

Evaluation Of Mechanical Properties In AA2219-B₄C Composites Produced By Stir Casting And Age Hardening

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Abstract:

The mechanical properties exposure to heat treatment is examined in this work for AA2219 strengthened by boron carbide (B₄C) particles. The content of reinforcement B₄C included 2 wt% and 4 wt%. Consistent reinforcing particle distribution was visible in the microstructure and improved strengthening phases. Vickers' hardness increased to 9.67% at 4wt% of B₄C and for 2wt% of B₄C the hardness was enhanced to 11.24% after the completion of the heat treatment. At a 2 wt% concentration of B₄C, UTS grew by 15.16%, and at a 4wt% concentration, it increased by 6.80%. The improvisation has been found in the yield strength of 6.37% at B₄C particles containing 4wt% and at 2wt% of B₄C particles exhibited 10.32%. Additionally, there had been a drop in ductility of 25.09% and 14.29%, and this implies that strength and ductility compromise. The conclusion of composites' have the potential for high-performance application.

Keywords: AA2219 Alloy, Boron Carbide, Sir casting, Tensile Properties, Age Hardening.

1.0 Introduction:

The group of cast aluminum alloys is great in virtue, and they have lightweight as well; hence, these resources are extensively utilized within several associated industries. These alloys resist corrosion well, have an excellent strength-to-weight ratio, and excellent thermal conductivity too being suited for applications in automobile, aerospace & consumer electronics industries. The cast aluminum alloy's mechanical properties; which includes tensile strength, stiffness, and hardness are affected by parameters like the chemical composition of specific alloys die-cast whereas microstructure and heat treatment processes also play an important role. [1-2].

A higher strength aluminium has led to an alloy known as 2219 which is mainly made from aluminum and copper, mainly popular for its exceptional mechanical features and utilized in different industries. Having excellent machinability, high tensile strength and good stress corrosion cracking resistance this alloy is best-suited for use in aerospace sector as well as military applications. One of the major challenges with AA2219 is its ability to maintain mechanical properties at warm temperatures, as components operating under high thermal stresses [3-4].

Age-hardening influence on the mechanical properties of AA2219 is significant since it has notable improvement in strength and hardness, which dominates others after heat treatment. It is shown that copper existence as a major content leads to precipitation that can reject edge dislocations and thus

enhance mechanical strength even more extensively. The alloy is also highly weldable, which will help in forming complex assemblies such as fuel and structural tanks for spacecraft. The aviation industry uses it widely for aircraft and space launch vehicles owing to its exceptional specific strength and resilience to corrosive conditions. It possess the unique quality of being used in cryogenic environments (such as space shuttle external fuel tanks) with phenomenal high bake strength. Initialization files, on the other hand, were made from AA2219 alloy and employed in high-performance conditions that necessitate a high level of reliability. [5-8].

The composite materials based on aluminum 2219 alloy are remarkable in relevant fields for mechanical reinforcement that is indispensable to high-performance applications. The composites have characteristics of AA2219, which are its innate properties such as tensile strength in the longitudinal direction, machinability, and stress corrosion resistivity along with the reinforcements like boron carbide (B_4C) or silicon carbide (SiC) particles. These ceramic reinforcements significantly improve the composites' hardness, wear resistance and overall durability [9-10].

The incorporation of B_4C particles, example imparts the composite with good hardness and wear resistance making it appropriate for those components that undergo high mechanical stress/friction. This is especially useful for aerospace and military applications where the materials have to survive severe stress, pressure, and temperatures in addition must keep structural integrity. In addition, the AA2219 composites' mechanical properties are additionally expanded by applying an age-hardening treatment that promotes precipitate formation strengthening phases leading to a rise in yield strength and hardness [11-12]

Studies conducted by Hashim, Looney and Hashmi [13] reported the mechanical behavior of AA2219 alloy in reinforced with boron carbide (B_4C) particulate. Noticeable hardness and wear resistance enhancements qualitatively explained by the even distribution of these B_4C particles within aluminium matrix, were recorded as significant improvements. AA2219- B_4C composites were regarded as promising materials for applications that require increased wear performance and mechanical durability [10].

Totten & Mackenzie [14] had examined different heat treatment processes influence on AA2219 composites. The study indicates that age hardening to a great extent influence composites' tensile strength and hardness. The precipitation phases which were developed during the aging process also took part in restricting dislocation movement and thereby improved the material's mechanical properties. Miller [15] studied side by side high temperature mechanical properties of AA2219 and its composites. AA2219 alloys showed no major loss of mechanical strength at high temperatures by this study, so they could be eligible materials for aerospace purpose. In this study, the reinforcement of AA2219 with ceramic particles has been found to have a more pronounced effect than that previously reported in terms of its potential for high-temperature applications which ends up being an excellent choice for critical structural parts. Polmear [16] et al. carried out an analysis of AA2219 composites' mechanical characteristics at cryogenic temperatures. The composites also continued to exhibit high toughness and strength at low temperatures, which is crucial for aerospace and space exploration uses the study noted. Results proved that AA2219 composites are a potential high strength-low temperature duty material. Microstructural changes of AA2219 composites during heat treatment were investigated by Kaufman in [17]. The solution and aging treatment precipitates were finely distributed and greatly enhanced the yield strength and hardness of composites. The study highlighted the areas which need to be tackled for choosing the right set of parameters of heat treatment for materials based on AA2219 depending on the necessary mechanical qualities.

Literature review reveals how various mechanical testing conditions affect the mechanical features is less investigated for age-hardened AA2219 and its composites, even so, a variety of engineering applications have made extensive use of these alloys. Therefore, this investigation intends to enhance the mechanical characteristics of aluminium AA2219 matrix by integrating B_4C as reinforcements. As an additional step, an age-hardening process is also applied to enhance the composite's overall mechanical qualities like strength, hardness and yield stress. Given that dual process is used, it is

expected to produce a composite material with improved mechanical properties for high-performance applications.

2.0 Experimental Details:

The ingot-cast Al2219 alloy served as the study's matrix material. Al2219 is an Al–Cu alloy noted for having a high ratio of strength to weight, good machinability and excellent resistance to stress corrosion crack. This makes it an ideal choice for high end applications such as aerospace and military builds. The best material to use as reinforcement is boron carbide (B₄C), which comes in third place behind diamond and cubic boron nitride in hardness. The exceptional rigidity, lightness weight, high elastic modulus and good wear resistance of theirs make it an excellent candidate for metal matrix reinforcements to improve the superior characteristics.

Fig.1 (a-b) presents the SEM and EDAX of the as received particles' B₄C. Table 1 displays the comprehensive makeup of the Al2219 alloy, emphasizing its primary components and their corresponding proportions.

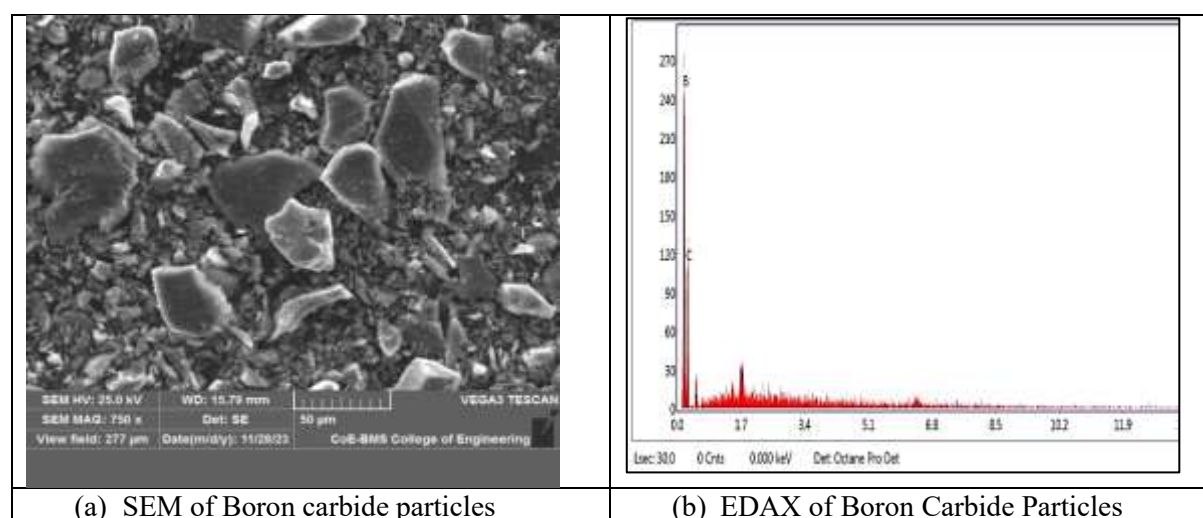


Figure 1(a-b). Boron Carbide particles' SEM and EDAX

Table 1. Aluminium 2219 alloy's Composition

| Elements | Si. | Fe. | Cu. | Mn. | Mg. | Zn. | Ti. | Al. |
|------------|------|-------|------|------|-------|------|-------|---------|
| Percentage | 0.17 | 0.275 | 5.62 | 0.18 | 0.019 | 0.13 | 0.018 | Balance |

3.0 Composite fabrication

Aluminium matrix composites were processed using stir casting techniques in this work. For melting the ingot AA2219 alloy at 700 °C, the furnace "innothermic electric resistance" is employed. Once the entire alloy had melted, a mechanical stirrer was placed inside and revolved at 300 rounds per minute in order to create vortices within this pool of liquid metal. A four-bladed, basic stirrer coated with alumina was used to minimize contamination at the time of the entire process. To improve wettability and remove moisture, 200°C-heated boron carbide (B₄C) particles were gradually introduced to the swirling molten aluminum alloy. The stirring process had been developed to ensure that the B₄C particles were dispersed uniformly. The duration of the experiment was 15 minutes, interspersed with 1-minute breaks every 5 minutes to enhance mixing efficiency. This study evaluated the impact of different reinforcement levels by systematically varying the B₄C particle concentration from 0 to 4 wt% at an interval of every two weight percent (2 wt%). After thorough mixing, the cast iron molds were heated, then molten liquid was poured into them for solidification to produce a composites of required dimensions.

3.1 Heat Treatment

The heat treatment was carried out in the laboratory to promote age-hardening precipitation and increase composites' hardness and strength after casting. The samples' soluble components were first dissolved by heating them at 540 °C in a muffle furnace for two hours as part of the solution process. The samples were then quenched in water to rapidly super saturation. Following this, artificial aging had been one at 200°C for four hours to diffuse solute atoms and harden the alloy. The present systematic heat treatment process is performed to enhance the hardness and strength of AA2219-B4C composites.

3.2 Hardness and Tensile test

Samples of alloys and composites that had been cast and heat-treated were examined for hardness using the Vickers hardness test, following ASTM E92. Tests on polished surfaces utilized a 100-gram load and a ten second dwell period. A servo-driven hydraulic system drove a 10-ton universal testing equipment, which was used to measure the tensile qualities. Specimens were loaded perpendicular to the loading direction. All tests adhered to the ASTM-E8 standard and were conducted at room temperature. After casting, specimens were sectioned longitudinally. The samples of a total of 3 were tested for every composition. The testing involves ductility, yield strength and UTS. The tensile test specimens' dimensions are displayed in Fig. 2.

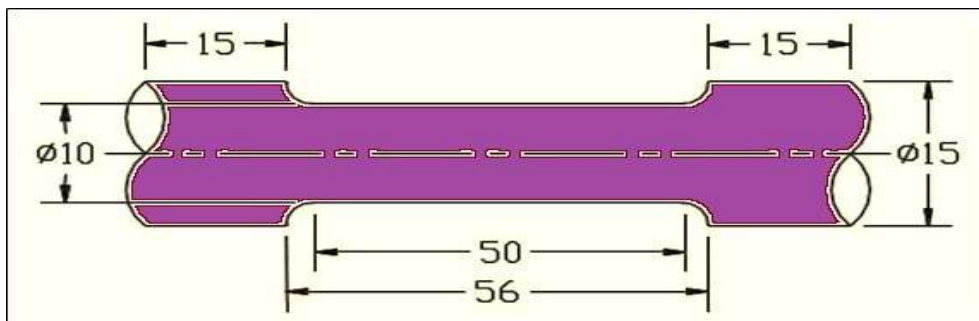


Figure 2. Dimensions of the Tensile test Specimen as per ASTM standard

4. Results and Discussions:

4.1 Microstructure:

Fig.3(a-d) illustrates the scanning microscopy (SEM) of AA2219-B4C composites produced by stir casting before and after heat treatment. The SEM pictures of the AA2219 alloy and composites, consisting of 2 and 4 weight percent B4C, are displayed in the Figure. The B4C particles have been uniformly spread throughout the matrix, forming a good connection between the matrix and reinforcement. Boron carbide (B4C) particles are observable both at the interfaces between grains and within the grains themselves. During the casting process, the B4C particles are compelled to the grain boundaries and remain there. The improved microstructure seen in AA2219-B4C composites owing to B4C particles presence, which serve as effective reinforcement during the solidification process.

Boron carbide (B4C) particles are distributed evenly within the matrix alloy, this is mainly due to two important factors: wettability of particle in molten metal and quality of interfacial bonding between reinforcement and matrix. Wettability is a very desirable characteristic for the molten matrix metal to completely cover B4C particles surface from every side giving necessary uniform particle distribution in alloy. Where the wettability is good, liquid metal can completely cover B4C particles and no agglomeration will occur in metallic melts which ensure proper distribution of such reinforcement material throughout the matrix. Revealing a homogeneous distribution is crucial to achieve the required enhancements in mechanical properties, including potential increases in both hardness and wear resistance. Apart from wettability, the strength and stability of interfacial bonding between matrix alloy and B4C particles are essential for overall performance on composite material. This results in the particles fixed into a matrix with excellent bonding at interfacial level, so that stress can be effectively transmitted between particle and matrix deformed under load [18-19].

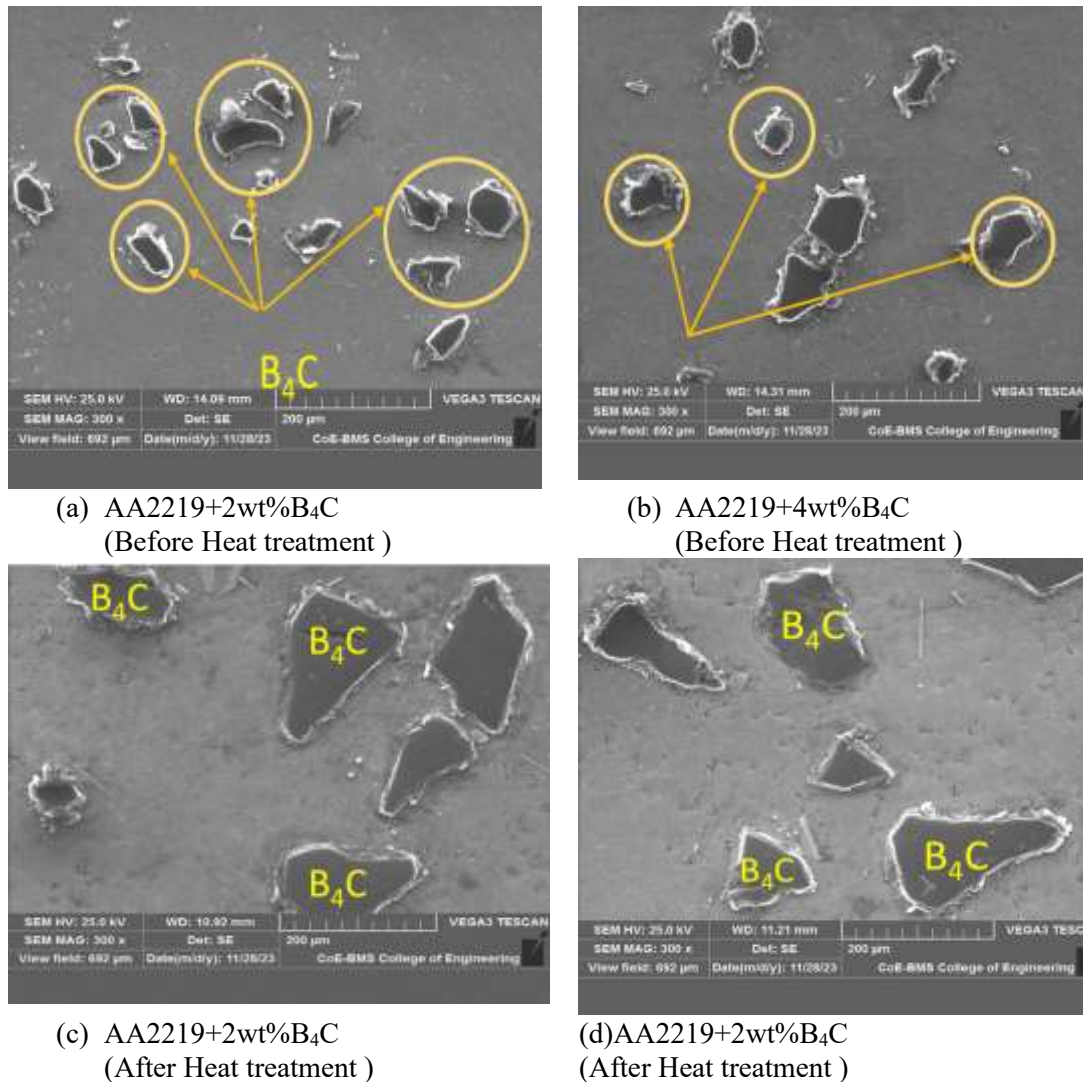


Figure 3. SEM of AA2219+B₄C composites before and after heat treatment

Fig.3 (a-d) shows composites SEM after heat treatment. A lot of substantial microstructural features observed on the scanning electron microscope (SEM) images of AA2219 alloy after solution treatment. Once generally all soluble components are dissolved, a homogenous solid solution is created through a comprehensive solid-solution treatment performed at 540°C for two hours. The uniform dispersion of alloying elements within the structure indicates that a highly concentrated solid solution is formed when a substance is rapidly cooled in water. Moreover, the precipitation of tiny, uniformly distributed strengthening phases, like θ' (Al₂Cu), is seen. The precipitates are visible in the SEM images as distinct particles that are uniformly dispersed within the aluminum matrix. By preventing dislocation migration, the precipitates' presence improves the alloy's strength and hardness [20-21].

4.2 Hardness

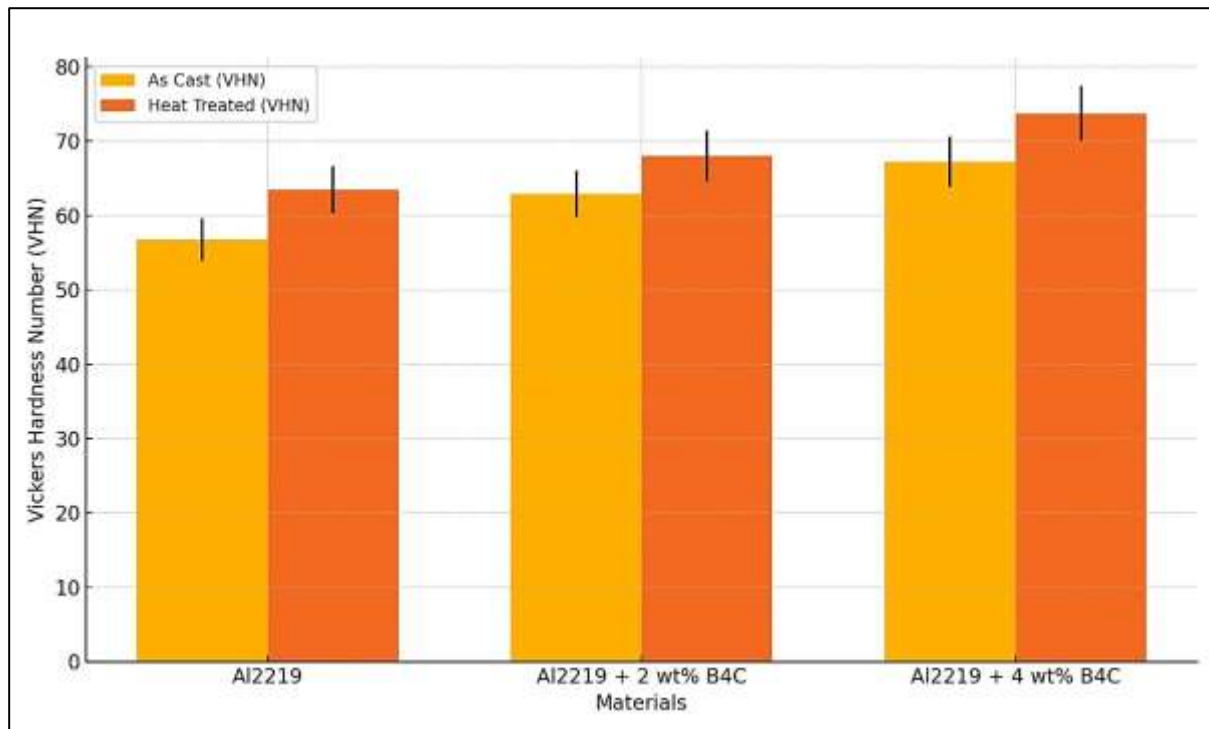


Figure 4. Graphical representation of hardness of AA2219+B₄C before and after heat treatment

The boron carbide (B₄C)-infused composites of the AA2219 alloy Vickers hardness values (VHN) are shown in the Fig.4. The percentage increase in hardness is highest for the composite with the addition of B₄C. This trend suggests that the B₄C inclusion and heat treatment process is effective in enhancing the hardness of the material, likely due to the precipitation of strengthening phases. Incorporating B₄C increases hardness; the positive effects increase with increasing B₄C content. The inclusion of B₄C, however, partly mitigates the relative increase caused by heat treatment, suggesting that the reinforcing particles may already be making a substantial contribution to the material's hardness in its as-cast form. This implies that in the as-cast condition, the hardening impact of B₄C is more noticeable.

Adding 2 wt% and 4 wt % boron carbide (B₄C) to the AA2219 alloy significantly enhances Vickers hardness of cast samples. Various research investigations have examined the potential causes of the noticeable rise in hardness. Boron carbide (B₄C) is known for its extremely hard surface and high modulus of elasticity, as well as exceptional resistance to wear. The average size of B₄C particles when dispersed in an Al matrix, they serve as strong impediments to dislocation motion; thus strengthening the material. B₄C particles have high hardness and can effectively transmit the externally dependent load to composite material, thereby reducing stress in surrounding aluminum matrix. This stress transfer mechanism makes their overall mechanical properties including hardness better. B₄C particles promote grain refinement of as-cast phase. Fine, evenly dispersed grains are responsible for the composite's excellent strength and hardness. This phenomenon has been well-documented through studies on ceramic-reinforced aluminum composites. The effective stress transfer and better interfacial bonding of aluminum matrix and B₄C particles improve the composites' mechanical properties. The necessity to achieve solid interfacial bonding in effort of maximizing benefits by particle reinforcement has been evidenced through thorough studies [22-23].

Solution treatment of AA2219 results in the dissolution of its soluble components at a temperature of 540°C, which forms a supersaturated solid solution. The supersaturated state is maintained by quenching. Aging at 200°C facilitates the development of fine precipitates, such as Al₂Cu. These precipitates cause an increase in hardness by limiting the dislocations' mobility. The B₄C particles function as a dispersion-strengthening agent. Their elevated hardness and modulus of elasticity confer substantial resistance to dislocation motion, so significantly augmenting the hardness of the composite. Studies on composites reinforced with ceramic particles have validated the efficacy of this method.

4.3 Tensile Properties

4.3.1 Ultimate Tensile Strength

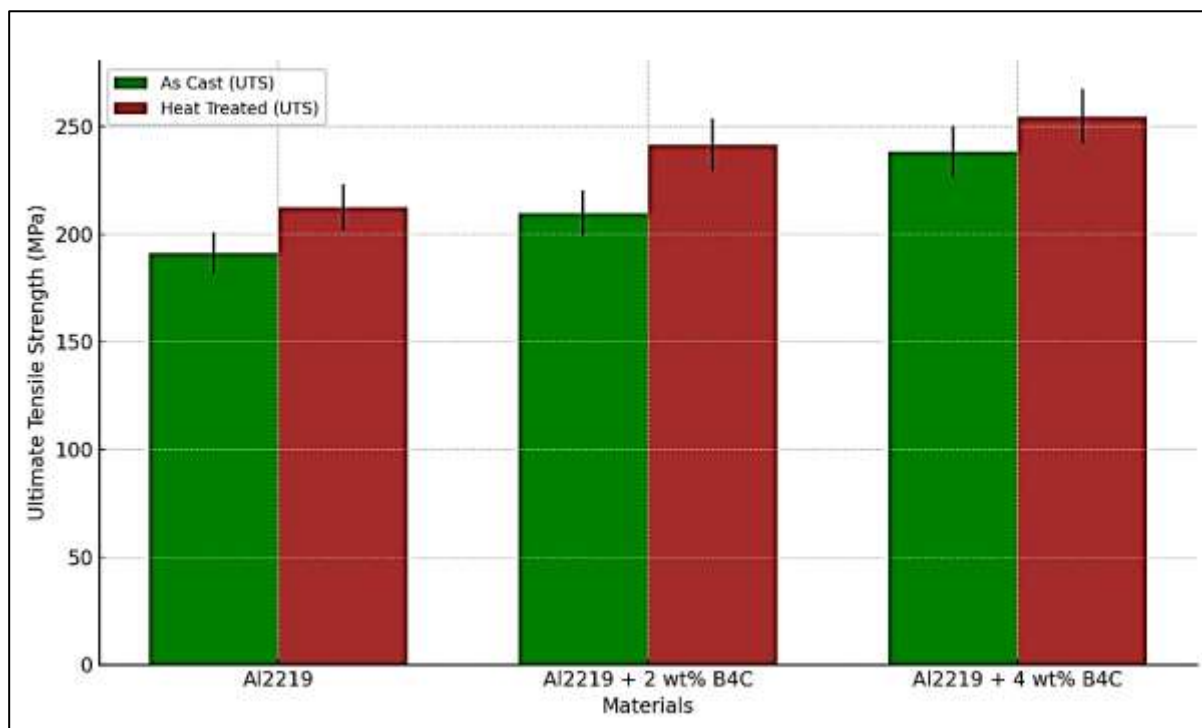


Figure 5. Graphical representation of ultimate tensile strength of AA2219+B₄C composite before and after heat treatment

Fig.5 presents the variation of ultimate tensile strength (UTS) values for AA2219 alloy-based composites reinforced with boron carbide (B₄C) which shows a clear trend of improvement with both B₄C addition and heat treatment. The inclusion of B₄C of two weight percent and four weight percent results in the enhancement of as-cast UTS for AA2219 from 191.11 MPa to 209.8 MPa and 238.3 MPa, respectively. The improvisation in the UTS was seen further after the heat treatment process. The observed values were 212.6 MPa for AA2219, 241.6 MPa for AA2219 + 2 wt% B₄C and 254.5 MPa for AA2219 + 4 wt% B₄C. The B₄C addition and subsequent heat treatment have been shown to significantly increase the UTS of the AA2219 alloy. There are many reasons for this phenomenon. The rigid B₄C particles inclusion to the AA2219 improves the mechanical characteristics of the material by means of dispersion strengthening. B₄C particles impede the dislocation motion, and this is a basic mechanism of metal deformation, thereby enhancing the strength of the material. The B₄C particles, known for their hardness, efficiently transmit applied stress from the aluminum matrix to the ceramic particles, hence enhancing the composite's total load-bearing capability. This phenomenon is most noticeable in the higher ultimate tensile strength (UTS) values as the boron carbide (B₄C) percentage increases. After undergoing heat treatment, the ultimate tensile strength (UTS) values see a further rise. The material is put through a solution treatment at 540°C, which causes precipitation hardening, and then aging is followed at 200°C. Well-dispersed, high-quality precipitates such as Al₂Cu are produced during the process of aging. These precipitates greatly improve the material's strength while preventing dislocations from occurring.

The process of heat treatment also contributes to the microstructure's refinement. The B₄C particles' inclusion helps in achieving a smaller grain structure and also aids in the generation of a more homogeneous and thus enhances the composites' mechanical properties. When heat treatment and B₄C reinforcement are used together, they work in concert to improve the processes involved in strengthening. The B₄C particles serve as sites for nucleation, promoting the production of precipitates throughout the aging process, hence enhancing the tensile strength of the composite [24-28].

4.3.2 Yield Strength

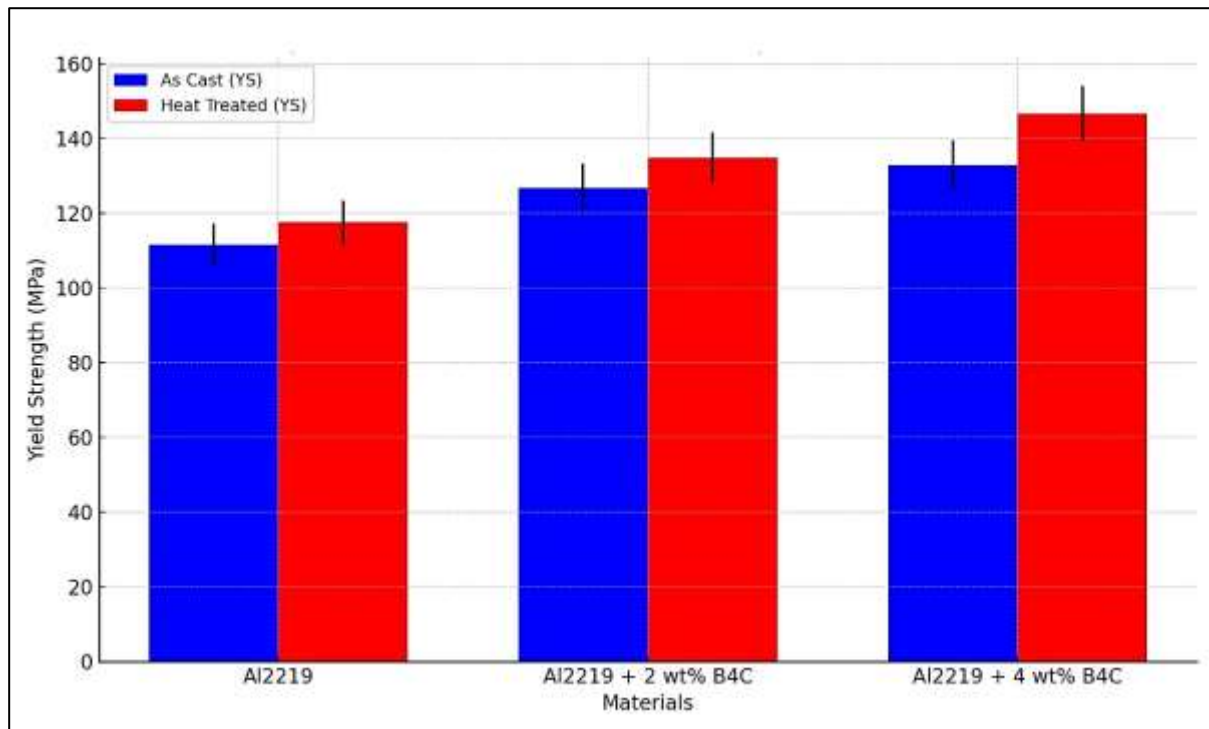


Figure 6. Graphical representation of yield strength of AA2219+B₄C composite before and after heat treatment

Fig.6 displays the yield strength fluctuation of AA2219 alloy reinforced with boron carbide and subjected to heat treatment. Yield strength values of composites improvisation based on AA2219 alloy is reported due to boron carbide particulates inclusion as well as heat treatment. The as-cast AA2219 material shows an YS of 111.67 MPa and it increases to 126.88MPa, and 132.98 with B₄C (2 wt% and 4 wt%) inclusion. In this instance, the hard B₄C particles' dispersion strengthening was credited with the strength enhancement. These particles increase the composite material's overall strength by preventing dislocations from moving.

The YS values are 117.56 MPa, 134.96MPa and 146.7 for AA2219, AA21-19 +2wt% B₄C, AA21-19 + 4wt% B₄C after heat treatment respectively. The increased strength of the material is primarily due to the precipitation hardening effect during aging under artificial conditions. The formation of these fine precipitates, in turn, pin down dislocations and significantly raise the material strength.

Evidently, the mechanism of increased mechanical behavior along with improved network strengthening associated to both B₄C reinforcement and heat treatment makes these composites suitable for high performance applications requiring enhanced yield strength. This result is proving the potency of these techniques in improving mechanical strength properties of AA2219 alloy composites. As stated earlier, the B₄C particles included into the aluminum matrix function as effective impediments to dislocation motion. The dispersion strengthening effect leads to increase in resistance against plastic deformation, thus expanding the composite material's yield strength.

The B₄C particles are considerably more durable and stiffer compared to the aluminum matrix, which enables efficient transfer of load. The applied stress is transferred from the more malleable aluminum matrix to the more rigid ceramic particles, leading to enhanced mechanical strength. Al₂Cu precipitates are produced when the material is put through 540°C of heat treatment and then artificial aging is done at 200°C. This results in a small, uniform distribution of particles. The dislocations movement is obstructed owing to these precipitates and this leads to an advancement of materials' yield strength. The inclusion of B₄C particles during the heat treatment process leads to a microstructure that is more precise and uniform. The enhanced mechanical qualities are attributed to the presence of fine grains and precipitates. The mechanical characteristics see a synergistic enhancement because of the combined influence of B₄C

reinforcement and heat treatment. The B₄C particles serve as sites of nucleation for the development of precipitates throughout the aging process, hence further improving the yield strength.

4.3.3 Ductility

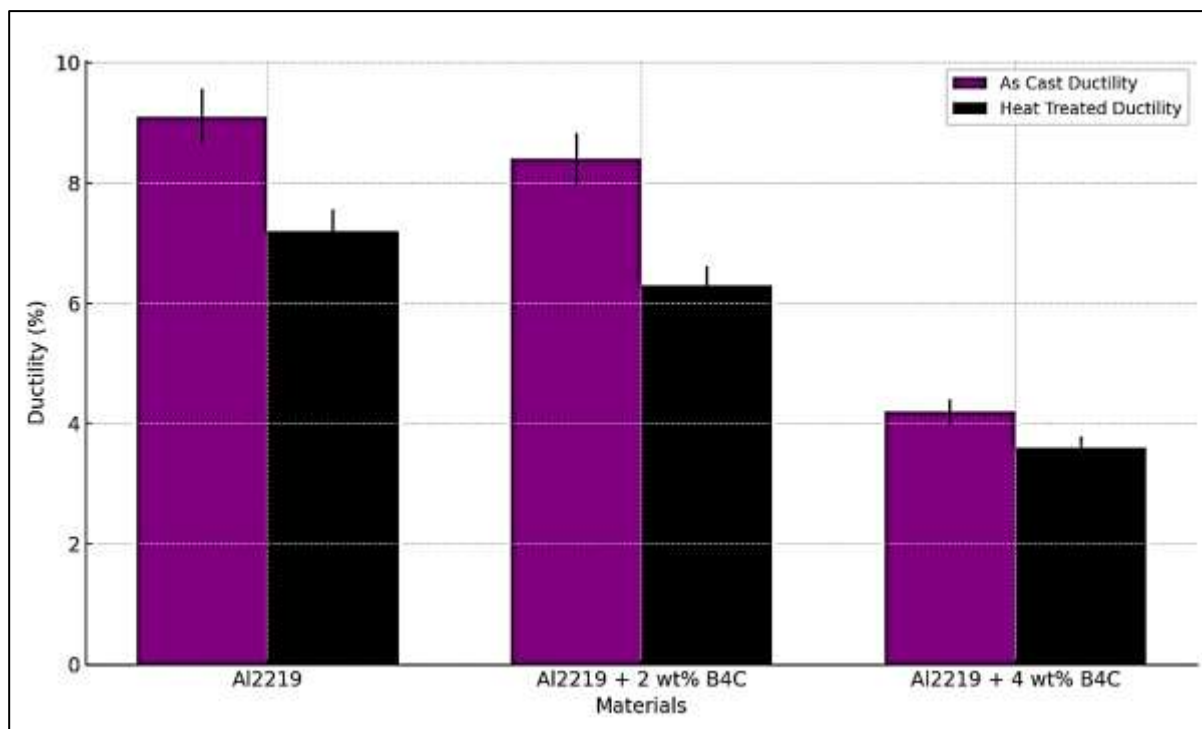


Figure 7. Graphical representation of ductility of AA2219+B₄C composite before and after heat treatment

Fig.7. displays the ductility variation with B₄C inclusion before and after heat treatment. The composite of AA2219 strengthened with B₄C particles and undergoing them the heat treatment leading to a decline of ductility owing to the heat treatment process and enhancement of B₄C. The ductility of the basic AA2219 alloy to 8.41% and 4.2% from 9.1% when 2 wt% and 4 wt% of B₄C are included in the basic composition. After heat treatment, the ductility of AA2219, AA2219 + 2% B₄C, and AA2219 + 4% B₄C decreases to 7.2%, 6.3%, and 3.6%, respectively. Heat treatment results in a reduction of 20.88%, 25.09%, and 14.29% in ductility in the respective composites.

The flexibility of the heat-treated AA2219 alloy with B₄C particles is lower. This means it doesn't bend or flow as easily because of the B₄C particles and the heat treatment. This behavior can be explained by several processes and rationales. The B₄C particles inclusion into the AA2219 matrix can improve the strength in spite that its ductility is generally reduced. This decrease in strength is directly related to hard B₄C particles that act as stress concentrators throughout the aluminum matrix. These particles have a propensity to initiate fractures when placed under tension, which can in turn lead to early failure and reduced ductility.

Precipitation hardening, a process that involves solution treatment and artificial aging, strengthens the composites and increases their mechanical strength. When small particles, like Al₂Cu, precipitate during artificial aging, it prevents dislocations from moving, which increases the material's strength but also makes it more brittle. The material's fragility contributes to the reported reduction in flexibility.

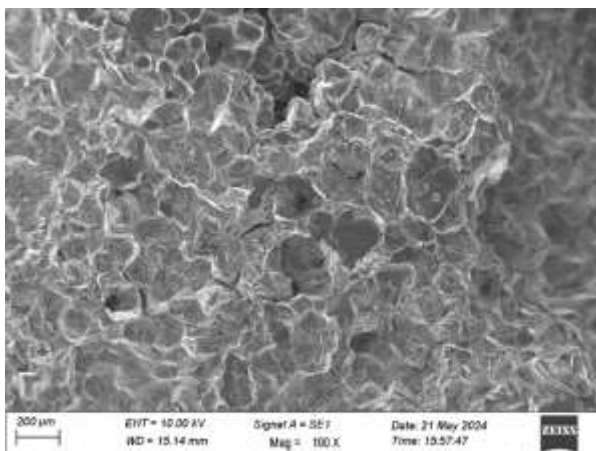
The combination of B₄C reinforcing and heat treatment intensifies the decrease in ductility. The inclusion of B₄C particles has two purposes: first, it creates locations where cracks can start, and second, it interacts with the precipitates that form throughout the aging process, which hinders the mobility of dislocations and enhances the brittleness of the material. This synergistic impact results in a more significant decrease in ductility when compared to the individual effects of reinforcing or heat treatment.

The addition of B₄C particles can modify the microstructure by facilitating grain refinement. Nevertheless, the engagement of these particles with the interfaces between grains might result in heightened fragility. Particles have the ability to immobilize grain borders, hence decreasing the occurrence of grain boundary sliding. This sliding is a process that plays a role in the malleability of metals. Residual strains can be generated because to the thermal mismatch between the aluminum matrix and the B₄C particles as they cool down from the heat treatment procedure. These forces can also decrease ductility by encouraging the beginning and spread of cracks [29-31].

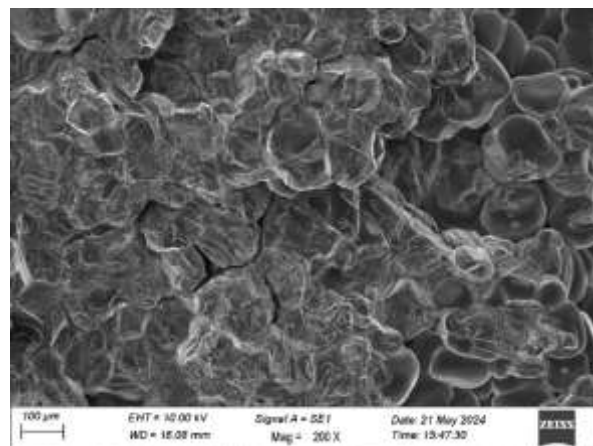
4.4 Fractured Surface Analysis

SEM pictures of the alloy and composites as cast and heat-treated, both before and after heat treatment, are shown in Fig. 8(a–f). The SEM was used to analyze the tensile fracture surface of both the AA2219 alloy and its composites. The study included examining the samples before and after heat treatment. The resulting images can be seen in Figure 8 (a-f), respectively. Figure 8b displays the fracture surfaces of AA2219 alloy and composites containing 4 wt% boron carbide (B₄C) content before and after heat treatment. Regarding the AA2219 alloy, as depicted in Figure.8(a-b), the fracture consists of voids and dendritic structures. The fracture surface exhibits visible aluminum dendrites, however, no notable harm was detected in primary aluminum. The fracture surface of the AA2219 alloy showed voids and dimples on a macroscopic level, suggesting ductile failure. The failure of the alloy can be ascribed to shrinkage porosity brought on by the large number of dendrites seen on the fracture surface. The shrinkage porosity that occurs throughout the processing stage acts as preferred locations for the development of cracks, and the fractured surfaces exhibit these locations. During the casting process, the occurrence of shrinkage porosity is highly likely when the molten metal's temperature is extremely high. In addition, the creation of gas pores and the segregation of materials are notable issues that are likely to occur when molten metal is kept for an extended period then poured at extremely high temperatures. Cracks often begin at the area of shrinkage porosity and then spread along the gas pores, resulting in the material breaking apart.

Another example can be seen in Figure 8(c-d) for composites with a 4 wt% content of B₄C particles, where it is shrinkage porosity that contributed most to the failure. Unlike the AA2219 alloy, this case of failure has not only derived from shrinkage porosity but also resulted that the particles cracked. Under strong tension, the failure process could first start with some small voids being formed. The increase of these vacancies is, however, limited by the triaxial stresses on matrix-reinforcement interface. Composites contain nanoscale voids, and this is thus the cause of fracture when stress concentration surrounding B₄C particles becomes high. However, for composites with a higher weight percentage of B₄C (as much as 4 wt%), some clusters are seen in which the particles cluster together and may also cause crack initiation/growth. These clusters prevent composites from succeeding in addition to leading to shrinkage porosity and particle cracking.



(a)AA2219 alloy (100X)



(b)AA2219 alloy (200X)

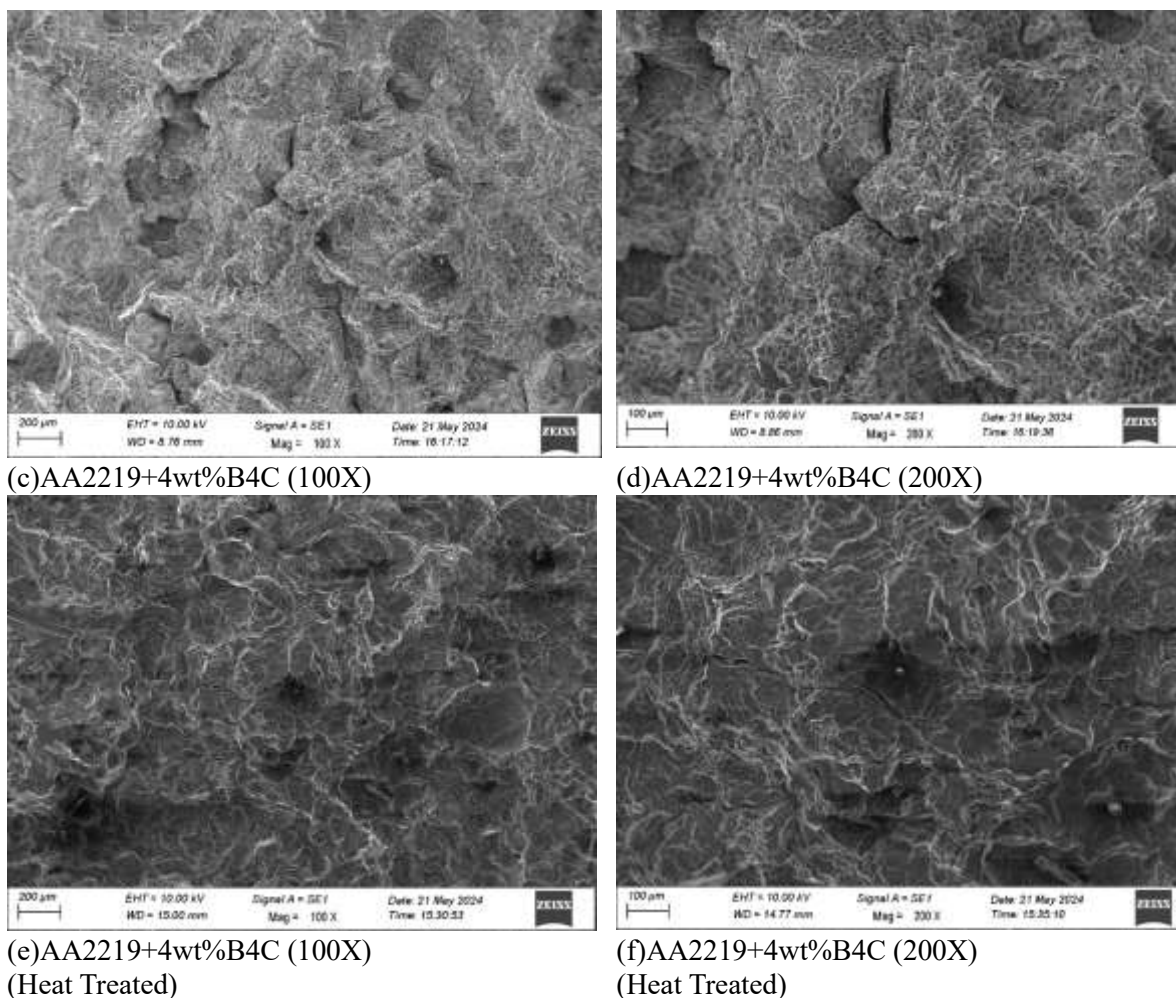


Figure 8(a-f). SEM of AA2219 alloy, and AA2219+4wt%B4C composite before and after heat treatment

The fracture surfaces of heat-treated AA2219 alloy and composites with 4 wt% B₄C content are illustrated in Fig. In the case of AA2219 alloy, as shown in Fig. (a), the fracture is formed of voids and dendritic structures, with aluminum dendrites evident across the fracture surface. Although the fracture surface suggested that the AA2219 alloy failed ductility, shrinkage porosity and stress concentration sites such as intermetallic compounds were the main causes of the failure. Although no appreciable damage was seen for primary aluminum, intermetallic complexes were seen in the grain boundaries. These intermetallic compounds serve as locations where stress is concentrated and are powerful sources for the initiation of fractures. In addition to shrinking porosity, the presence of stress concentration sites increases the likelihood of fracture formation and accelerates their propagation, ultimately resulting in the failure of the alloy.

Similarly, shrinkage porosity was the main reason for failure in the composites' case with 4 weight percent B₄C particles, as shown in Figure (c). All of the composites experienced restricted ductility as a result of the B₄C particle inclusion and precipitates, which caused brittleness. The brittle fracture and reduced ductility observed in the composites are because of the B₄C particle's premature cracking. As the tensile loading increases, the stress that occurs at the interface in three different directions restricts the expansion of empty spaces and prevents them from merging together. Continued accumulation of significant stresses causes a substantial concentration of stress in the vicinity of the B₄C particles, ultimately resulting in their fracture. Furthermore, cracks begin at the intermetallic compounds and, as the tensile stress increases, they tend to propagate more rapidly. Moreover, the failure of composites occurs as a result of fracture propagation caused by particle cracking and intermetallic pull-out [32-35].

5.0 Conclusions:

The present study's conclusions were deduced.

1. The scanning electron microscopy (SEM) observations indicated a more or less consistent dispersion of B₄C particles in the AA2219 matrix and that led to refined, as well as uniformly strengthened composite structure
2. AA2219 based composite found the best mechanical properties upon reinforcement with B₄C particles. After heat treatment, the Vickers hardness increased by 11.24% for a 2 weight percent B₄C composition and by 9.67% for a 4 weight percent B₄C composition.
3. After heat treatment, the Ultimate Tensile Strength data showed a considerable improvement with B₄C inclusion, showing an improvement of 15.16% at 2 wt% concentration of B₄C and 6.80% at 4 wt% concentration.
4. Heat treatment recrystallization significantly increased the composites' yield strength, 6.37% for composite specimens with 2 wt % B₄C and by as much as 10.32% in composite specimens containing B₄C particles of four percent.
5. A decline in the composites' ductility was seen. The reduction for the four-weight percent of B₄C is 14.29% and for the two-weight percent of B₄C is 25.09%. This highlights the trade-off between increased strength and decreased ductility. This indicates the compromise that exists between reduced ductility and greater strength.
6. The fracture surfaces' SEM analysis showed that shrinkage porosity along with particle cracking was the main reasons for the AA2219-B₄C composites' failure. Furthermore, a key factor in the initiation and spread of cracks was the stress concentrations existence at intermetallic compounds.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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