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DEVELOPMENT AND MORPHOLOGICAL STUDY OF THE STIR CAST AL/B_4C COMPOSITE

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ABSTRACT

Aluminium Composites are strtagically applied to civil and defence applications since long. Boron carbide is one of such additions to aluminium which has made the application more vibrant due to its excellent combination of hardness and wear resistant properties. The size and dstribution of these boron carbide are expected to control the mechanical and wear properties. Present work aims to understand the effect of size of boron carbide particles on the morphology and hardness in aluminum The present study involves alumninum alloy LM27 due to its stratagic applications in defence . Stir casting process has been used to fabricate the composite. The composites fabricated by varying the amount and size of boron carbide particles. Microstructural study has been undertaken by using optical microscope. Boron carbide particles of size ranging 20-100 µm has been used in the present study. Micro hardness and bulk hardness measurement has also been undertaken for developed composites.

Keywords:Al/B_4C Composite,hardnes,morphology,reinforcement,stircasting.

I. INTRODUCTION

Increasing demand for light metal alloys especially for their high strength to weight ratio and wear resistance, has limited the use of aluminum and its alloys. These aluminum alloys has high strength and high stiffness at low weight but are subjected to corrosion, fatigue and wear easily. Hence, to improve the corrosion resistance, fatigue and wear properties of the alloy, they are replaced by aluminum matrix composites. Such Al alloy composite is Al/ B_4C composite. Now a day's these aluminum matrix composites have wide range applications in automobile and aerospace industry such as pistons, transmission system, brake drums, tubes, plates, panels and other components.

The aluminum alloys reinforced with Silicon carbide, Boron carbide, Graphite, Zircon sand, Alumina and a combination of above, to develop the aluminum matrix composite. Panwar et al. [1] had found that the wear resistance of the Al-Si alloy (LM13) increases with increase in amount of reinforcement of zircon sand. The wear rates of both the alloy and composite increased with increase in applied load. Nagaral et al. [2] found that aluminum based metal matrix composites was successfully fabricated by Melt stirring method by two stage addition of reinforcement combined with preheating of particulates and the wear rate decreases with increase in percentage of silicon carbide.

Roystan et al. [3] proposed that Stir casting technique can be considered as an effective liquid based technique for developing the aluminum metal matrix composites. Mechanical properties such as tensile strength and hardness increases with increasing the percentage contribution of SiC reinforcement. It was also found that, increasing the SiC particles content in matrix reduces the material loss so that the wear resistance of the material improves to the considerable extent. Thirumalai et al. [4] produced Al-B_4C-Gr composites with the stir casting method using various levels of B_4C reinforcement and a constant amount of 3 % graphite addition. An evaluation of the morphological properties and the wear showed that the B_4C reinforcement of up to 9 % was beneficial in increasing the wear resistance of aluminum hybrid composites.

Toptan et al.[5] in their work developed the Al-B_4C composites through a casting route with addition of K_2TiF_6 flux to form a reaction layer contains TiC and TiB_2 at the interface, in order to increase wettability and interface bonding. The wetting issue was effectively solved by the formation of very thin (80-180 nm in thickness) TiC and TiB_2 reaction layers with addition of K_2TiF_6 flux. Rajesh et al. [6] found that wear rate of composite containing 7 wt% of boron carbide was lower due to formation of tribolayer at pin disc interface thereby reducing less exposure of pin surface with hard steel disc. Larger size wear debris was obtained for 6061Al alloy with increase in normal load applied. Abrasion grooves on the small sized wear debris of composite was observed which indicates abrasive wear mechanism.

Considering all these parameters, this study is aimed to analyze the effect of coarse, medium and fine sized boron carbide particle reinforcement in commercial grade LM27 aluminum alloy composite. For this purpose stir casting route is adopted for the development of composite. For the reinforcement a boron carbide particles in different sizes and different amount composition has been taken to develop composite. In order to increase the wettability of boron carbide with aluminum alloy potassium titanium fluoride (K_2TiF_6) flux has been added. The surface morphology and the hardness testing have been carried out of the developed composite.

II. MATERIAL AND EXPERIMENTAL DETAILS

2.1. Materials

Commercial grade aluminum alloy LM27 containing 7.53 wt. % Si was chosen as the matrix and boron carbide with a particle sizes ranging 100-20µm are used. To cover the complete range coarse (100µm), medium (50µm),fine(20 µm) are used for reinforcement. Potassium Titanium Fluoride with same amount as boron carbide was added as flux in order to increase the wettability of boron carbide with aluminum alloy. The chemical composition of aluminum alloy LM27 is given in Table 1.

Table 1.Chemical composition of LM27 alloy

Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
1.98	0.07	7.85	0.785	0.34	0.13	0.92	0.05	0.08	0.05	Rest

2.2.Melting and Casting

For melting, a resistance furnace was used. The stirrer was attached at the top of the furnace. About 320gm of aluminum alloy (LM27) was melted at 750 °C in a graphite crucible of 10 kg capacity. The molten metal was stirred with stainless steel stirrer at 250 rpm to get the vortex condition in the melt. Boron carbide particles were preheated at a temperature of 200°C and after preheating B_4C particles were mixed with potassium titanium fluoride in the same amount and the mixture was added inside the vortex during the stirring of molten metal.

The details of processing parameters are shown in Table 2. The molten mass was poured into mould which has cylindrical cavity of dimensions 160×Ø25 mm. From this stir cast composite material, specimens were prepared for the characterization and testing. Total ten samples were prepared including base LM27 sample with composition detail are shown in Table 3.

Table 2. List of processing parameters for stir casting of B_4C alloy

Melting temperature	750°C
Preheat temperature of particles	200°C
Total stirring time	20-25 min
Mixing time	8-10 min
Stirring speed	250 rpm
No. of blades	3
Blade angle	60°
Position of stirrer in melt	up to 2/3 depth

2.3.Characterization and testing

For metallographic study, base alloy (LM27) and composite samples were mechanically polished and etched with Keller's reagent. The chemical composition of Keller's reagent is shown in Table 4. The surface morphology of each sample was examined with the help of optical microscope. Micro hardness values at different phases were measured using Vickers hardness testing machine and bulk hardness was carried out using Rockwell hardness testing machine.

Table 3. Composition of reinforcements and K_2TiF_6 flux

Particle size (µm)	Amount of reinforcement and flux (wt %)			
	0	5	10	15
0	Base Alloy LM27	-	-	-
100	-	LM27+B_4C + Flux	LM27+B_4C + Flux	LM27+B_4C + Flux
50	-	LM27+B_4C + Flux	LM27+B_4C + Flux	LM27+B_4C + Flux
20	-	LM27+B_4C + Flux	LM27+B_4C + Flux	LM27+B_4C + Flux

Table 4. Chemical composition of Keller's Reagent

Chemicals	Distilled water	Nitric acid	Hydrochloric acid	Hydro-fluoric acid
Amount (ml)	190	5	3	2

III. RESULTS AND DISCUSSION

3.1.Microstructural Study

In order to analyze the microstructure of the base alloy and the developed composites optical microscopy was used. Optical micrographs of the base cast LM27 alloy are shown in Fig.1 (a&b).The dendretic growth of silicon at grain boundaries has been observed in LM27 alloy.

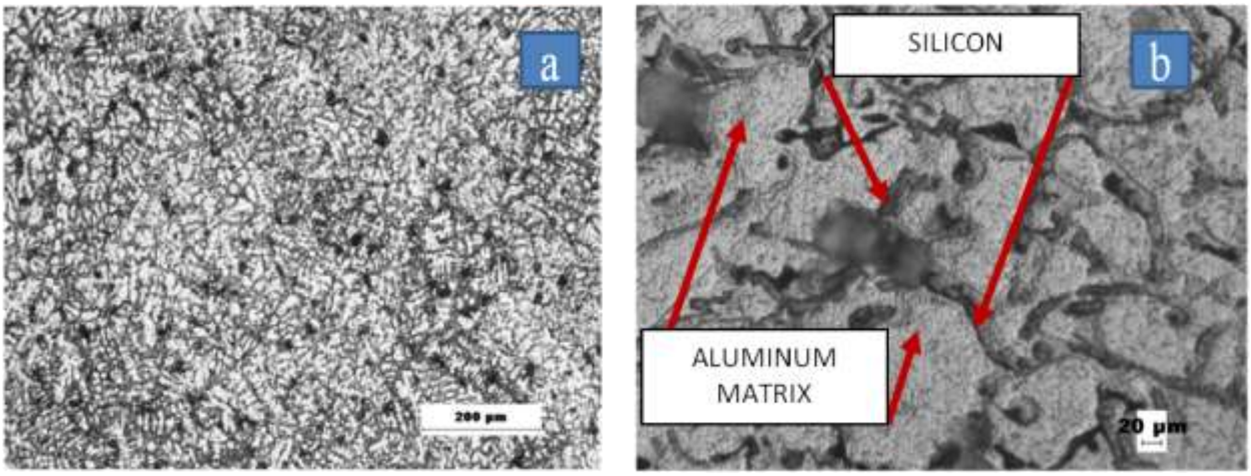

Fig.1. Optical micrograph of base alloy LM27 (a) at 50 x and (b) at 500 x.

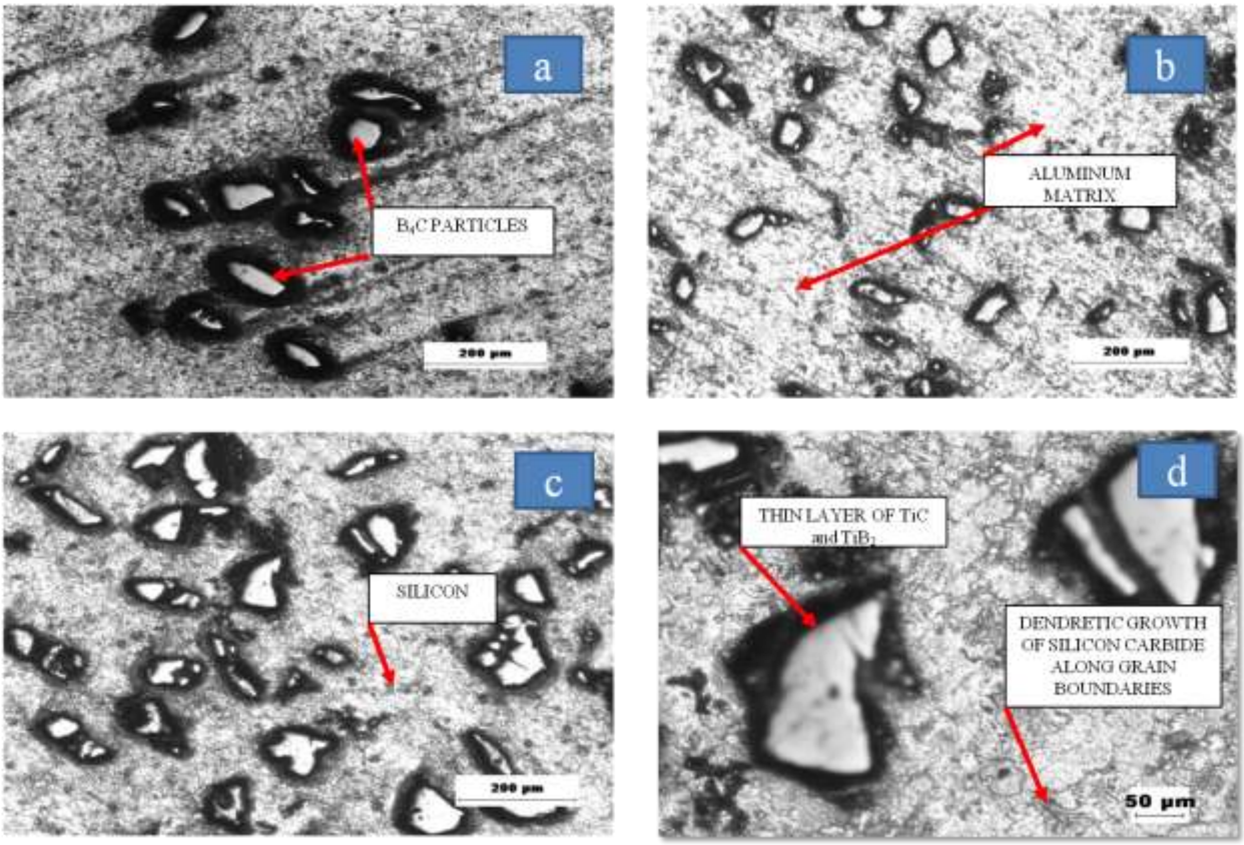

Fig.2. Optical micrograph of (a) LM27/5%B_4C (Size 100μm) at 50 x, (b) LM27/10%B_4C (Size 100μm) at 50 x, (c) LM27/15% B_4C (Size100μm) at 50 x,(d) LM27/Coarse size B_4C at 200 x.

Fig.2 (d) showing the coarse size particle, interface and matrix at higher magnification. It is clear from the figure that the particles are bonded strongly to the matrix forming the interfaces and restricting the dendretic growth of silicon along grain boundaries, where as dendretic growth is seen in area where there is no particle. A thin layer around the particles has been observed which was the reaction product of potassium titanium fluoride flux and the boron carbide particles. The titanium react with boron carbide to form titanium carbide and titanium diboride which increases the wettability of boron carbide particles with aluminum alloy and results in formation of strong bond between aluminum matrix and boron carbide particles as earlier described by Toptan et al.[5]

$$\frac{3}{4}\,\mathrm{Ti} + \frac{1}{4}\,\mathrm{B_4C} \rightarrow \frac{1}{2}\,\mathrm{TiB_2} + \frac{1}{4}\,\mathrm{TiC}$$

Optical micrographs of composites of particles size 50 µm with 5%, 10% and 15% composition are shown in Fig. 3(a-c) respectively. It has been clear from the micrographs that the particles are uniformly distributed and result in the formation of strong bond with the matrix. Similar type of thin layer has been observed around the particles as in case of coarse size particles which results in formation of the strong bonding between aluminum matrix and the boron carbide particles.

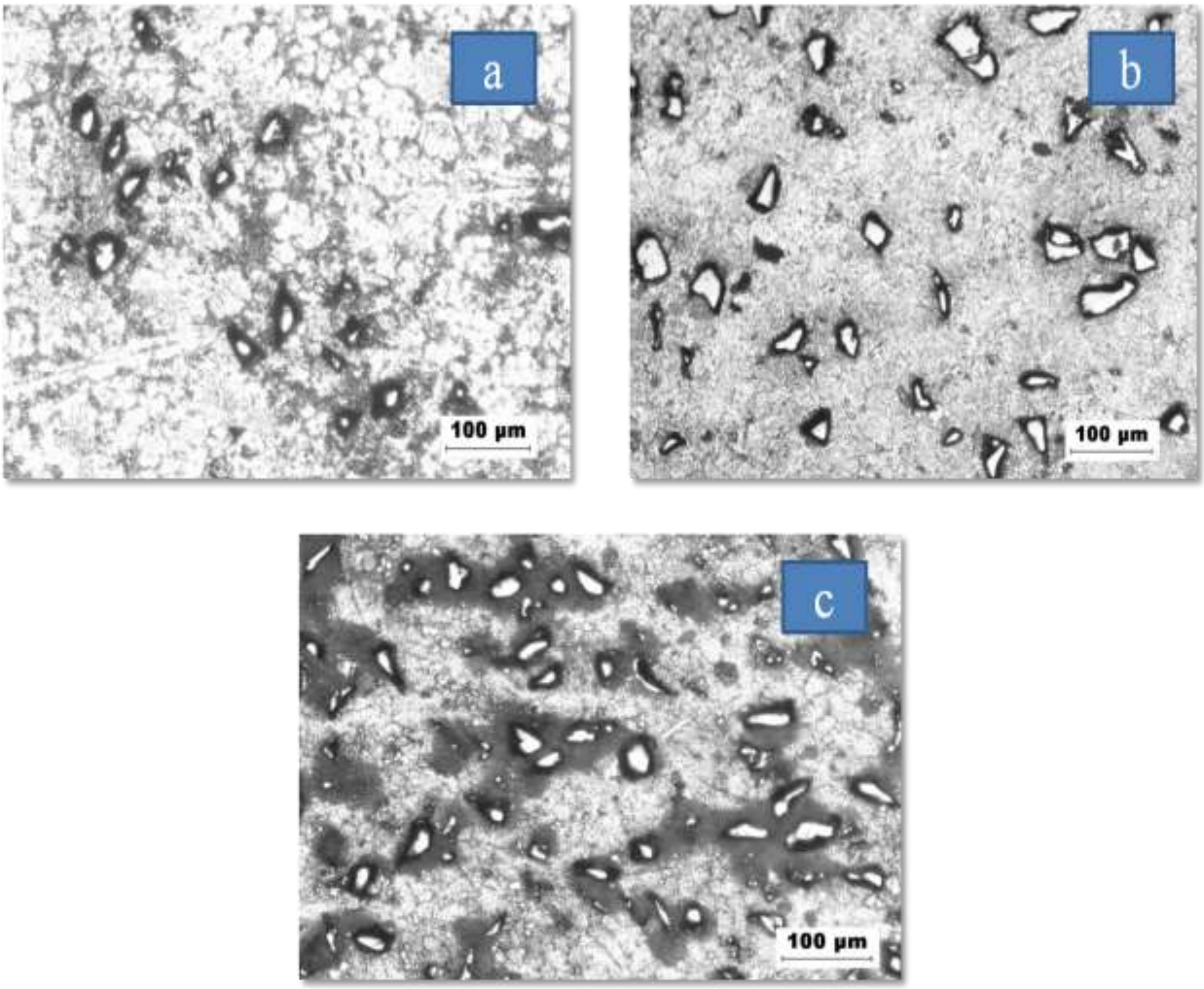

Fig.3. Optical micrograph at 100 x (a) LM27/5%B_4C (50µm) (b) LM27/10%B_4C (50µm) (c) LM27/15%B_4C (50µm).

Optical micrograph of composites of particles size 20 µm with 5%, 10% and 15% composition are shown in Fig. 4(a-c) respectively. It has been clear from the micrographs that the particles are uniformly distributed and result in the formation of strong bond due to formation of thin layer of titanium carbide and titanium diboride with the matrix. As compared to coarse and medium size particles there is more agglomeration is observed in case of fine size particles. But the inter-particle distance between the fine size particles is less as compared to coarse and medium size particles which offer more advantageous properties to the composite.

Fig. 4(d) shows the bonding and interfaces formed by fine size particles with the matrix at higher magnification. As it is clear from the figure that particles are strongly bonded to matrix and forming the clear interfaces. Similar thin layer of titanium carbide and titanium diboride has also been observed around the boron carbide particles which was also observed in case of medium and coarse size particles.

3.2 Hardness testing

The micro hardness of base LM27 alloy and alloy containing 10 wt% reinforcement of boron carbide particles of sizes 100µm, 50 µm, 20 µm was observed. The micro hardness of the base alloy was observed as 103 HV. Table 5 shows the micro hardness of composite at the particle, at interface between particle and matrix and at the matrix.

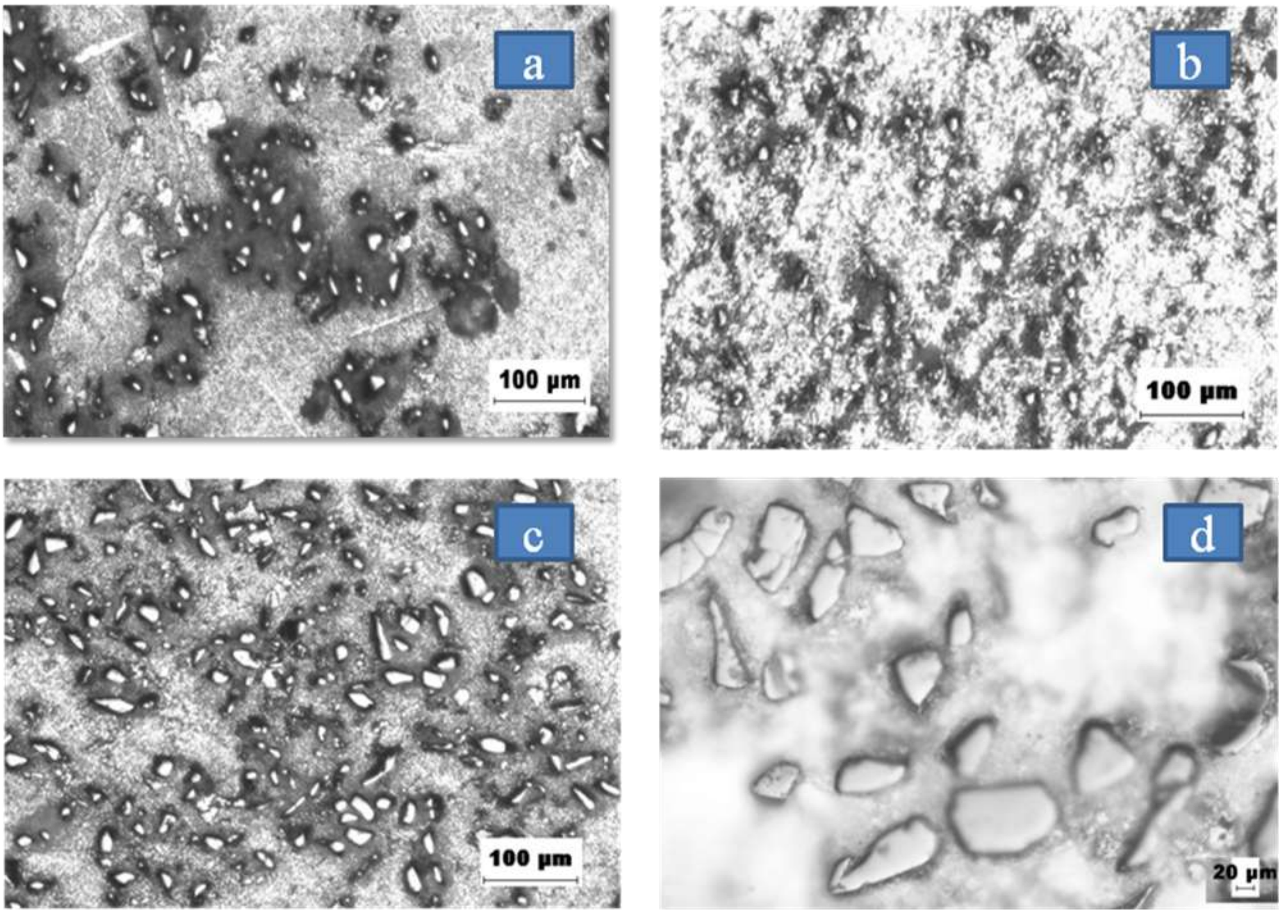

Fig.4. Optical micrograph of (a) LM27/5%B_4C (20µm) at 100 x (b) LM27/10%B_4C (20µm) at 100 x (c) LM27/15%B_4C (20µm) at 100 x, (d) LM27/fine sized B_4C at 500 x.

Table 5. Micro hardness of LM27/B_4C composite containing 10 wt% reinforcement

Particle size (µm)	Micro hardness (HV)		
	Particle	Interface	Matrix
100	695	145	105

50	726	273	96
20	711	349	107

It is clear from the Table 5 that the micro hardness decreases as we move from particle to the matrix. The interface formed between the particles and the matrix also shows a remarkable increase in the hardness as compared to matrix which points towards the strong interfacial bonding between the particles and the matrix.

The bulk hardness of the developed composites was carried out by using Rockwell hardness testing machine. The results obtained are shown in Table 6.

Table 6. Bulk hardness of LM27/B_4C composites

Particle size (µm)	Hardness(HRB)			
	0% B_4C	5 % B_4C	10% B_4C	15 % B_4C
0	30	-	-	-
100	-	46	61	63
50	-	45	57	60
20	-	54	56	67

The bulk hardness of composite increases as we increase the amount of reinforcement from 0 to 15 wt% and decrease with the increasing size of reinforcement particles from 20 – 100µm. As it is concluded from the table above that the fine size particles offers more resistance to indentation as compared to coarse size particles this is because the inter particle distance between fine size particles is less as compared to coarse size particle. The comparisons of bulk hardness of base alloy and alloy with coarse, medium, fine sized reinforcements are shown in fig. 5(a-c) respectively.

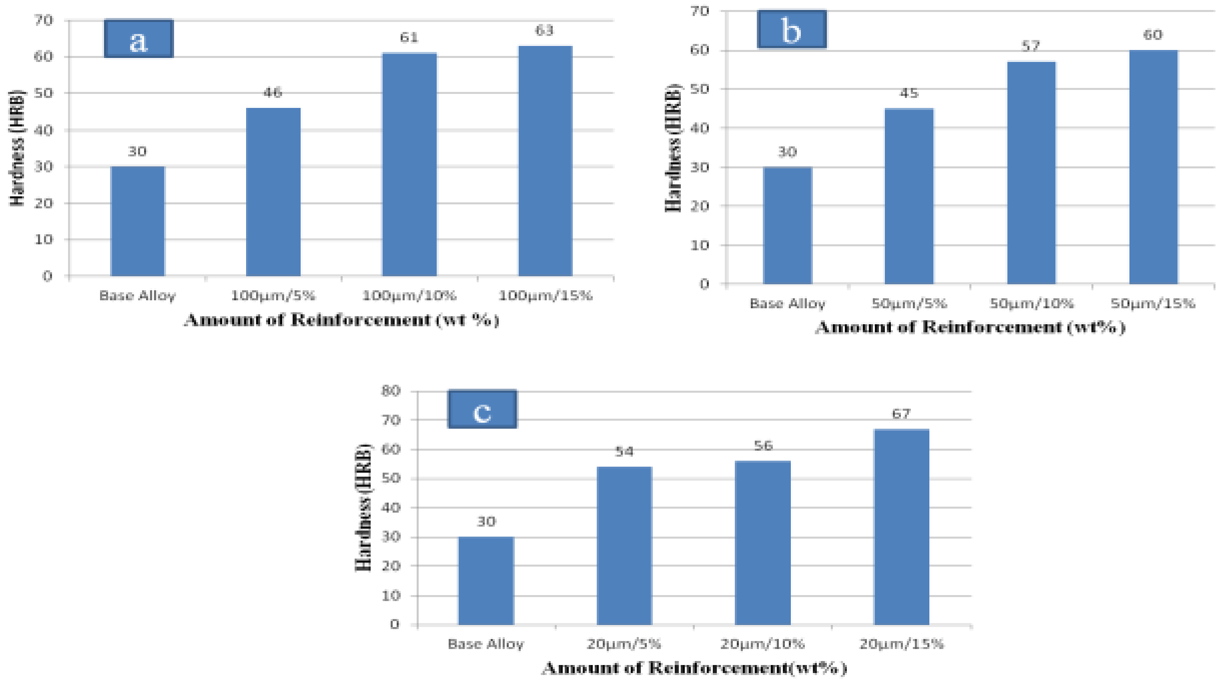

Fig.5. Bulk hardness comparisons of Base alloy LM27 and (a) Composite containing coarse size particles with different amount of composition (b) Composite containing medium size particles with different amount of composition (c) Composite containing fine size particles with different amount of composition.

IV. CONCLUSIONS

The study on the effect of boron carbide reinforcement (with different sizes and different amount) in stir cast LM27/B_4C composites is concluded as follows:

- Stir casting has resulted in uniform distribution of reinforced particles B_4C within the Al matrix.
- Potassium titanium flux increases the wettability of B_4C with the aluminum matrix and results in the formation of strong interfacial bonding.
- There is sufficient increase in the micro hardness at the interface which decreases as we move away from interface to matrix and increases as we move from interface to particle. It is also concluded that there is an increase in micro hardness as the percentage of reinforcement increases.
- The bulk hardness of the composite increases as the size of the particle decreases i.e. fine size particles offers more resistance to indentation as compared to coarse size particles.

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