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Processing, Microstructure, Hardness and Wear Behaviour of Nano B_4C Particulates Reinforced Al2219 Alloy Composites

Shashidhar S[1], P Vijaya Kumar[2], Shivanand H K[3], Madeva Nagaral[4]

[1]*Research Scholar, Department of Mechanical Engineering, UVCE, Bangalore-560001, Karnataka, India*
[2] *Professor, Department of Mechanical Engineering, UVCE, Bangalore-560001, Karnataka, India*

[3]*Associate Professor, Department of Mechanical Engineering, UVCE, Bangalore-560001, Karnataka, India*
[4]*Deputy Manager, Aircraft Research and Design Centre, HAL, Bangalore-560037, Karnataka, India*

Abstract

Nano Aluminum metal matrix composites are considered as sophisticated materials in the field of Aerospace, Naval automotive, and other industrial considerations. The current work investigations are made to understand the impact of nano B_4C particulates inclusion on the Hardness and Wear characteristic behavior of Al2219-Nano B_4C alloy. Nano B_4C particles of 500nm size were adopted as the reinforcements in the Al2219 alloy matrix. Nano composites fabricated by using two stage liquid stir melt method in order of 2, 4, 6 and 8 wt. % in the Al2219 alloy matrix. Specimens were subjected for microstructural characterization using scanning electron microscope (SEM) and energy dispersive spectroscope (EDS). Hardness and Wear strength were evaluated as per ASTM standards. Scanning electron micro photographs revealed the uniform distribution of nano B_4C particles in Al2219 alloy and confirmed by EDS analysis. Further, Hardness and Wear strength of the foundation matrix Al2219 alloy is improved with the addition of Nano B_4C particulates.

Keywords: Al2219 Matrix Alloy, Nano B_4C, Melt Stirring, Microstructure, Hardness and Wear Behavior

1. INTRODUCTION

In the nearby scenario, there is a constant requirement for the weight and cost effective product designs to remain competitive all time, synthesis of composite materials and its improved material properties is always remained as best practical solution to convince market demand. In metallic materials, aluminum alloy is most preferred for research and development activities for its low density, economical, ease of accessibility and production, good interfacial bonding with reinforcements [1]. The combination of one or more materials, with one being with matrix phase (Al, Zn, Mg, Ti etc) and other being reinforcement phase (SiC, B_4C, TiC, Gr, Al203 etc), the two phases having different physical properties are combined by different processing techniques to form a new material known as composites with improved mechanical and physical properties [2-4].

From the matrix constituent, composites are categorized as organic-matrix composites, metal matrix composites (MMCs) and ceramic-matrix composites. Among these composites, aluminum metal matrix composites (AMMCs) with reinforcement of nano material possess highly enhanced mechanical properties such as good strength to weight ratio, improved specific modulus, superior damping capacity, stiffness, and good wear resistance. AMMCs have been the advances in materials in the past two to three decades and are widely used for major engineering applications like aeronautical, automotive, naval and civil structures [5, 6].

The reinforcement material is categorized in to four major groups based on the shape and size i.e. (i) continuous fibers (ii) short fibers (iii) whiskers and (iv) particulates. Among these particulates having a nano size reinforced MMCs are more attractive due to their cost-effectiveness, and isotropic properties [7, 8]. Various techniques are evolved for developing particulate reinforced AMMCs such as 1) liquid stage processing; 2) semi-solid manufacturing; and 3) powder metallurgy. From all liquid state processing the stir casting process is preferred because of its several advantages like simple process, cost effective, flexibility and help full in the mass production [9].

The significant problem in the procedure is to improve adequate wetting of scattered by the liquid fluid and to get a uniform homogeneous scattering of the nano particles. Interior imperfections, for example, porosity, molecule bunches, oxide considerations and interfacial responses are found because of unsuitable throwing innovation. With all the positive and negative focuses, just couples of researchers have been accounted for accomplishing fruitful throwing of AMMCs.

In current study, Al2219 is reinforced with nano B_4C particulates, by liquid stir metallurgy with two step stirring technique, which is identified to be one of the most potential method for different application under various controlled parameters in stir casting such as constant feed rate, stirring speed and room temperature cooling for the better interface bonding and distribution of the nano particles. The main objective of the current experimental study is to determine the Hardness and Tribological properties of the AMMCs by adding hard nano ceramic particles into the aluminum metal alloy.

2. MATERIAL USED

2.1Aluminium

Table 1: Shows the Chemical Composition of Al2219 Alloy by wt%.

Al	Cu	Fe	Mg	Mn	SiC	Ti	V	Zn	Zr	Others
Bal	6.8	0.3	0.02	0.4	0.2	0.10	0.10	0.1	0.20	0.15

The matrix stage, for the current experimental study depends on Al-Cu composition combination, assigned as aluminum association of Al2219. Aluminum is the third abundant component after oxygen and silicon. This baseline compound has low density 2.8 g/cm^3 among all Al composites and gives superior mix of quality, high erosion resistance, high elasticity, and great machinability and weldability. Table 1 demonstrates substance structure of Al2219 discovered by Spectro examination strategy.

2.2Nano B4C

Nano B_4C is one of the top order hardest material nano-boron carbide (B_4C) particles have high impeccability, limit run molecule estimate appropriation, and bigger particular surface region with low thickness of 2.52 g/cm^3. It as liquefying point up to 2350˚C, breaking point higher than 3500˚C, hardness up to 2800 BHN, flexural quality ≥ 400MPa; It has great as against oxidation, high temperature safe, high quality, high granulating proficiency, high hardness, high versatile modulus, high wear-safe, and great self-oil attributes alongside warm neutron catch cross segment, with brilliant neutrons retention property and great hostile to radiation execution.

3. EXPERIMENTAL PROCEDURE

The preparation of Nano reinforced metal matrix composites (MMCs) is carried out by the liquid metallurgy Stir casting method. By the choose of stir casting process, it is easy to achieve enhanced mechanical properties of the prepared Nano composite and to obtain a good interfacial bonding (wetting) between the nano reinforcement phase and the liquid matrix. In the present experiment, initially the matrix alloy (Al2219) is kept in the graphite crucible in an electric furnace having a maximum temperature of 1300˚C. The entire matrix alloy is melted at temperature of 750˚C, and then the degassing tablet known as solid hexa chlro ethane was added to the molten melt to remove all the unwanted slag content and volatile gases. At the drop of the temperature during the addition of C2Cl6 to the molten matrix [10], the Nano B4C particles are preheated to temperature of 600˚C to provide good bonding with the matrix phase, and mechanical equipment's such zirconium coated stirrer, and the mold are also preheated at temperature of 350-400˚C to remove all the moisture content. Then the 2% weighted amount of Nano particulates was added in to the melt at a constant feed rate and the continuous vigorous stirring was done for about 10 minutes at stirring speed of 400rpm. Then the entire molten melt was poured into the preheated mould cavity and allowed to cool at a room temperature. Similarly, the same process was repeated for different weight percentage (4, 6 & 8%).

4. TESTING

4.1 Hardness:

Brinell hardness test is used to examine the hardness of Al2219-Nano B_4C alloy composite specimens as per ASTM E-10 standard. The specimens of 12 mm dia and 5 mm thick are cut from as cast condition and the specimen surfaces are polished. Brinell hardness test is conducted for Nano aluminum alloy with a load of 500 kgf. The hardened-steel round ball of 10 mm diameter is used as indenter.

4.2 Wear:

A pin on disc model (Model: TR-201CL of Ducom, Karnataka, India), is used to inspect the dry sliding wear characteristics of composite as per ASTM G99 - 95 standards. The wear specimen (pin) of 8mm diameter and 25 mm height is cut from as cast samples machined. The weight of specimen is measured on a digital micro balance weighing machine with an accurate 0.1 mg and initial weight of the specimen is noted. During the test the pin is pressed against the counterpart, rotating against EN32 steel disc with hardness of 65 HRC, shown in **Figure 1**. After running through a fixed sliding distance, the specimen were removed and weighed to determine the weight loss due to wear. The difference in the weight measured before and after test gave the sliding wear of the Nano composite specimen and then volume and Weight loss is calculated.

Figure 1: Pin on Disc

5. RESULTS AND DISCUSSIONS

5.1Microstructural Studies

The prepared composites are characterized for microscopic studies. Specimens of 12mm diameter and thickness of 5mm were cut from the central portion of the casting for SEM//EDAX microanalysis studies.

Figure 1 (a-b) demonstrates the SEM microphotographs of Al2219 composite as thrown with 8 wt. % of nano B_4C particulate composites. This uncovers the uniform circulation

of B_4C particles and low agglomeration and isolation of particles, and porosity. The Figure b unmistakably demonstrates the even conveyance of nano B_4C particles in the Al2219 compound lattice. As it were, no grouping of nano B_4C molecule is apparent. There is no confirmation of giving deformities such a role as porosity, shrinkages, slag incorporation and splits which is characteristic of sound castings. In this, wetting impact amongst particles and liquid Al2219 amalgam network additionally hinders the development of the nano B_4C particles. In this manner, the particles can stay suspended for quite a while in the liquefy prompting uniform dissemination.

Fig A: As cast Al2219 Alloy

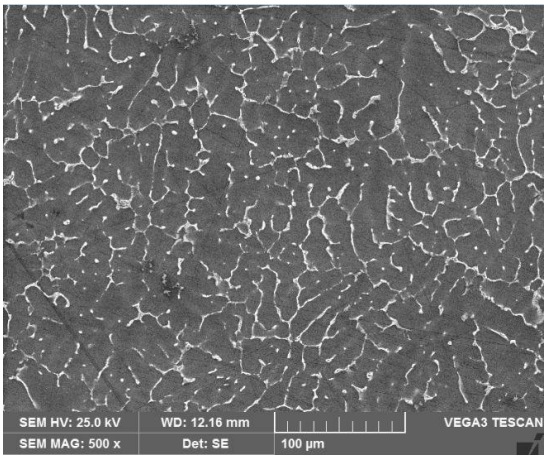


Fig B: Al2219-2%B_4C

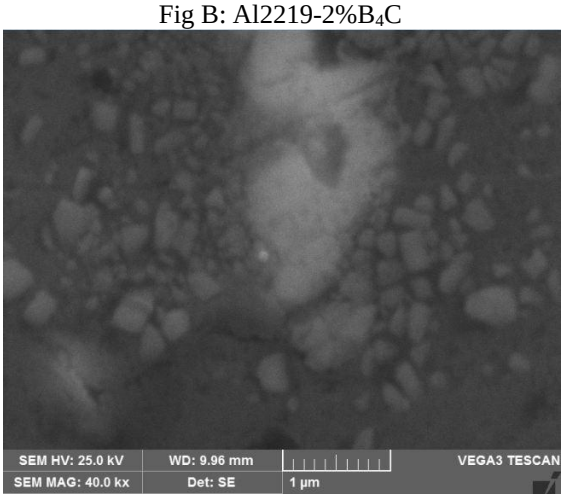


Fig C: Al2219-4% B4C

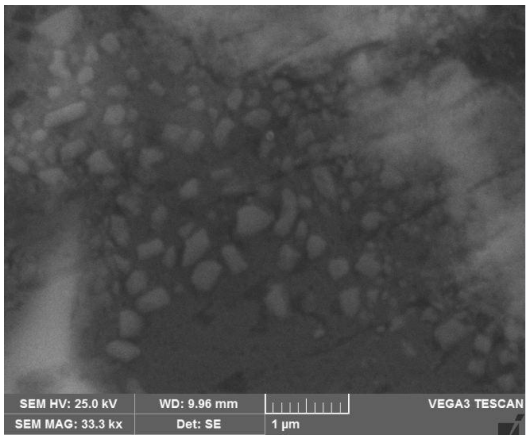


Fig D: Al2219-6% B4C

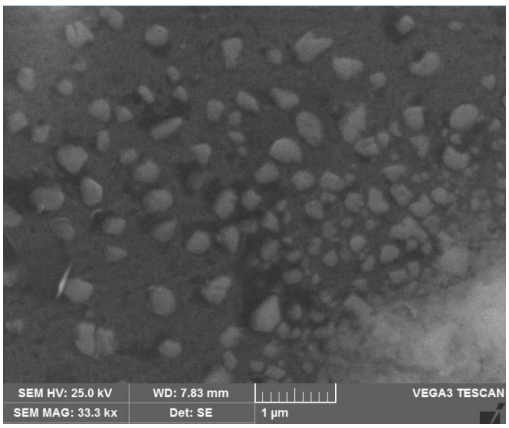


Fig E: Al2219-8% B4C

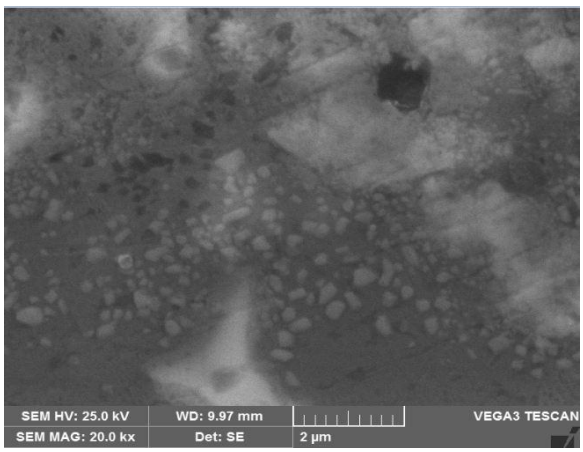


Figure 1: Scanning Electron Micrographs of Al2219 nano B_4C composites

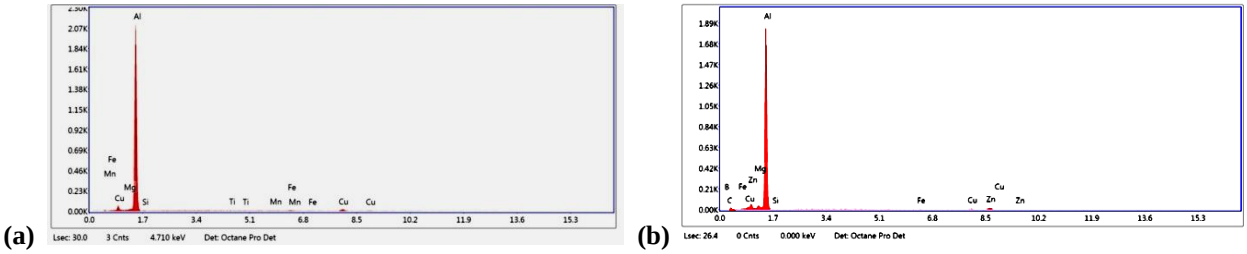


Figure 2: EDS spectrum of (a) Al2219 Alloy and (b) Al2219-8%nano B_4C composites

Figure 2 a, shows and reveals the chemical composition of Al2219 alloy without addition of reinforcement and figure 2b revealed the presence of nano B_4C particles in the aluminum matrix in the form of Boron (B) and Carbon (C).

When these high wear strength particles are added into the base soft matrix helps in the improvement of properties. Further, the enhanced wear strength is mainly due to presence of nano particles and acts as a barrier for the deformation during the wear load.

5.2 Hardness Measurements

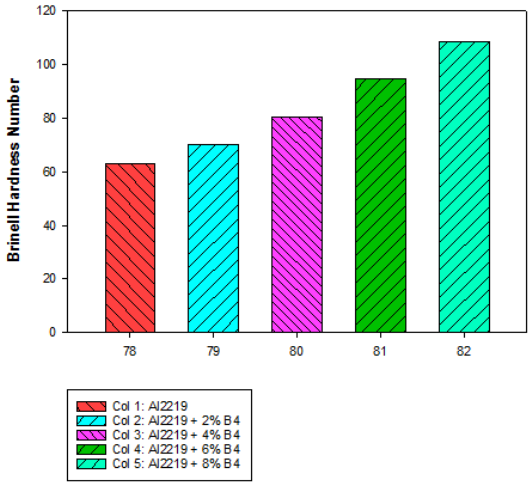


Figure 3: Shows the variation in Hardness of Al2219 alloy and nano composites

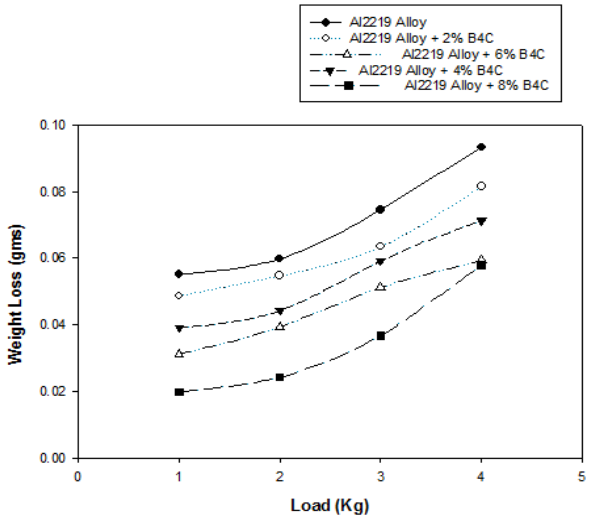


Figure 4: Shows the Weight Loss of Al2219 alloy and nano composites with Varying load and Constant Speed

Figure 3 indicates the variation in Hardness of Al2219 alloy and 2, 4, 6 and 8 wt.% nano B_4C particulates reinforced composites. Addition of nano reinforcements in the Al2219 matrix increases the surface area of the reinforcement particles and the matrix grain sizes are decreased. The presence of such hard nano B_4C material offers more resistance to plastic deformation which leads to increase in the hardness of nano composites.

5.3 Wear Strength

The results of Wear test for the as-cast and the nano B_4C composites are presented in Figure 4 & 5. It is shown from the graph, the Wear strength of Al2219 alloy enhanced with the addition of nano B_4C particles. Further, as weight percentage increases from 2 to 8 wt.%. The improved Wear strength is observed in the case of Al2219-B4C composites, due to high hardness of ceramic particles. Usually, these particles exhibits the high hardness and very strong in the wear nature [11, 12].

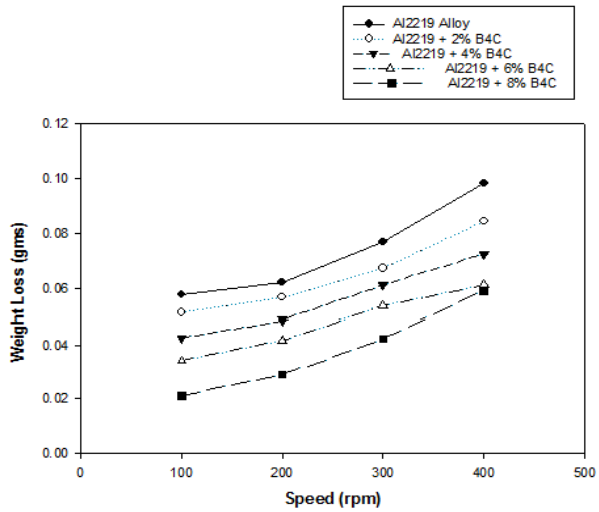
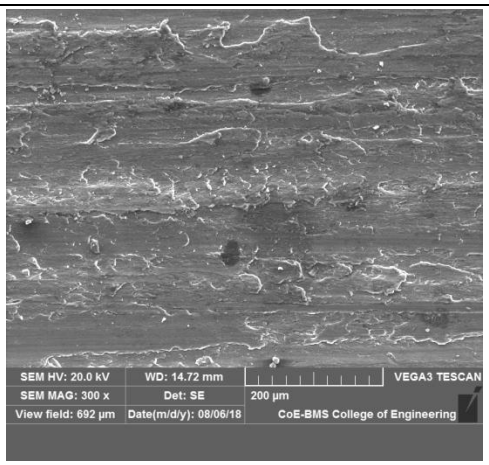


Figure 5: Shows the Weight Loss of Al2219 alloy and nano composites with Varying Speed and Constant Load

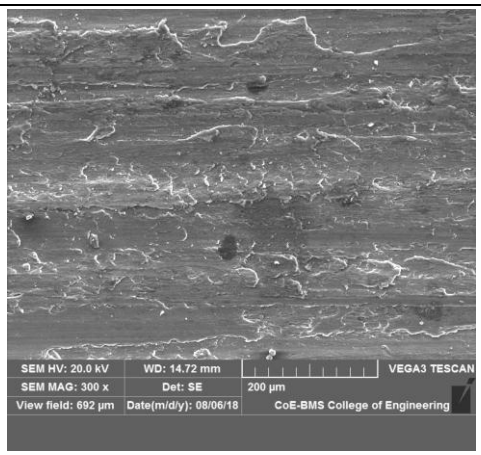
Weight losses recorded on Al2219 as cast and 2 to 8 wt.% B_4C reinforced conditions are shown in Fig. 8. Dry Sliding wear tests revealed that the addition of B_4C Reinforcements improve the wear resistance of the alloy. This beneficial effect of enhanced wear resistance is more apparent in the Nano Composites. The decreased wear is due to the formation of a stable B_4C on the worn surface.

5.4 Study of wear debris and worn surfaces

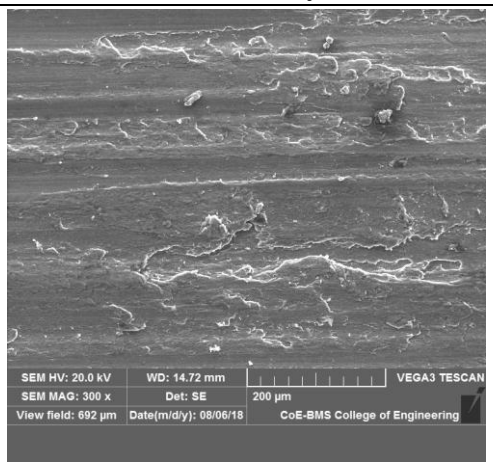
Using SEM the worn surfaces of the specimen are studied after the wear test. From the morphology of the worn surfaces it is observed that, the debris obtained from Nano composite specimen are fine and smooth. Deeper and Wider grooves in addition to craters are observed on the worn surfaces on Nano composites (as shown in Fig. 6) with coarse and rough debris.



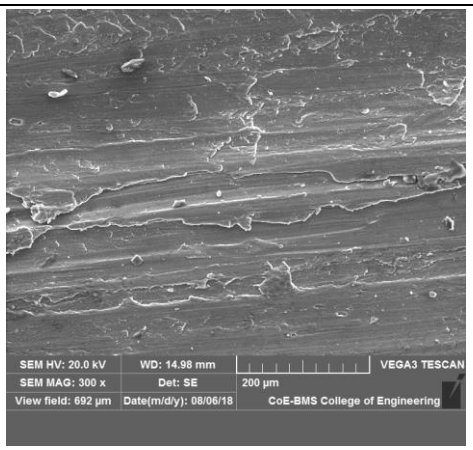
Al2219 Alloy



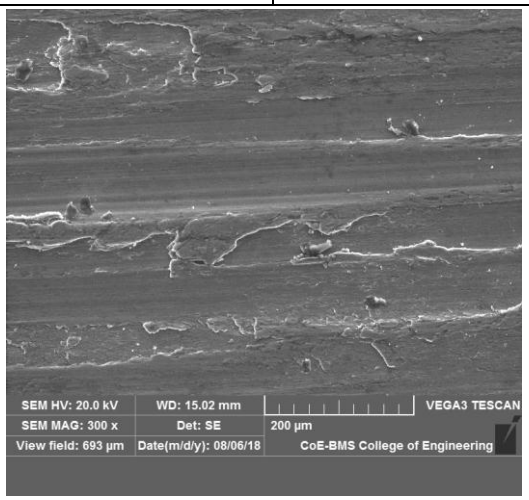
Al2219 + 2% B_4C



Al2219 + 4% B_4C



Al2219 + 6% B_4C



Al2219 + 8% B_4C

Fig. 6. Worn surface of Al2219 Nano Composites

6. CONCLUSIONS

In this research, nano B_4C/Al2219 composites have been fabricated by stir casting method by taking 2, 4, 6 and 8 wt. % of reinforcement. The microstructure, hardness and wear strength of prepared samples is studied. The matrix is almost pore free and uniform distribution of nano particles, which is evident from SEM microphotographs. The EDS analysis confirms the presence of nano B_4C particles in the Al alloy matrix. Abrasive action is in the direction of sliding but the wear debris are finer and smoother for Nano composite than conventional composites The Hardness of the composites are increased with the addition of nano B_4C particles. Wear properties of Al2219- nano B_4C composites are superior to those of unreinforced material.

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