Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Microstructural evolution and mechanical behavior of 90 micron sized B_4C particulates reinforced Al2219 alloy composites

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ARTICLE INFO

Article history:
Received 16 January 2021
Received in revised form 26 January 2021
Accepted 1 February 2021
Available online xxxx

Keywords:
Al2219 alloy
B_4C particles
Hardness
Tensile strength
Density

ABSTRACT

The microstructure and mechanical behavior of Al2219 metal alloy with 2, 4, 6, 8 and 10 wt% of B_4C composites were studied. The composites comprising 2 to 10 wt% of B_4C in Al2219 alloy were amalgamated by liquid metallurgy process. The prepared composites were subjected to the microstructural studies using SEM. Further, the mechanical behavior of Al2219 with B_4C composites were tested as per ASTM methods. The SEM characterization identified thorough dispersal of particles in the base alloy. Further, mechanical behavior of Al2219 alloy has been improved with the addition of B_4C particles. The enhanced hardness and tensile strengths were obtained in the composites. The ductility and density of the Al2219 alloy was reduced after the inclusion of boron carbide particles.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Mechanical, Electronics and Computer Engineering 2020: Materials Science.

1. Introduction

In a previous couple of decades, improvements in the mechanical properties of new materials are broadly and commonly used in several applications. A broad investigation has been finished for the development of new materials either with reinforcement particulate or without the reinforcement particulate which results in the improvement of mechanical properties of new materials, such as hardness ultimate tensile strength, wear resistance, corrosion resistance, density, percentage elongation and fatigue life [1,2]. Fig. 1.

In the automobile industry, these materials are used to enhance the life of engine as well as the fuel efficiency. The high strength of the material and thermal efficiency make suitable use of new material in the aerospace industry [3]. Due to this advancement in the new materials, the demand for metal matrix composites is very high in automobile and aerospace research industries which led to the vast research in the field of composite materials.

Metal matrix has heightened mechanical properties than the pure metal. Composite materials are widely used as a commercial material in the cutting tools industry due to its extraordinary strength with stiffness, wear resistance, lesser density and good thermal conductivity [4,5]. There are several techniques available for the fabrication of these cast composite but the liquid metallurgical technique known as vortex method is one of the best methods to fabricate the cast due to less residual void, no dissolved gases in a final product, a good interface between the reinforcement and the matrix material [6].

The easy availability of raw materials, good mechanical and wear properties make aluminium-based metal matrix more comfortable in the research work. There are numerous benefits of MMC's. From the industrial point of view which improves various mechanical properties such as wear life, fatigue life, corrosion behavior, benefits for an environment like noise resistance and easy machinability makes the reduction in the economic cost [7].

Metal matrix composites are the mixture of base material and one or more than one reinforcement particulate. The reinforcement particulate is added to the metal matrix in small percentage which results in the enhancement of the mechanical properties and tribological properties of the base metal present in the metal matrix [8,9].

In the current research an endeavor has been made to prepare the Al2219 alloy and B_4C reinforced composites. These prepared Al2219 with 2 to 10 wt% of micro B_4C composites were tested for microstructural and mechanical characterization. The hardness

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https://doi.org/10.1016/j.matpr.2021.02.026
2214-7853/
Selection and peer-review under responsibility of the scientific committee of the International Conference on Mechanical, Electronics and Computer Engineering 2020: Materials Science.

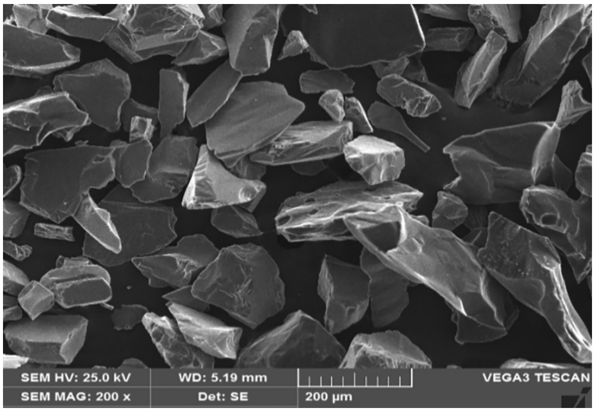

Fig. 1. SEM microphotograph of B_4C particles.

and tensile properties were conducted as per ASTM methods. Density of the prepared composites were estimated by weight method and compared with the theoretical values obtained by rule of mixture.

2. Experimental details

2.1. Materials

The experimental set-up of traditional casting process are used to prepare metal matrix composites of micro-B_4C of 0%, 2% and 4% by weight rates into Al2219 by the liquid metallurgy process. For the preparation of MMCs, an Al2219 alloy was utilized as the base/framework material and micro-B_4C was used as the particulates to give strength. The theoretical density of grid material Al2219 amalgam is 2.80 g/cm^3 and support particulates micor-B_4C is 2.52 g/cm^3. The chemical composition of Al2219 composite used for current study is as given in Table 1.

In the existent work, micro B_4C particulates with 80 to 90 µm size are used as the fortification materials. The density of B_4C is lesser than the Al2219, which is 2.52 g/cm^3.

2.2. Preparation of composites and testing

The formation of Al2219-2 and 4 wt% B_4C composites were made by fluid metallurgy course. Chosen extent of the Al2219 compound ingots were kept into the furnace for dissolving. The melting temperature of aluminum mix is 660 °C. The Al2219 compound was superheated to 750 °C temperature. The temperature of the break down was recorded utilizing a chrome-alumel thermocouple. The liquid metal is then degassed utilizing hexachloroethane (C_2Cl_6) for 3 min [10]. A steel impeller made sure about with zirconium is used to mix the liquid metal to make a vortex. The stirrer are turned at a speed of 300 rpm and besides the centrality of soaking of the impeller was 60% of the apex of the liquid metal from base of the consolidate. Further, the B_4C particulates were preheated in a pre-radiator upto 500 °C joined into the vortex with the K2TiF6 halide salt. Blending was gone before until interface relationship between the fortification particulates and besides the Al system impels wetting. Around then, Al2219-2 wt% micro scale B_4C liquefy was filled in the cast iron mold. Further, Al2219-4, 6, 8 and 10 wt% B_4C particulates composites were manufactured by the indistinguishable strategy. The castings in this way got were sliced to a size of 15 mm diameter across and 5 mm thickness which is then exposed to various dimensions of cleaning to get required example piece for microstructure studies. Hardness tests were performed according to ASTM E10 [11]. The tensile tests were done on the cut examples according to ASTM E8 [12] at room temperature to ponder properties like UTS, yield strength and % of elongation.

3. Results discussion

3.1. Microstructural studies

Fig. 2a shows the SEM photos of Al2219 amalgam. Also Fig. 2b indicating 2 wt% B_4C fortified composites and Fig. 2c-f demonstrating scanning electron photos of 4, 6, 8 and 10 wt% of B_4C strengthened composites individually. From the SEM photos, it is uncovered that there is uniform homogenous circulation of auxiliary period of smaller scale particulates in the Al2219 combination framework with no agglomeration. It is additionally seen that there is a brilliant interfacial holding between the B_4C and Al2219 amalgam grid, which further upgrades the properties of Al2219 compound.

3.2. Density measurements

Fig. 3 is indicating to the hypothetical (theoretical) and exploratory (experimental) densities of as cast Al2219 amalgam, Al2219 combination with 2, 4, 6, 8 and 10 wt% of micro scale B_4C particulates fortified composites. From the diagram it is seen that as weight level of micro scale B_4C particulates content increments from 2 to 10 wt% in the Al2219 compound, both the hypothetical and test densities of Al2219 amalgam diminishes. This reduction in the thickness of Al2219 amalgam is for the most part because of the expansion of light density material in the Al composite. The hypothetical density of Al2219 amalgam is 2.80 g/cm^3, however the hypothetical density of the B_4C is 2.52 g/cm^3, expansion of this lesser density material causes the abatement in density of Al2219 combination. Further, from the plot it is apparent that both the hypothetical and the test densities are practically equivalent to one another.

3.3. Hardness measurements

The hardness of Al2219 with 2, 4, 6, 8 and 10 wt% of micro B_4C combinations are existing in the Fig. 4. From the graph it is evident that as weight % of B_4C particles increased from 2 wt% to the 10 wt %, there is an increase in the hardness of Al2219. The hardness of Al2219 alloy is 62.4 BHN, with the addition of 2 wt% of micro B_4C particles it is found 70.8 BHN, further the hardness enhanced to 113.2 BHN in Al2219 alloy with 10 wt% of B_4C reinforced composites. There is an improvement of 81% in the hardness of Al2219 alloy after the addition of 10 wt% of B_4C particles. The improvement obtained in the base matrix Al2219 is due to existence of hard phases in the alloy. This hard B_4C particle creates the density dislocations during the solidification process which causes further strain hardening in the Al composites [13,14]. This phenomenon helps in improving the hardness of the Al2219 alloy.

Table 1
Chemistry of Al2219 Alloy.

Elements	Si	Fe	Cu	Mg	Zr	Zn	Ti	Mn	Al
Weight (%)	0.2	0.3	6.8	0.02	0.20	0.1	0.10	0.02	Bal

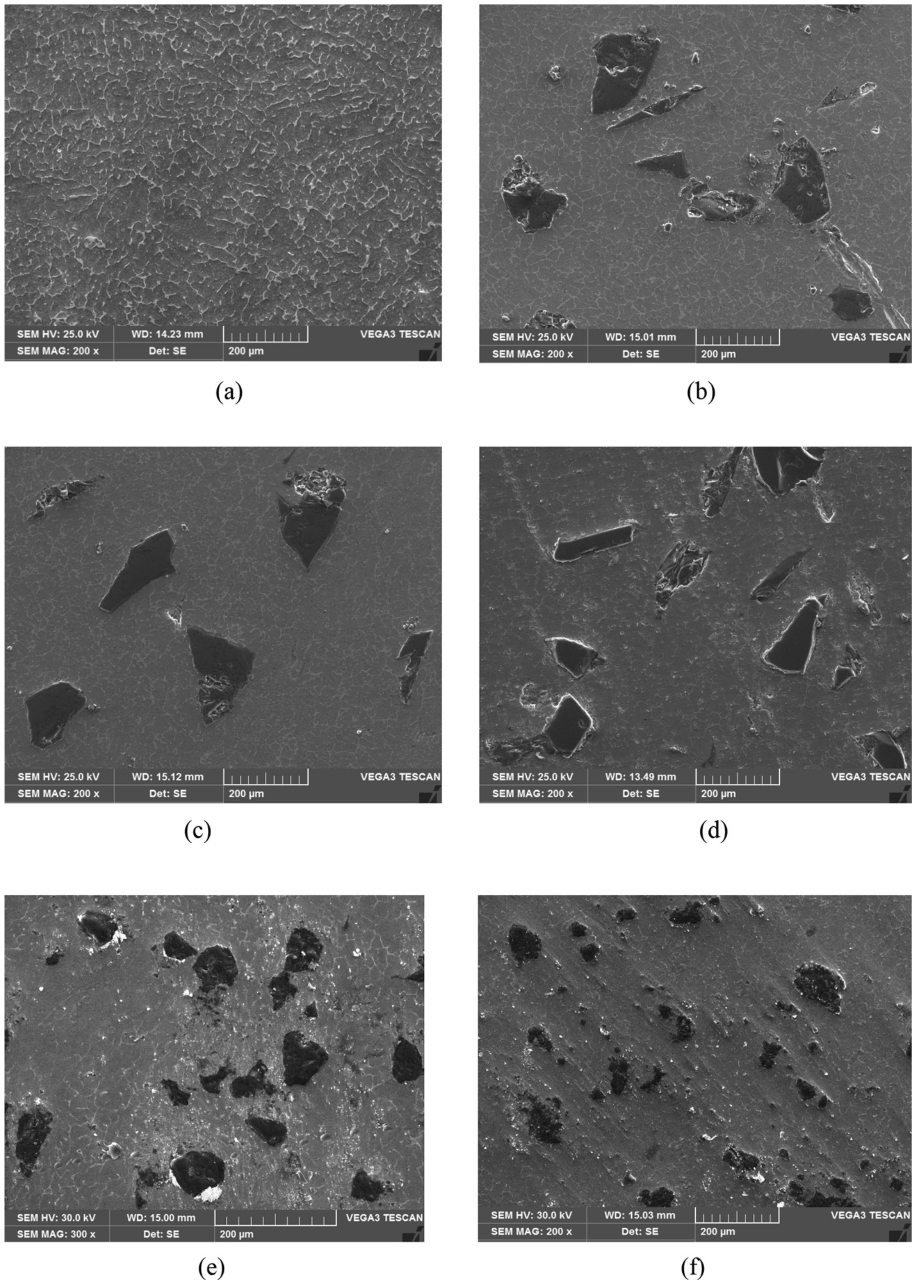

Fig. 2. SEM microphotographs of (a) as cast Al2219 alloy (b) Al2219-2 wt% B_4C (c) Al2219-4 wt% B_4C (d) Al2219-6 wt% B_4C (e) Al2219-8 wt% B_4C (f) Al2219-10 wt% B_4C composites.

3.4. Ultimate tensile and yield strength

Tensile test has been conducted on the Al2219 and its 2, 4, 6, 8 and 10 wt% of micro B_4C particulates reinforced composites as per ASTM E8 standards. Figs. 5 and 6 showing the variation in the ultimate and yield strengths of Al2219 alloy and its 2, 4, 6, 8 and 10 wt % B_4C composites.

Fig. 5 is representing the ultimate strength of Al2219 alloy and B_4C composite. The UTS of as cast Al2219 alloy is 199.47 MPa. The ultimate strength of Al2219 alloy with 2, 4, 6, 8 and 10 wt% of B_4C reinforced composites are 213.4 MPa, 229.93 MPa, 261.14 MPa, 287.33 MPa and 301.8 MPa respectively. Similarly, Fig. 6 is demonstrating the yield strength of Al2219 alloy and its B_4C particulates reinforced composites.

From the graph 6 it is evident that as the B_4C reinforcement wt. % increased from 2 wt% to the 10 wt% there is an enhancement in the yield strength of the Al2219 alloy. The yield strength of as cast Al2219 alloy is 165.48 MPa, the yield strength obtained with the addition of 2, 4, 6, 8 and 10 wt% of B_4C particles it is 175.2 MPa, 188.66 MPa, 209.29 MPa, 231.12 MPa and 241.62 MPa respectively. From the Figs. 5 and 6 enhanced ultimate tensile and yield strengths are presented with the incorporation of B_4C particles. The improvement in ultimate and yield strength obtained after the addition of 10 wt% of B_4C particles is 51.3% and 46.01% respectively. The improved UTS and YS of Al2219 material is due to the uniform distribution of hard particles within the matrix, which is evident from the microstructural studies section. This hard particle present in the matrix avoids the plastic deformation of the Al

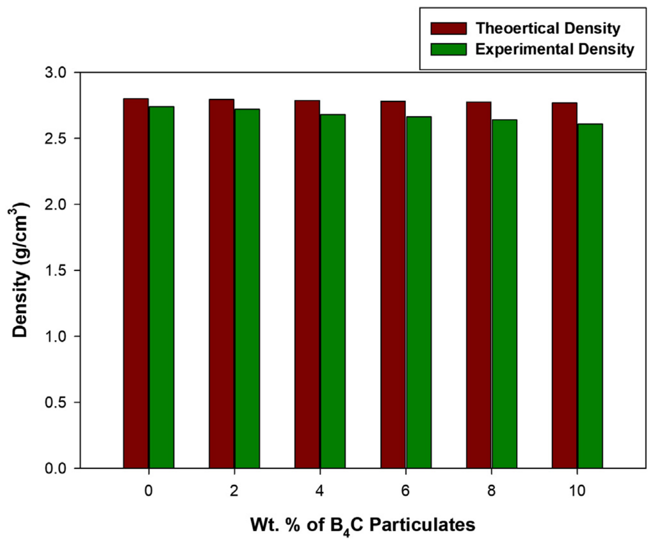

Fig. 3. Theoretical and experimental densities of Al2219 alloy with B_4C composites.

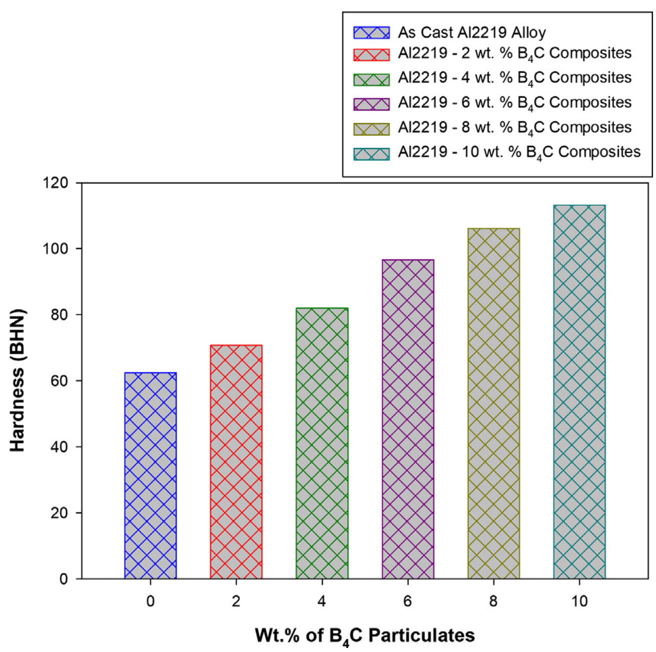

Fig. 4. Hardness of Al2219 alloy with varying wt. % of B_4C particles reinforced composites.

matrix during the tensile test [15,16]. The presence of particles creates the strain hardening due to thermal mis-matching between the matrix and alloy.

3.5. Percentage elongation

Fig. 7 is indicating the percentage elongation of Al2219 alloy with 2, 4, 6, 8 and 10 wt% of B_4C composites. The effect of addition of B_4C particulates on the ductility of the Al2219 is demonstrated. The ductility of Al2219 alloy is decreased with the content of hard particles. The percentage elongation obtained in the as cast Al2219 alloy is 14.37%. The Al2219 with 10 wt% of B_4C composites exhibited the percentage elongation of 9.15%. The decrease in the elongation is mainly due the incorporation of hard particles makes the soft matrix brittle. The brittle behavior of the ceramics causes decrease in the ductility.

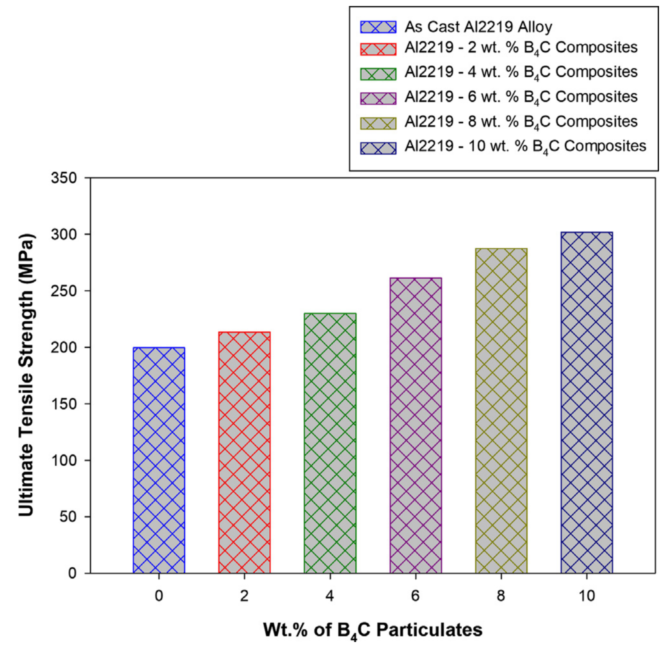

Fig. 5. Ultimate tensile strength of Al2219 alloy with varying wt. % of B_4C particles reinforced composites.

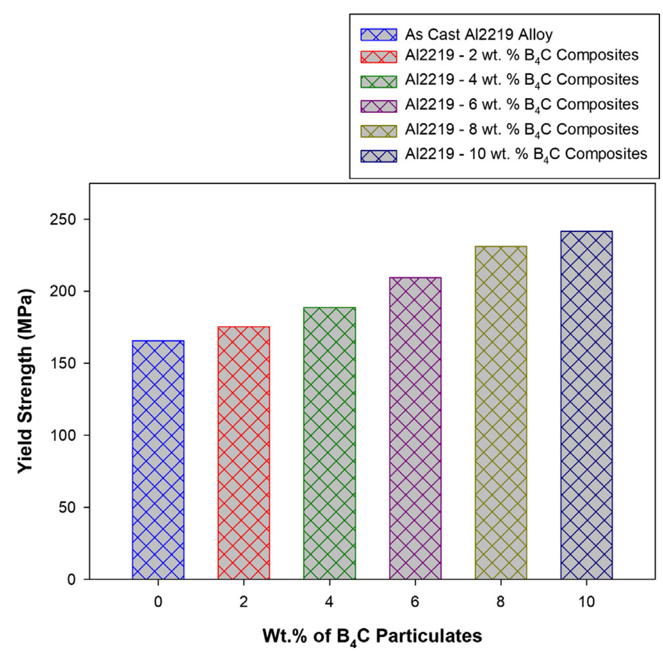

Fig. 6. Yield strength of Al2219 alloy with varying wt. % of B_4C particles reinforced composites.

4. Conclusion

The Al2219 with 2 to 10 wt% of micro boron carbide particles composites were made-up by stir casting method. The prepared composites have been subjected to the microstructural and mechanical behavior evaluation. The microstructural studies carried out with SEM micrographs, which revealed the fairly thorough distribution of particles in the Al2219. The mechanical properties of B_4C reinforced composites were exhibited superior properties in ultimate and yield strength. Further, the elongation of the Al2219 was decreased as wt. % of B_4C content increased from

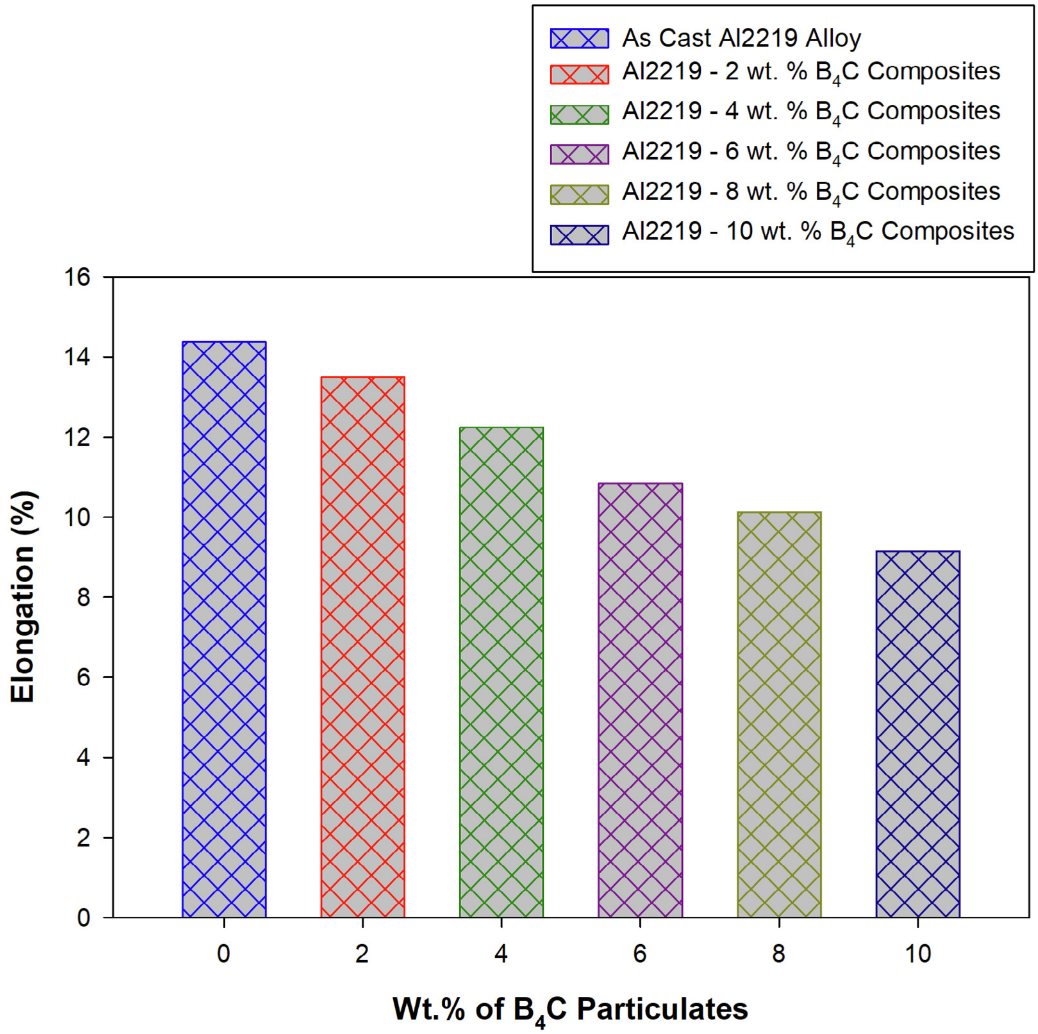

Fig. 7. Elongation of Al2219 alloy with varying wt. % of B_4C particles reinforced composites.

2 wt% to the 10 wt%. The density of the Al2219 alloy was decreased as increased content of reinforcement in the base.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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