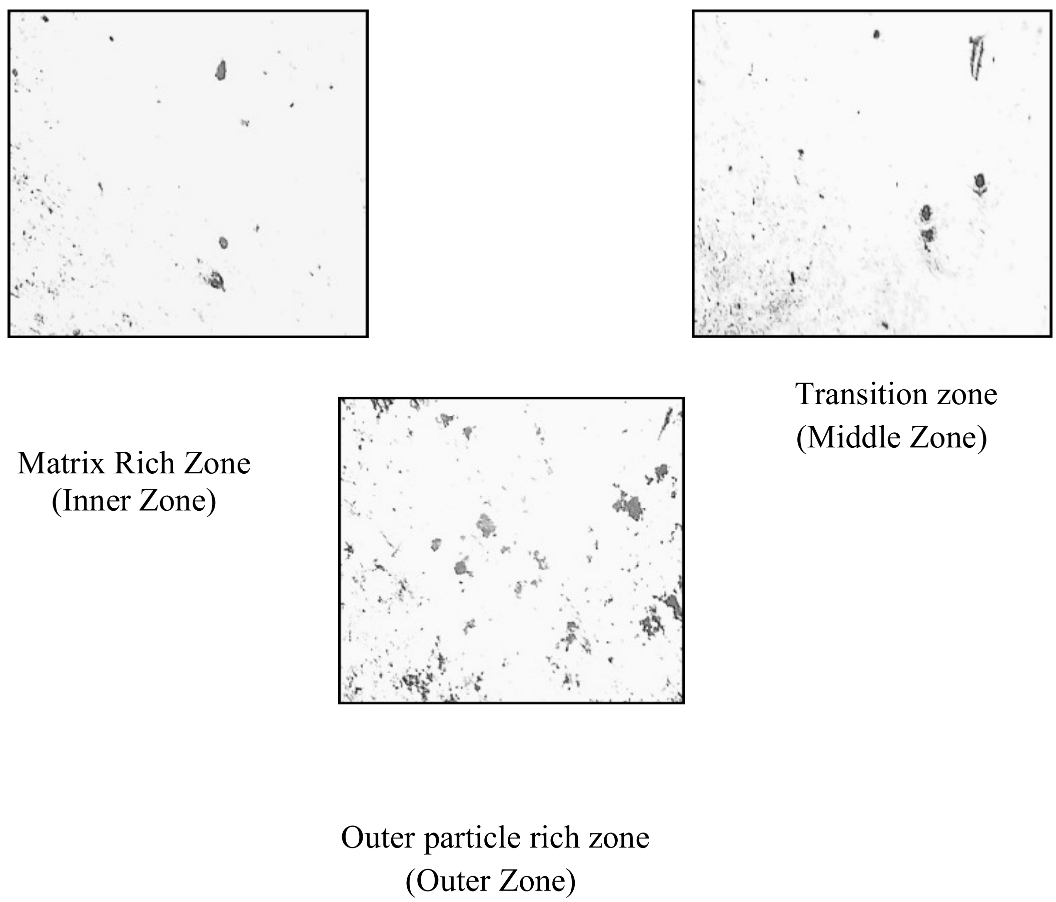
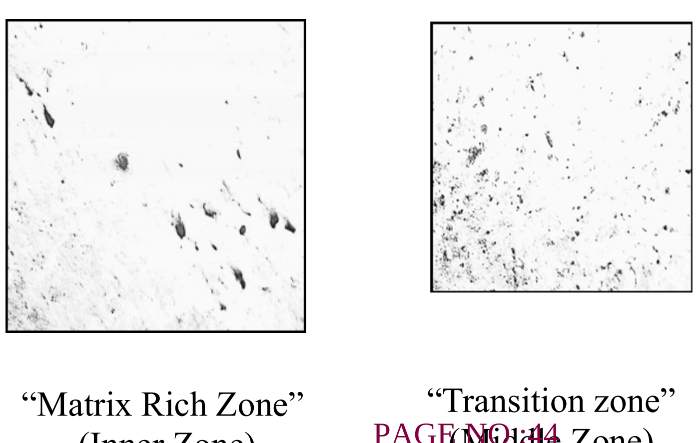
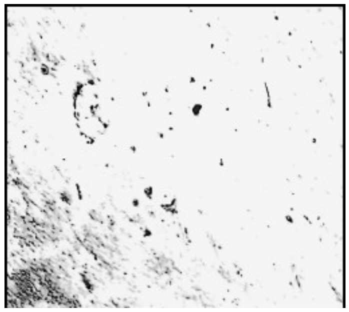


Figure 3. Optical micrograph of Al(6061)- 5% SiC-10%B_4C-3%Mullite FGMMC ring taken at different regions starting from the inner towards the outer periphery





Outer particle rich zone
(Outer Zone)

Figure 4. AI with Optical Micrograph (6061)- 10%, SiC-5%, B_4C-6%. Mullite FGMMC ring taken at regions start from inner towards outer periphery.

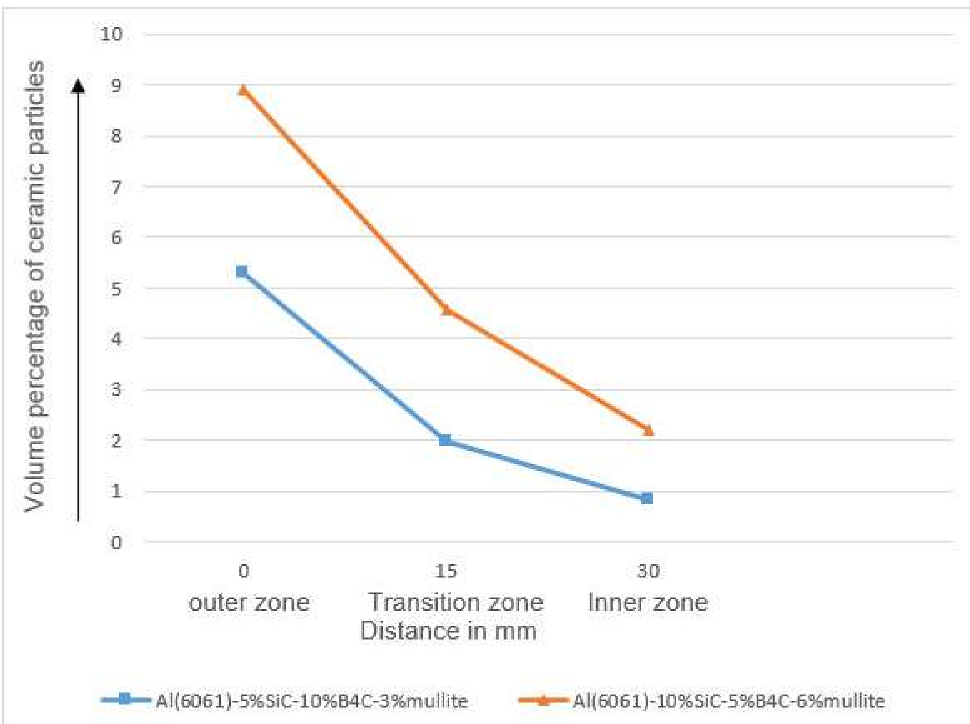


Figure 5. The volume percentage of ceramic particles at different zones

3.2 SEM analysis

Figure 6 to Figure 11 Shows the SEM image of the Al 6061 as cast and FGMMC. From the SEM images, A Ceramic Particle with distribution in the alloy of matric and formation pore can be viewed. A matrix alloy with microstructural features ranges from the outer to the inner circumference. This microstructural change is leads to various phenomena that occur during solidification under centrifugal force. The outer and inner periphery of Al (6061) - 5% SiC-10%B_4C-3%Mullite FGMMC ring obtained fine microstructure and there is no porosity resulting. The increase of main aluminum leads to a massive fraction of the extent through the presence of ceramic particles and shear forces implement ceramic particles through solidification which leads to smashing dendrite fingers with microstructure shapes. The motion of air bubbles from the outer circumference to the internal circumference for the duration of rotation impedes the motion of particles on the contrary route and may additionally raise some particles away. Shrinkage cavities pressed into the internal circumference can be eliminated using machining. Al (6061)-10% SiC-5%B_4C-6%Mullite FGMMC ring microstructure shows the presence of porosity in the outer periphery, it is because of more percentage of mullite particles in the aluminium matrix.

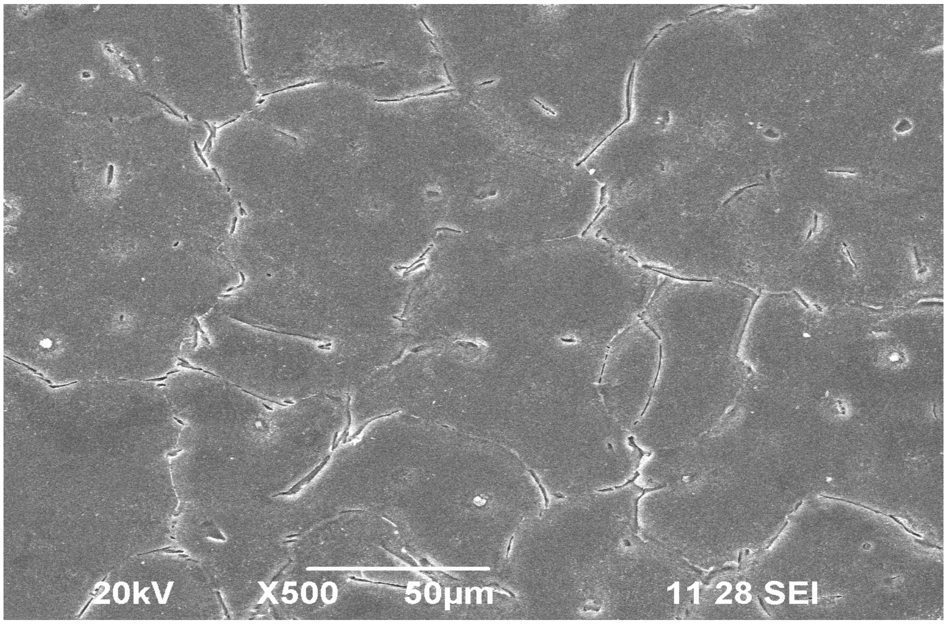


Figure 6. SEM image of Al(6061) centrifugal cast ring at Inner periphery

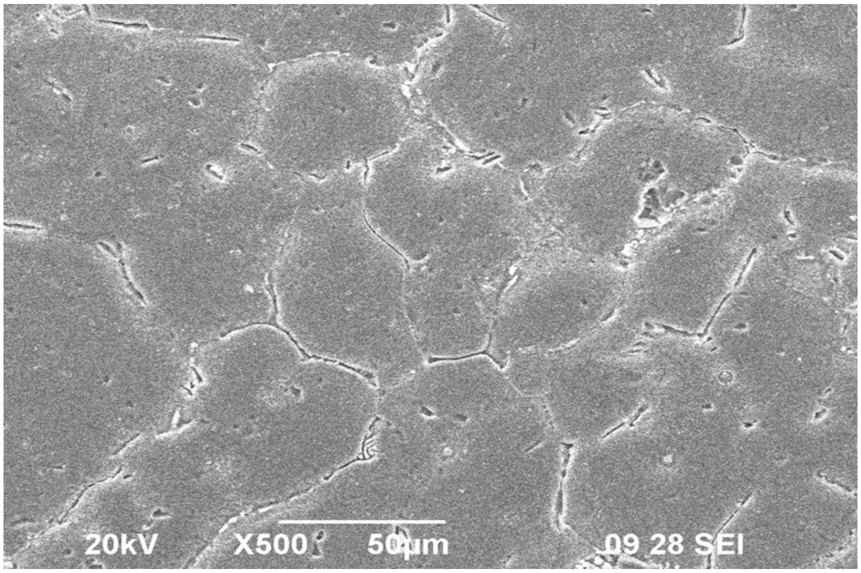


Figure 7. SEM image of Al(6061) centrifugal cast ring at the outer periphery

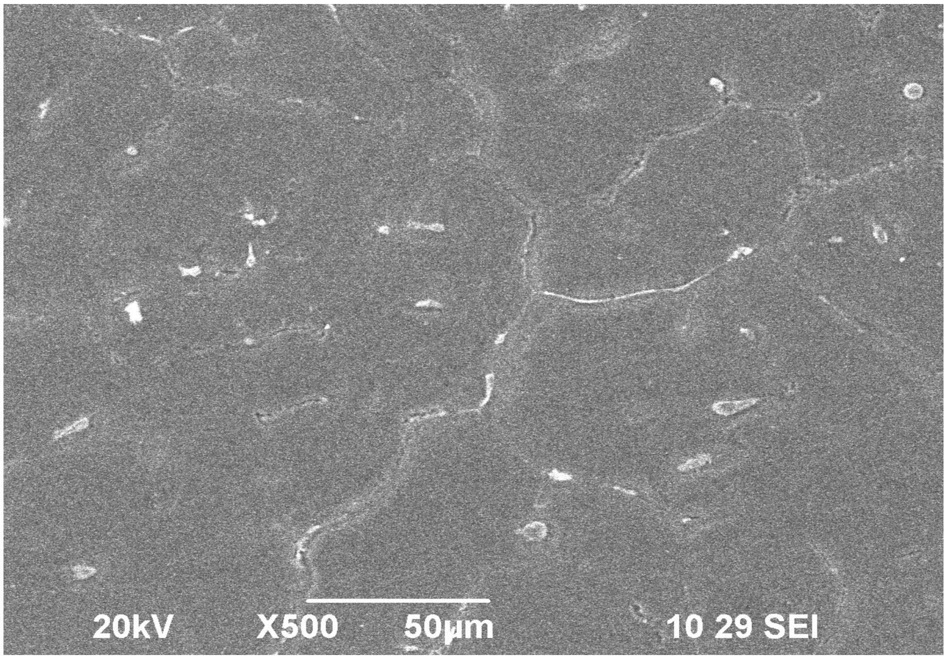


Figure8. SEM image of Al(6061)- 5% SiC-10%B_4C-3%Mullite FGMMC ring at inner periphery

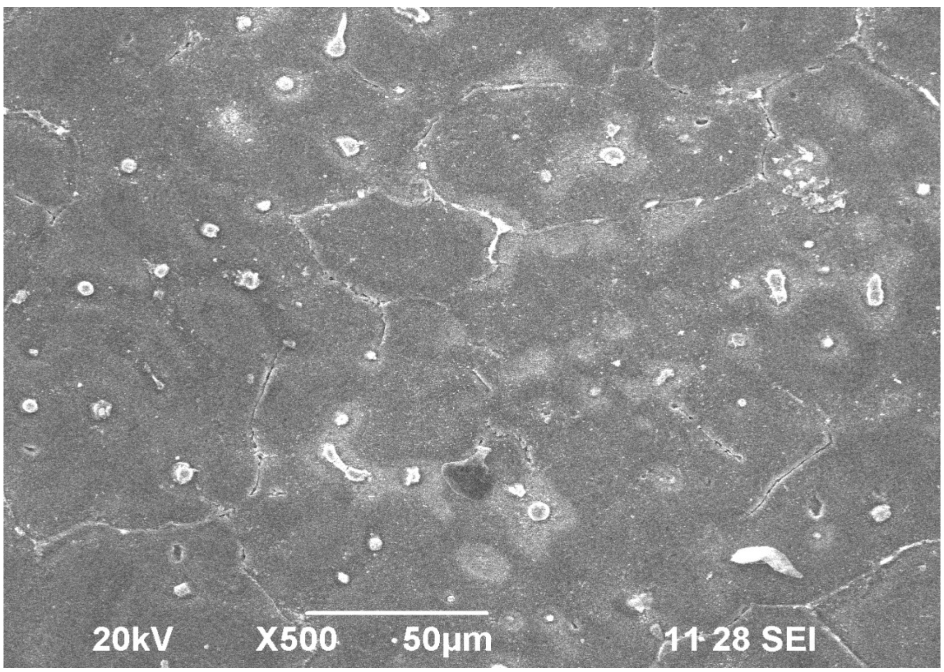


Figure 9. SEM image of Al(6061)- 5% SiC-10%B_4C-3%Mullite FGMMC ring at outer periphery

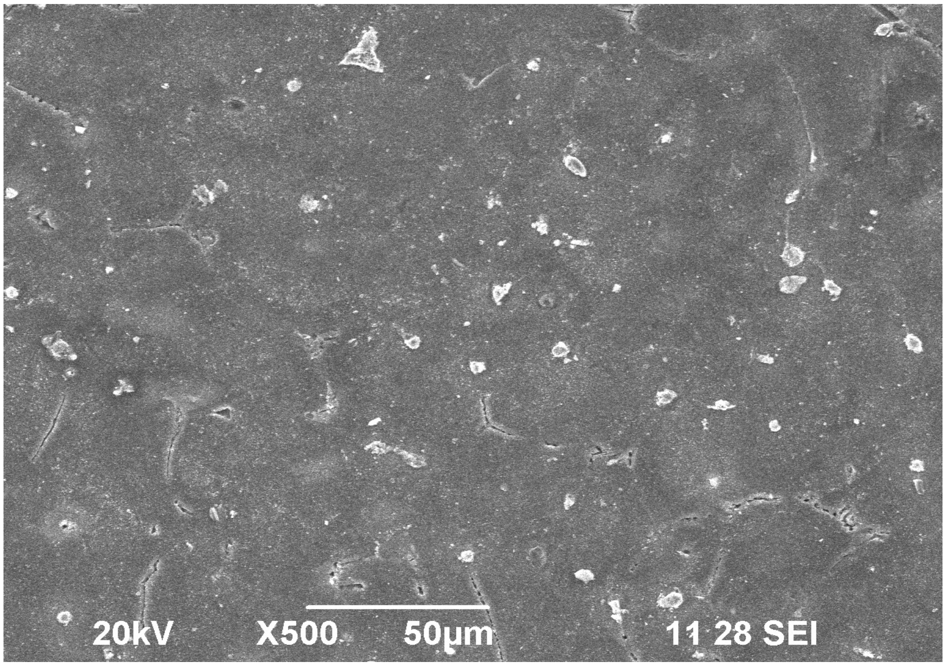


Figure 10. SEM image of Al(6061)-10% SiC-5%B_4C-6%Mullite FGMMC ring at Inner periphery

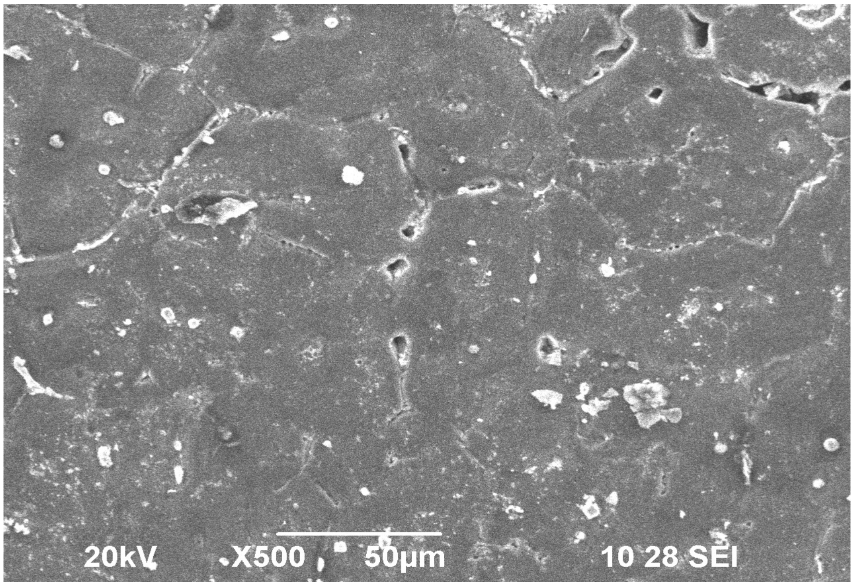


Figure 11. SEM image of Al(6061)-10% SiC-5%B_4C-6%Mullite FGMMC ring at outer periphery

3.3 Hardness test

Figure 12 shows the Variation in hardness from the outer to the inner zone of Al 6061 as cast and FGMMC ring. The graph clearly shows that hardness value which leads to proportion to the fraction of volume with ceramic particles in both cast and FGMMC rings. Maximum hardness value (63.4 BHN) is obtained at the outer periphery of Al (6061) - 10%SiC - 5%B_4C - 6%Mullite FGMMC ring due to the presence of higher concentration ceramic particles and the hardness value (57.1 BHN) is obtained at the inner periphery of the casting. It is because more percentage of silicon carbide and mullite in the aluminum matrix may help improve the hardness value. A hardness value of 52.3 BHN is obtained at the outer periphery of Al (6061) - 5%SiC - 10%B_4C - 3%Mullite FGMMC ring and a hardness value of 49.1 BHN is obtained at the inner periphery casting. As compared to the hardness value of Al (6061) - 10%SiC - 5%B_4C - 6%Mullite FGMMC ring, the Al (6061) - 5%SiC - 10%B_4C - 3%Mullite FGMMC ring having the less hardness. It is because of more percentage of boron carbide along with silicon carbide and mullite in the aluminium matrix. As compared to the hardness value of Al 6061 as cast with an FGMMC ring, the FGMMC has higher hardness.

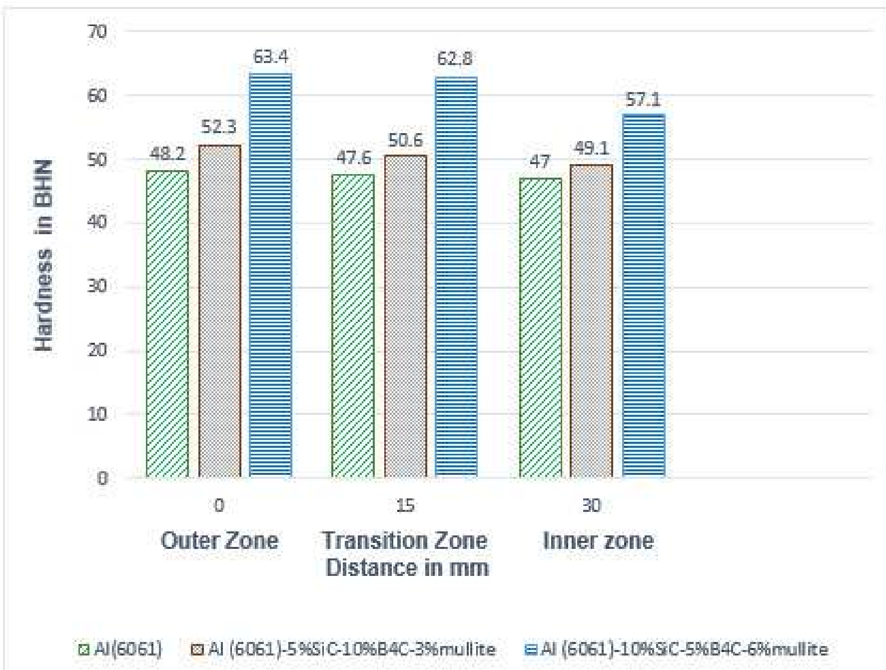


Figure 12. Variation in hardness from the outer to the inner zone of Al 6061 as cast and FGMMC ring

4. Conclusions

From the present investigation following conclusions are made:

- Al(6061)-SiC-B4C-Mullite FGMMC with different compositions have been successfully by the centrifugal casting process with fabrication.
- The analysis of image gradient reveals the distribution of SiC, B4C, and Mullite particles from the inner zone to the outer zone of the casting.
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- FGMMC ring obtained from the outer periphery with a maximum fraction of ceramic particle.
- Hardness of three regions namely, matrix-rich, transition, and the outer particle-rich zone are depending upon the concentration of ceramic particles.
- But there is no large variation in the hardness from the outer to the inner zone of the FGM ring

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