Mechanical Behavior and Fractography of Al2218-Nano B_4C Metal Composites

Vidyadhar Pujar, Srinivas H K, Madeva Nagaral, V Auradi

Abstract *: In the present examination, the mechanical properties of Al2218-nano B_4C composites displayed. The composites containing 4 to 8 wt. % of nano boron carbide in ventures of 4 wt.% were readied utilizing liquid metallurgy method through stir casting. For every composite, fortification particles were preheated to a temperature of 400˚C and afterward added in ventures of two into the vortex of liquid Al2218 compound to improve the wettability and dispersion. Microstructural examination was carried out by SEM and elemental investigation was finished by EDS. XRD Analysis used to recognize the B_4C phases in the Al grid. Density, tensile, compression and hardness tests were done to distinguish various properties of composites. The aftereffects of this investigation uncovered that as the weight % level of nano B_4C particles were expanded, there was noteworthy increment in hardness, UTS, yield and compression strength of Al2218 amalgam composites. Further, there was slight drop in the density and malleability of the Al2218 amalgam composites when contrasted with the base. Tensile fractured surfaces analysis was conducted by using SEM.*

Keywords: Al2218 Alloy, Nano B_4C particles, Stir Casting, Microstructure, Mechanical Behaviour, Fractography

I. INTRODUCTION

Aluminum compound nano-composites are valuable in the aviation, car, marine, and auxiliary applications. The nano-composites have superior properties by using diverse ceramic powders, for example, boron carbide, zirconia, aluminum oxide and silicon carbide are added to the lightweight aluminum composite to improve the mechanical properties.Aluminum matrix composites (AMCs) are broadly utilized in aerospace, autos, and marine field because of the great quality, light weight and ease. Mechanical and wear conduct can be seen in brakes, gears, valves, cams, cylinder liners, grasps and different applications including sliding contact or moving contact [1]. AMCs are one of the propelled building materials that have been created for weight basic applications in the aviation, and more as of late in the automotive enterprises because of their astounding properties of high specific quality and better wear obstruction [2] Hard earthenware particulates, for example, zirconia, alumina (Al_2O_3) and silicon carbide (SiC) [3], have been brought into aluminum-based framework to build the quality, stiffness, wear opposition, erosion obstruction, weariness obstruction and high temperature resistance. Among these fortifications, B_4C is artificially perfect with aluminum (Al) and structures an enough bond with the grid [4]. Wear rate of aluminum lattice composites fortified with B_4C and SiC particles created through a similar course (weight less infiltration strategy) were dissected; the wear rate and contact coefficient of Al–B_4C was observed to be lower than those of Al– SiC under similar conditions. The point of the present examination is to assess the microstructure and mechanical conduct of Al2218 compound strengthened with nano B_4C particles. The stir technique is picked for the processing of AMCs. The impact of nano B_4C expansion on the hardness, tensile and compression strength of composite is researched. The microstructures of the example are considered utilizing SEM for the particle circulation and fractography examination.

Revised Manuscript Received on April 25, 2020.
* Correspondence Author
Vidyadhar Pujar*, Research Scholar, Don Bosco Institute of Technology, Bangalore and Assistant Professor, Dept., of Mechanical Engineering, The Oxford College of Engineering, Bangalore, India. Email: prasadnayak990@gmail.com
Srinivas H K, Professor, Department of Mechanical Engineering, SJBIT Bangalore, India. Email: khsri2006@gmail.com
Madeva Nagaral, Deputy Manager, Aircraft Research and Design Centre, HAL, Bangalore, India. Email: madev.nagaral@gmail.com
V. Auradi, Associate Professor, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur, India. Email: vsauradi@gmail.com

II. EXPERIMENTAL STUDY

A. Materials

In the present study Al2218 is used as the matrix material, most of the applications in areas such as aerospace, automobile, marine make use of 2xxx series, aluminium-copper alloys. Al2218 normally has 4.5% of copper and 1.8% of magnesium. The theoretical density of Al2218 alloy is taken as 2.80 g/cm^3.

Table1-I: The chemical composition of Cu-Zn alloy

Elements	Content wt. %
Si	0.90
Cu	4.50
Mg	1.80
Mn	0.20
Fe	1.00
Zn	0.25
Ni	1.5
Al	Bal

In the present work, nano B_4C particulates are used as the fortification materials, 500 nm particulates were used, which were obtained from Reinste Nano Ventures Ltd., Delhi. The density of B_4C is smaller than the matrix material, which is 2.52 g/cm^3.

B. Methodology

The manufacture of Al2218-B_4C composites were completed by liquid metallurgy through stir cast method. Determined measure of the Al2218 compound ingots were kept into the heater for liquefying. The melting temperature of aluminum composite is 660°C. The Al2218 alloy melt was superheated to 750°C temperature. The temperature of the melt was recorded utilizing a chrome-alumel thermocouple. The liquid metal is then degassed utilizing solid hexachloroethane (C_2Cl_6) for 3 min [5]. A hardened steel impeller covered with zirconium is utilized to mix the liquid metal to make a vortex. The stirrer will be turned at a speed of 300rpm and the profundity of drenching of the impeller was 60 percent of the height of the liquid metal from the outside of the liquefy. Further, the B_4C particulates were preheated in a heater upto 400°C will be brought into the vortex. Stirring was proceeded until interface connections between the fortification particulates and the Al matrix advances wetting. At that point, Al2218-4 wt. % nano B_4C melt was poured into the cast iron mold having measurements of 120mm length and 15mm width. Additionally, composites were set up for 8 weight level of nano B_4C particles in the similar method.

C. Methodology

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. At first, the cut examples were cleaned with emery paper up to 1000grit size pursued by cleaning with Al_2O_3 suspension on a cleaning disc utilizing velvet material. The cleaned surface of the examples etched with Keller's reagent lastly exposed to microstructure in an electron microscope.

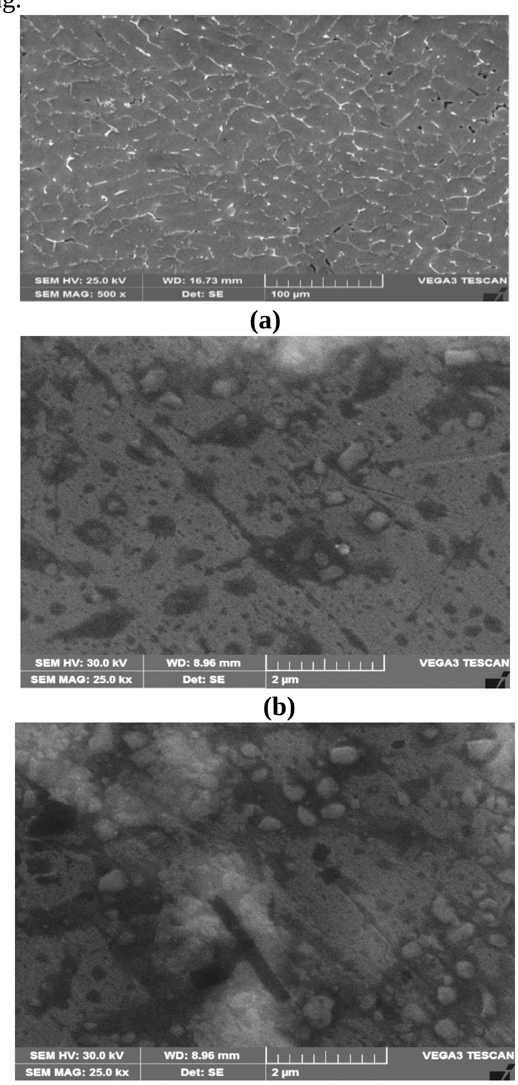
Hardness tests were performed on the cleaned surface of the examples utilizing Brinell hardness testing machine having a indenter of 5 mm diameter and 250 kg load for a stay time of 30 seconds, five arrangement of readings were taken at better places of the cleaned surface of the example and test was performed according to ASTM E10 [9]. The tensile and compression test was done on the cut examples according to ASTM E8 and E9 [10] standards utilizing universal testing machine at room temperature to ponder properties like UTS, yield strength, % of elongation and compression quality.

III. RESULTS AND DISCUSSION

A. Microstructural Analysis

Figure 1a-c shows the SEM micrographs of as cast alloy Al2218 and the composites of 4 and 8 wt. % of nano B_4C reinforced with Al2218 alloy composites. The microstructure of as cast Al2218 alloy comprises of fine grains of aluminium solid solution with an enough dispersion of inter-metallic precipitates.

It also exhibits the incredible bonding between the matrix system and the nano particles so uniform homogenous dissemination of nano evaluated B_4C particulates with no agglomeration and clustering in the composites. This is basically a direct result of the suitable mixing action achieved all through the extension of the fortress by two stages. The nano particles wherever all through the grain furthest reaches of the cross section hinder the grain improvement and contradict the partition advancement of grains during stacking.



(a)

(b)

(c)

Fig. 1 SEM of (a) as cast Al2218 alloy (b) -4 wt. % B_4C (c) Al2218-8 wt.% B_4C composites

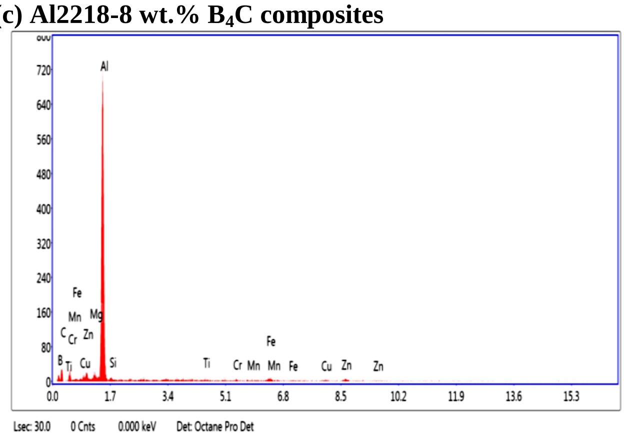


Fig. 2 Showing the EDS of Al2218-8 wt. % B_4C composites

From the figure 2 it is evident that nano B_4C particles are presented in the Al2218 alloy matrix in the form of B and C elements along with Al and Cu.

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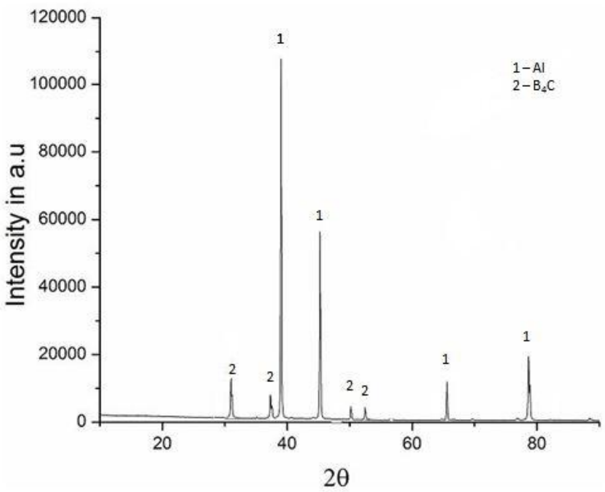

Fig. 3 XRD pattern of Al2218- 8 wt. % of nano B_4C composite

Figure 3 shows XRD pattern taken for Al2218- 8 wt.% B_4C nano composites to verify its quality and standard XRD pattern. It can be detected that peak height surges and then declines on 2-theta scale representing the occurrence of diverse phases of material. In fig. 3 it is visible that X-ray intensities of peak are higher at 38°, 45°, 65° & 78° demonstrating the occurrence of aluminium stage. Similarly, in fig. 3 it is observed the peaks for altered segments of boron carbide at 32°, 37°, 50° and 53°.

B. Density Measurements

Above figure 4 compares the theoretical & experimental densities of as cast Al2218 alloy, Al2218 – 4 and 8 wt. % B_4C composites. Aluminium alloy Al2218 has density of 2.8 g/cc, boron carbide has density of 2.52 g/cc. When aluminium alloy Al2218 is reinforced with 4 and 8 wt. % B_4C, the complete density of compound becomes less as B_4C density is lesser than Al2218 alloy. Further, it can be witnessed that experimental densities are slighter than the theoretical densities. Figure 5 demonstrates the variety in hardness with the expansion of 4 and 8 wt. % of nano B_4C particulates to the Al2218 composite. The hardness of a material is a mechanical parameter demonstrating the capacity of opposing nearby plastic twisting. The hardness of Al-B_4C composite is found to increment with the expansion of 4 and 8 wt. % nano B_4C particulates. This expansion is seen from 63.13 BHN to 96.7 BHN for Al composites. This can be attributed essentially to the closeness of harder carbide particles in the cross section, and moreover the higher limitation to the restricted framework disfigurement amid space because of the nearness of harder stage. Furthermore, B_4C, as like different fortresses strengthens the framework by creation of high-density disengagements in the midst of cooling to room temperature due to the qualification of coefficients of thermal extension improvements between the B_4C and network Al2218 compound. Confound strains created between the support and the lattice deters the development of separations, bringing about progress of the hardness of the composites.

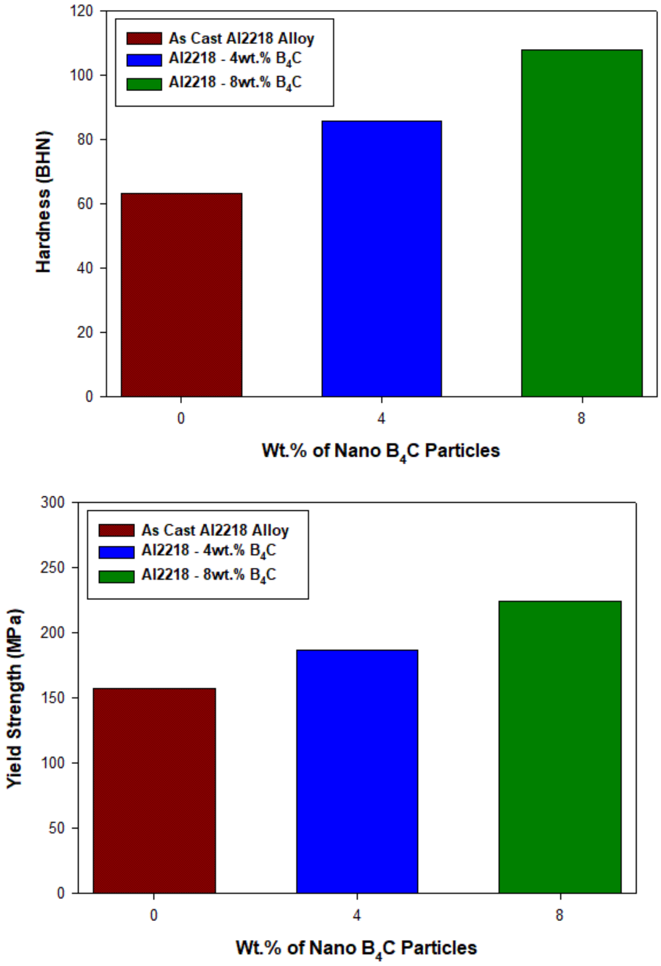

Fig. 5 showing the hardness of Al2218 alloy-4 and 8 wt. % B_4C nano composites

C. Ultimate Tensile and Yield Strength

The plot of ultimate strength (UTS) with 4 and 8 wt. % of nano B_4C dispersoid in metal grid composite has been presented in figure 6. The conscious estimations of UTS were plotted as a segment of weight rate of nano boron carbide particles. There has been a difference in 64 MPa in UTS regard when appeared differently in relation to base Al2218 compound when contrasted with 8 wt.% of nano B_4C strengthened composites.

The development in quality is credited on account of genuine contact between the matrix structure and nano materials. Better the grain gauge better is the hardness and nature of composites provoking to upgrade the wear opposition additionally. The improvement in UTS is credited to the closeness of hard nano B_4C particulates, which presents quality to the structure amalgam, along these lines giving improved unbending nature [6]. The extension of these particles may have offered climb to immense waiting compressive nervousness made in the midst of solidifying due to differentiate in coefficient of advancement between adaptable lattice and particles.

Retrieval Number: D7816049420/2020©BEIESP
DOI: 10.35940/ijeat.D7816.049420
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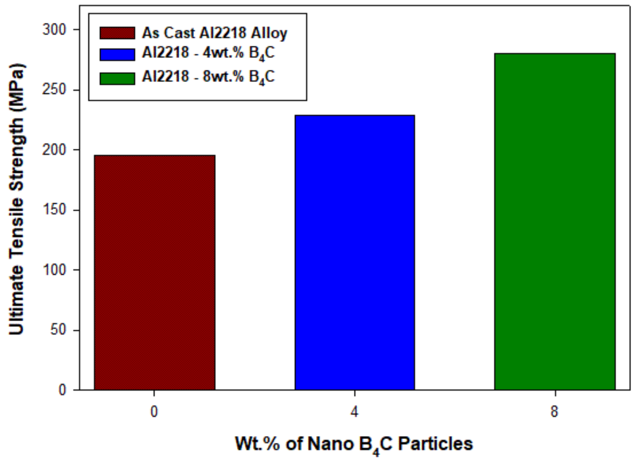


Fig. 6 Showing the ultimate tensile strength of Al2218 alloy-4 and 8 wt.% B_4C nano composites

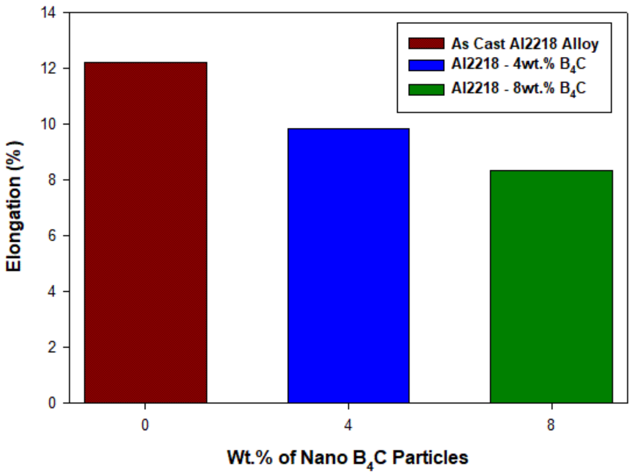


Fig. 7 Showing the yield strength of Al2218 alloy-4 and 8 wt.% B_4C nano composites

Figure 7 indicates variety of yield quality (YS) of Al2218 compound grid with 4 and 8 wt. % of nano B_4C particulate fortified composite. It tends to be seen that by including 4 and 8 wt. % of B_4C particulates yield quality of the Al amalgam expanded from 157.10 MPa to 165.30 MPa, and 211.12 MPa separately. The development in YS of the composite is plainly a result of proximity of hard B_4C particles which concede quality to the aluminum arrange achieving progressively conspicuous opposition of the composite against the associated load. Because of particles fortified composites, the dispersed hard particles in the matrix make impediment to the plastic stream, along these lines giving redesigned quality to the composite.

D. Percentage Elongation

Figure 8 showing the effect of nano B_4C content on the elongation (malleability) of the composites. It tends to be seen from the diagram that the adaptability of the composites decreases basically with the 4 and 8 wt. % B_4C sustained composites. This reducing in rate prolongation in connection with the base amalgam is a most often happening method in particulate invigorated metal cross section composites.

Fig. 8 showing the percentage elongation of Al2218 alloy-4 and 8 wt. % B_4C nano composites

E. Compression Strength

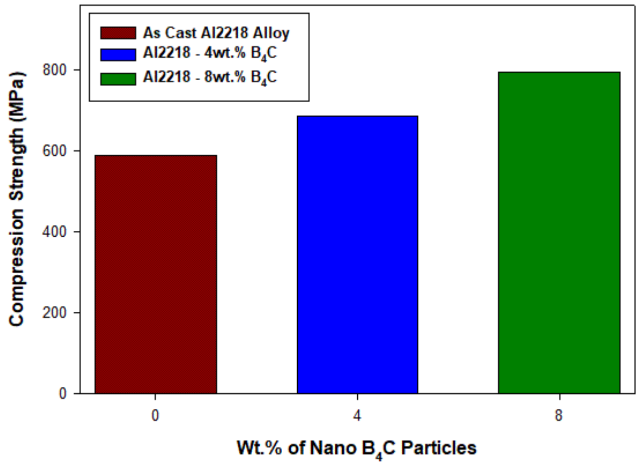
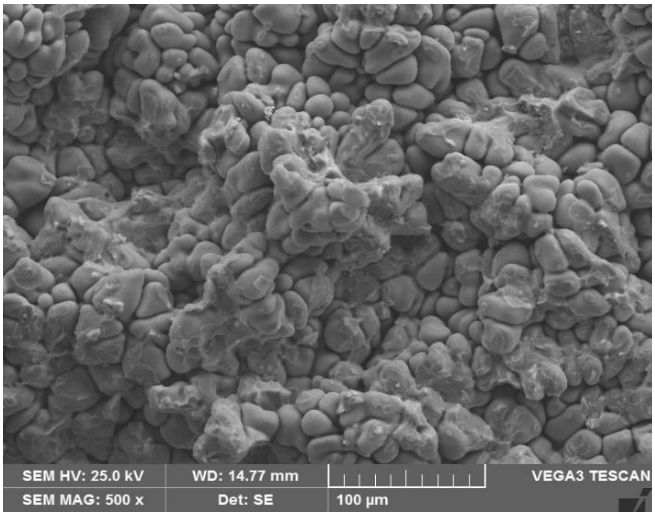


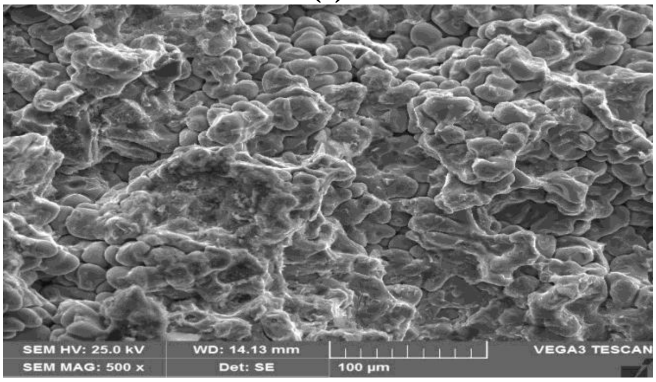
Fig. 9 Showing the compression of Al2218 alloy-4 and 8 wt.% B_4C nano composites

Figure 9 shows variation of compression strength (YS) of Al2218 alloy matrix with 4 and 8 wt. % of nano B_4C reinforced composite. By adding 4 and 8 wt. % of B_4C particulates compression strength of the Al alloy increased from 587.4 MPa to 684.97 MPa and 793.77 MPa respectively. This increase in compression strength is primarily due to the presence of hard ceramic particles in the Al2218 alloy matrix.

F. Fracture Studies



(a)



(b)

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DOI: 10.35940/ijeat.D7816.049420
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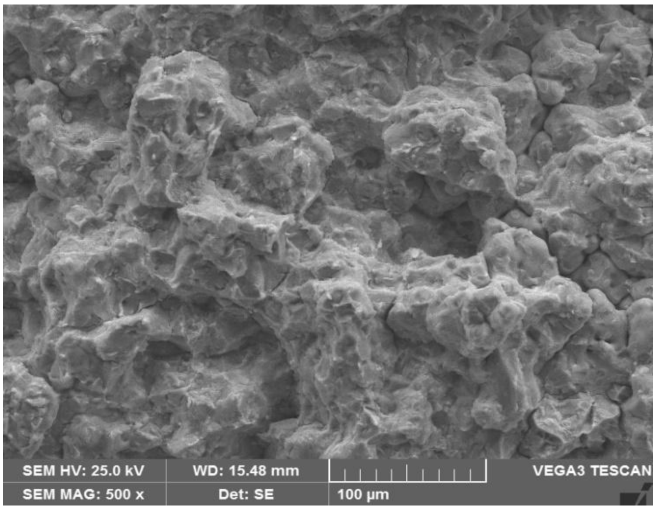

(c)

Fig. 10 Showing the tensile fractured specimens of (a) Al2218 alloy (b) Al2218-4 wt.% B_4C (c) Al2218-8 wt. % B_4C nano compositesTensile fracture of as cast compound and composite examples after tensile testing were examined by utilizing SEM pictures of crack surfaces (figure 10 a-c).

Figure 10b and 10c demonstrates that 4 and 8 wt. % B_4C strengthened MMCs fracture surfaces respectively. The brittle fracture has been observed in the case of B_4C reinforced composites. The surface indicates the particle full out during the tensile loading.

IV. CONCLUSIONS

In this exploration, Al2218-B_4C nano composites have been manufactured by stir casting technique by taking 4 and 8 wt. % of secondary particles. The microstructure, hardness, UTS, yield quality, rate prolongation, compression quality and fractography of arranged examples are examined.

The framework or composite is free from pores and uniform dispersion of nano particles, which is apparent from SEM microphotographs. The EDS and XRD examination affirm the nearness of B_4C particles in the Al2218 matrix. The mechanical properties of Al2218-4 and 8 wt. % nano B_4C composites are improved as compared to Al matrix material. The tensile fractured surfaces of the composite material indicate ductile and brittle fracture in Al matrix and its composites respectively.

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AUTHORS PROFILE

Mr. Vidyadhar Pujar has received the B.E degree in Mechanical Engineering from Bellary Institute of Technology and Management, Bellary and obtained M.Tech degree in Design Engineering from Dayanandsagar College of Engineering, Bangalore. Currently working has Assistant Professor Department of Mechanical Engineering, The Oxford College of Engineering, Bangalore, Karnataka, India. He made significant contributions are made in the fields of metal matrix composites.

Dr. H.K. Srinivas received his B.E. from Mysore University, M.Tech. and PhD from VTU Belagavi, Karnataka State, where he is currently Professor of Mechanical Engineering in SJB Institute of Technology, Bangalore. He has attended more than five international conferences and 15 national conferences. He has published ten research articles in reputed international journals.

Mr. Madeva Nagaral is working as a Deputy Manager in Configuration and Mass Properties Group, Aircraft Research and Design Centre (ARDC), Hindustan Aeronautics Limited (HAL, Bangalore since Jan 2012. He has done his BE and M.Tech from Basaveshwar Engineering College, Bagalkot. Presently he is pursuing his Ph.D in Siddaganga Institute of Technology, Tumkur. Previously, he worked as an Assistant Professor in the Department of Mechanical Engineering, MVJ College of Engineering, Bangalore, for the period of three years (2009-2011). Also, has worked as an Engineer in Bharat Electronics Limited, for the period of one year. Since 2012, his 102 research papers have been published in National and International Journals and he has presented more than 100 research papers in national and international conferences organized at various engineering colleges all over the country. His research papers are having more than 280 Google Scholar Citations. He guided more than 48 UG and 32 PG projects. 26 international journal papers were reviewed, as a reviewer. 21 guest talks were delivered as a key note resource speaker in various engineering colleges of India. He has chaired as a Guest and Session Judge for National and International Conferences held at various Engineering Colleges.

Dr. Virupaxi Auradi did his M. Tech degree in Materials and Metallurgical Engineering from KREC, Surathkal in the year 2002 and Ph. D. in Mechanical Engineering from Visvesvaraya Technological University, Belgaum in the year 2007. Currently, he is working as Associate Professor in the Department of Mechanical Engineering of Siddaganga Institute of Technology, Tumkur. From July 2002 to February 2007, he worked as Research Associate under the projects sponsored by Ministry of Defense, DRDO, New Delhi, India. He made significant contributions are made in the fields of Grain refinement and modification of Al and its Alloys, Metal Matrix Composites (MMCs), Insitu Composites, Tribology, Synthesis of Al Alloys for Aerospace Applications. He has undertaken R&D projects from agencies like AR&DB and AICTE New Delhi.