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Studies On Static and Fatigue Properties of Al2219 Reinforced with B4C

Dhruv Karkera[1], Suchith H Bhat[2], Akshay S[3], Suraj Naidu S[4], Supriya B[5]
[1,2,3,4]Student, UG – Mechanical Engineering, PES University, Bangalore, Karnataka, India.
[5]Assistant Professor, Department of Mechanical Engineering, PES University, Bangalore, Karnataka, India.
Emails: *dhruvkarkera03@gmail.com[1], suchithbhat.03@gmail.com[2], supriyab@pes.edu[3]*

Abstract
The static and fatigue behavior of Al 2219/B4C particle metal matrix composites are examined in this work. Using a stir casting procedure, 200 micron B4C particles with different weight percentages of 4 and 6 reinforced to create the composites. To examine how reinforcing particles improved fatigue and static behavior. The generated composites' performance compared to that of the alloy Al 2219.The outcome shows that adding B4C increases the fatigue strength of composites over the alloy. Using an optical microscope, the uniform distribution of the reinforcement particles within the matrix investigated. Additionally, both attributes significantly improved when the weight percentage of B4C reinforcement in the matrix was increased. There were fewer cycles as the load increased, suggesting that the load had a greater impact on the fatigue strength. In general, flexural strength and fatigue strength.
Keywords: *stir casting, 3 point flexural, fatigue strength, Metal matrix composites (MMCs), and particulate metal matrix composites (MMCp), scanning electron, microscopy (SEM).*

1. Introduction
A multiphase structural material made artificially or synthetically by mixing two or more components with different properties called a composite material. The substance produced shows a favorable mixture of the best qualities of the constituent phases and the constituents mixed at the macroscopic level and are insoluble in one another. Because they have become very popular because they are more affordable than continuous, fiber reinforced composites and have higher isotropic properties. Aluminum MMCs have been gaining popularity recently because of their unique qualities, which include being lightweight, inexpensive, resistant to corrosion, and having higher electrical and thermal conductivity. They provide a wide range of mechanical characteristics based on the chemical makeup of the reinforcement. Due to this they can demonstrate improved mechanical performance, such as strength, wear resistance and coefficient of thermal expansion [1–3], aluminum alloys with discontinuous or particulate ceramic reinforcements have grown in industrial significance. However, the sole disadvantage of these composites is that their inclusion in Al matrix composites causes them to become brittle and display low fracture toughness values [4-6]. The toughness of the composites mostly controlled by the characteristics of the particles, and cracking, non-uniformity, and modifications in matrix flow behavior thought to be the main causes of toughness deterioration. Numerous investigations on the mechanical behavior of particle- reinforced MMCs conducted, according to the literature, but relatively few studies have solely examined the mechanical characteristics of B4C particle-reinforced MMCs [8]. Thus, the current study examines the fatigue strength and three-point flexural test of an Al 2219 alloy matrix composite reinforced with B4C particles of various weight percentages of 4 and 6. Flexural stress thought of as a measurement of the energy used during bending. The composition of the matrix alloy, the kind, size, and orientation of the reinforcement, as well as the processing technique, all affect how flexural MMCs have the ability to resist bending. Fatigue is the phenomenon where a material or component fails under cyclic loading. The uneven distribution and inadequate bonding of reinforcement particles in the matrix phase are the main causes of crack formation and composite, heated B4C powder with particle sizes of 125 microns and weight percentages ranging failure of the composites under cyclic loading. [9]

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2. The Experimental Procedure and Methodology

The following steps make up the methodology used in this work:

- Material selection.
- Creating a composite by adjusting the quantity of reinforcement using the liquid metallurgical method (stir casting).
- Cast product manufacturing for test specimen preparation to assess fatigue and flexural behavior for both unreinforced and reinforced Al 2219 alloy
- In accordance with ASTM guidelines, specimens are prepared for fatigue and 3-point flexural test.
- Specimens are tested for fatigue and flexural in accordance with accepted test protocols.
- A comparison between the composites' outcomes and the basis matrix Al 2219's outcomes. (Table 1)

2.1.Material Selection

The materials selected for the composite's construction are B4C particles for reinforcement and Al 2219 alloy for the base matrix. Because of its uses in tip truck bodies, rail cars, pressure vessels, shipbuilding, mine skips, and cages, alloy Al 2219 was selected. Because of its great hardness, which ranks it among diamond and cubic boron nitride, the B4C particle is used to reinforce with the base matrix. The alloy and B4C have respective densities of 2.71 and 2.51 gm/cm3. Al 2219's chemical makeup listed in Table 1. Ingots of Al 2219 alloy and B4C particles seen in (Figure 1, 2) [2]

Table 1 Chemical Composition of Al 2219 by Weight Percentage [%] [11]

Cu	Fe	Mg	Mn	Si	Ti	V	Zn	Zr	Al
5.8-6.8	0.3max	0.02	0.2-0.4	0.2	0.02-0.1	0.05-0.15	0.1	0.1-0.25	Bal.

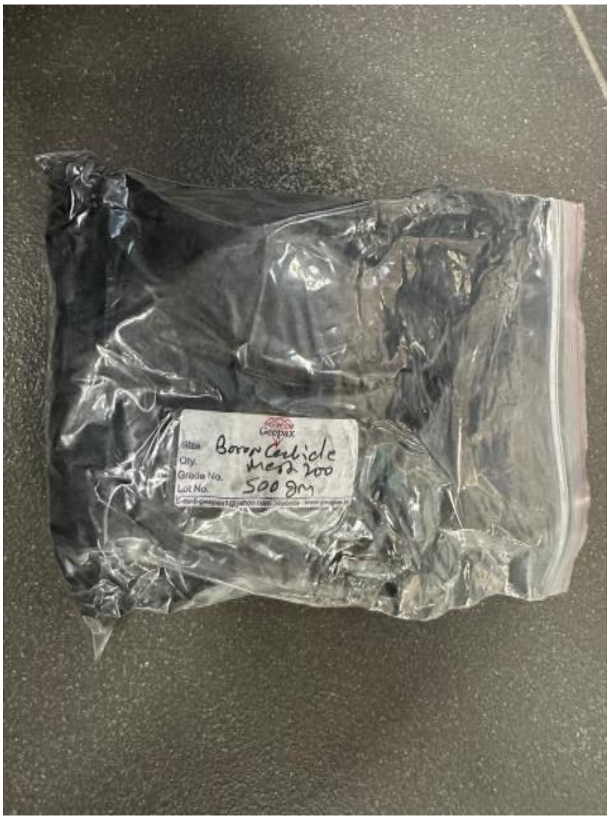

Figure 1 Boron Carbide Powder

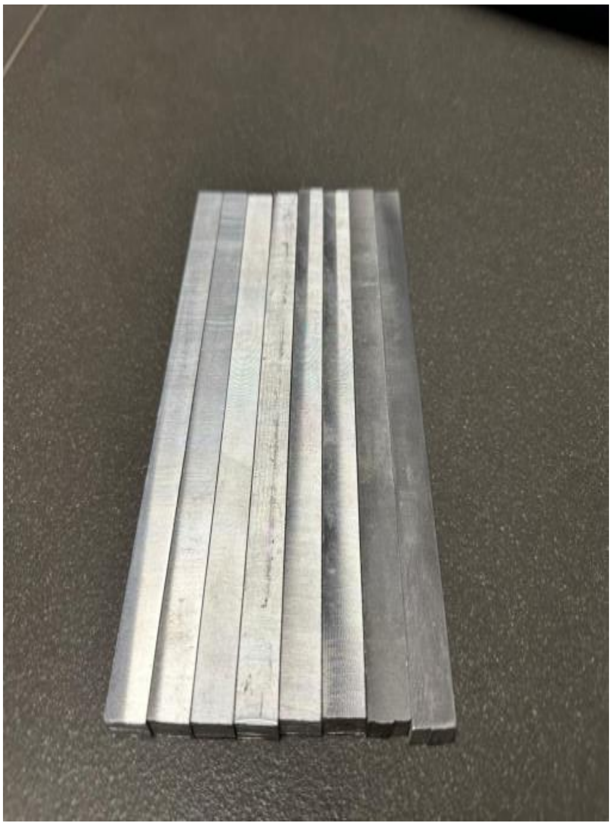

Figure 2 Al2219-Alloy Ingot

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2.2.Fabrication of Composites

Al 2119/B4C MMC prepared using the stir casting process. In an electric resistance furnace, the weighed amount of matrix metal Al 2219 heated above 7300C in a graphite crucible to melt it. In order to guarantee uniform dispersion of reinforcement particles in the composite, heated B4C powder with particle sizes of 125 microns and weight percentages ranging from 4 to 6 added to the molten metal's vortex at this point. The slurry continuously stirred for five to ten minutes by spinning the impeller at 450 rpm. Once more, the melt superheated above 8000C before placed into permanent cast iron molds warmed, sized for a flat dog bone shape of 28mm*150 mm.

2.3.Preparation of Specimens

The ASTM (E466-15) standard followed for machining the fatigue test specimens and flexural test specimens with elongated cuboid also machined and finished as per ASTM standards, shown in Figure 3 and 4) [3]

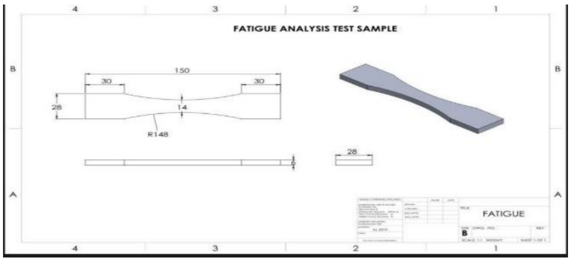

Figure 3 **Fatigue Test Specimen ASTM (E466-15)**

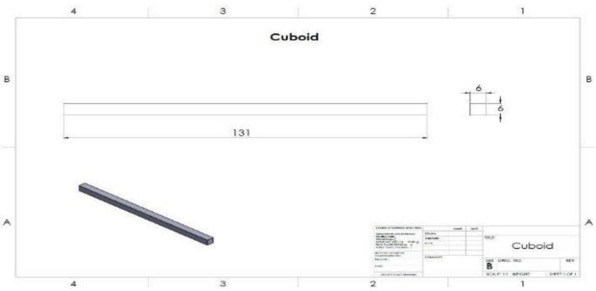

Figure 4 **Flexural Test Specimen ASTM**

2.4.Microstructural Study (SEM)

Cast specimens used to manufacture the specimens for the microstructure analysis. For a smooth 0.2 micron finish, later specimens were polished using fine-grade emery sheets. Prior to examination under an optical microscope for microstructural analysis, the polished specimens etched. [4]

3. Results and Discussions

3.1.Fatigue Behavior

The Al2219/B4C composite's fatigue behavior was assessed in terms of fatigue life. Data of the test is tabulated as shown in Table-2 and specimens before and after failure are as shown in figure 5(a) and (b). (Table 2) (Figure 5)

Table 2 **Fatigue Test Data**

Sl. No.	Material	Load (Kg)	Stress amplitude (MPa)	Speed (RPM)	No. of cycles to fail (N)
1	Al2219	4	1.40	2000	31,629
		3	1.05	2000	52,324
3	Al2219 + 4% B_4C	4	1.40	2000	48,812
		3	1.05	2000	78,123
4	Al2219 + 6% B_4C	4	1.40	2000	43,421
		3	1.05	2000	66,736

Figure 5 **Fatigue and Flexural Specimen ASTM**

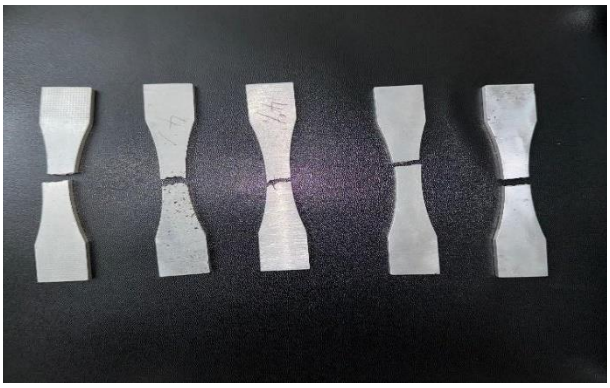

Figure 6 **Fatigue Test Specimens After Failure**

All test specimens' fatigue behavior is illustrated by S-N plots, as seen in Figure 6(a)(b)(c), where every component had normal S-N behavior and reached the fatigue limit prior to 105 cycles, which served as the fatigue studies' run-out point. Compared to pure alloy Al2219 and 6%B4C reinforcement, Al2219 with 4% B4C demonstrated a longer fatigue life. The fatigue lives of Al2219, Al2219 with 4wt% B4C, and Al2219 with 6wt% B4C were measured to be 52324, 78123, and 66736 cycles at an absolute stress level of 1.05MPa. This is because the reinforcing particles in the matrix phase are uniformly distributed and well bonded, which would otherwise be the main factor contributing to the composites' failure and crack initiation under cyclic loading. (Figure 7,8) [5]

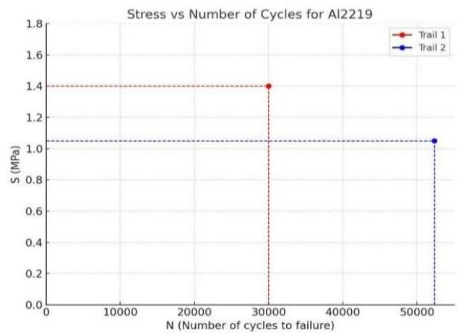

Figure 7 **S-N graph for Al2219**

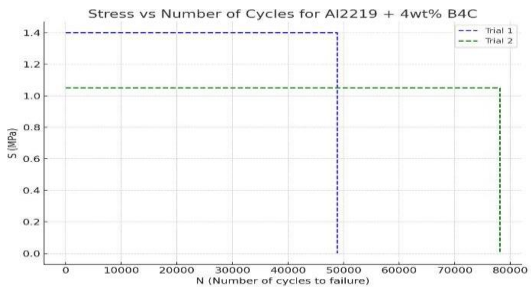

Figure 8 **Al2219+4%wtB4C**

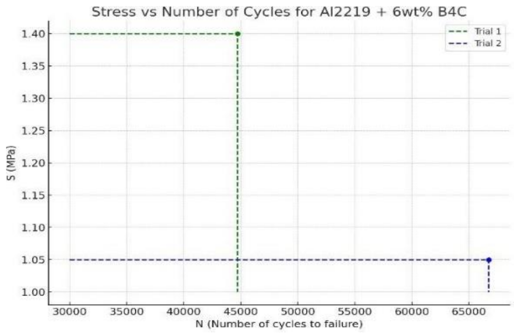

Figure 9 **Al2219+6%wt B4C**

3.2.Flexural Test

The modulus of elasticity in bending Ef, σf, and ϵf, as well as the material's flexural stress–strain response determined by the three-point bending flexural test. This test is conducted using a three-point fixture on a universal testing machine, also known as a tensile tester or tensile testing machine. A three-point flexural test's primary benefit is how simple it is to prepare and test the specimen. (Table 3) [6]

Table 3 **Flexural Test Data**

S No.	Al2219 Percentage (%)	Failure at load (kN)
1	0% 0%	0.321kN 0.311kN
2	4% 4%	0.387kN 0.379kN
3	6% 6%	0.376kN 0.371kN

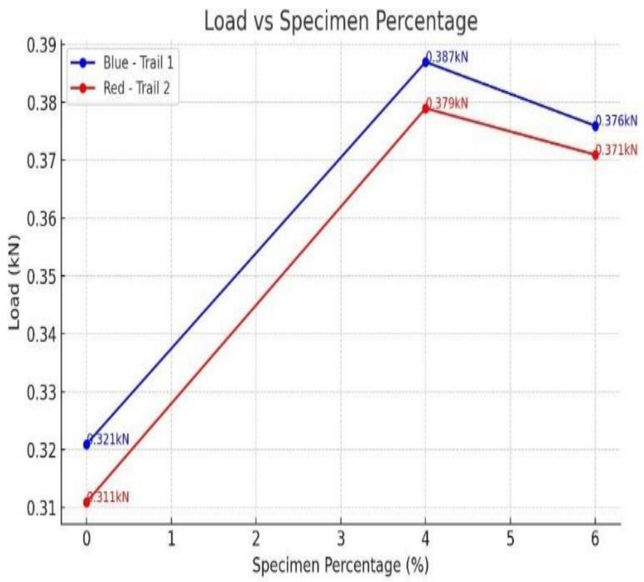

Figure 10 **Graph for Load Vs Specimen Percentage**

Through this result from 3-point bending test we can see that Al2219 when reinforced with 4wt% of B4C is the strongest composite among the 3 samples, while the flexural strength of 6wt% of B4C is more than that of 0wt% of B4C it is noted that there is drop in strength of the composite after 4wt% of B4C. Hence, we can say 4wt% of B4C is where the composite has the highest flexural strength. (Figure 11)

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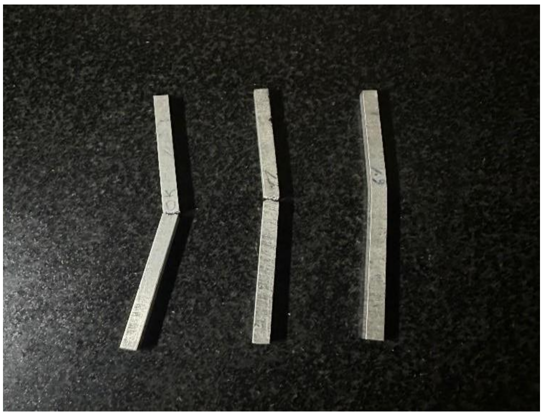

Figure 11 3-Point Bending Test Specimens After Failure

3.3.Microstructural Evaluation

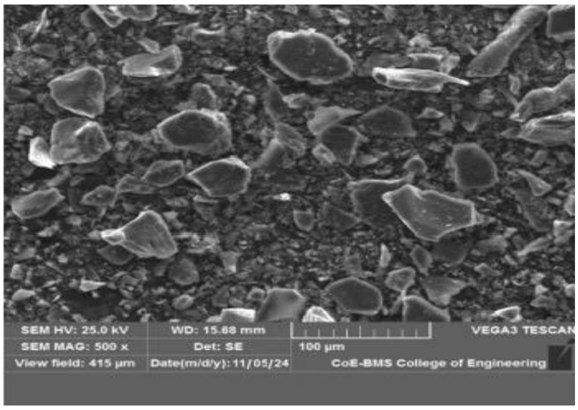

Figure 12 Boron Carbide Particles

Using a 500x magnification, SEM analysis was performed to assess the particle dispersion in 50-micron sized boron carbide. It determines if the boron carbide is pure or contaminated by using such a high magnification. (Figure 13) [8]

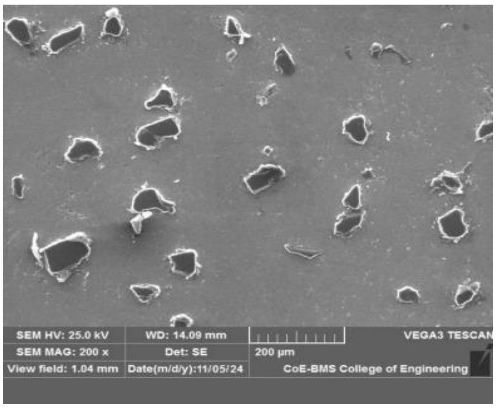

Figure 13 Al2219 with 4wt%B4C

The distribution of B4C in the Al2219 alloy was found to be uniformly distributed throughout the area of the composite where the examination was carried out, according to SEM analysis performed at 200x magnification. The particles effectively distributed throughout the plasticized aluminum alloy by a rotating tool (Figure 14) [7]

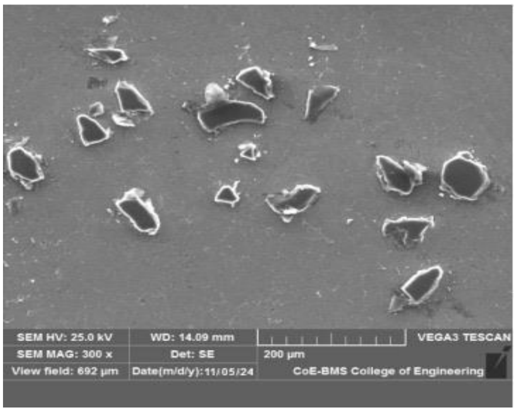

Figure 14 Al2219 with 4wt%B4C

300x magnification was used for the SEM study. B4C particles of varying sizes dispersed across the region. The B4C particles securely attached to the matrix, as this picture demonstrates. Additionally, particle clustering not seen throughout this research. (Figure 15) [9]

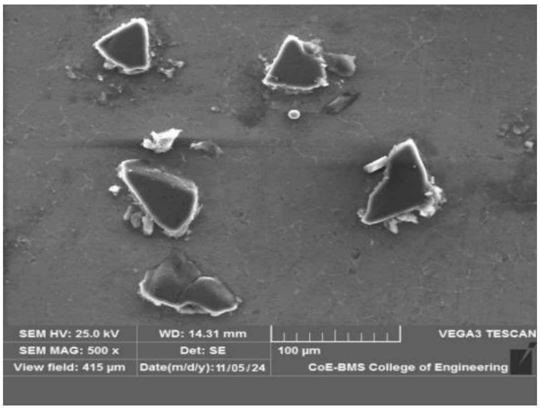

Figure 15 Al2219 with 4wt%B4C

SEM analysis at 500x magnification revealed larger B4C particles distributed at larger intervals, without defects. SEM allowed for uniform particle distribution, agglomeration, and interaction between reinforcement and aluminum matrix, detecting fine details like particle boundaries and defects. [10]

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Conclusion

The examination of the flexural and fatigue behavior of Al 2219/B4C particulate metal matrix composites was the current study's primary goal. The liquid stir casting process was used to successfully create MMCP with different weight percentages of 0, 4, and 6. During optical microscope microstructure evaluation, it was observed that B4C particles exhibit greater wettability with aluminum alloy, leading to a homogenous dispersion in the metal matrix. The B4C particles evenly distributed throughout the metal matrix. Due to the type, size and even particle distribution inside the matrix, the addition of B4C reinforcement to the Al 2219 alloy matrix improves both fatigue life and flexural strength. According to analysis, adding 4 weight percent B4C reinforcement to the Al 2219 matrix increased the alloy's flexural strength by 33.34% and fatigue life by 63.97%.

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