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Influence of Nickel Coated B_4C particulates Addition on the Mechanical Characterization of Al7020 Alloy Composites

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ABSTRACT: *In the present work investigations have been made on effect of nickel coated B_4C particulates addition on the tensilebehavior of Al7020 alloy. Nickel coating on the B_4C particles was done by using electroless coating method.Composites were prepared by using liquid melt method, 6 and 8 wt.% of B_4C particulates were used to fabricate the Al7020 alloy composites. Samples were tested for microstructural characterization by using scanning electron microscopeand X-Ray diffraction. Mechanicalbehaviors like hardness, ultimate tensile strength, yield strength and percentage elongation were evaluated as per ASTM standards. Scanning electron micro photographs revealed the uniform distribution of nickel coated B_4C particulates in the Al7020 alloy and confirmed XRD patterns. Further, hardness and tensile properties of base matrix Al7020 alloy was enhanced with the addition of B_4C particulates and ductility was slightly reduced. Fractography study was conducted on the tensile fractured specimens.*
Keywords: *Al7020 Alloy, Nickel Coated B_4C particulates,Microstructure, Hardness,Tensile Strength, Fractography*

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I. INTRODUCTION

Aluminum matrix composites are under consideration in aerospace, automotive and military industries, because of their low weight, high strength and excellent abrasion resistance [1]. Stir casting is a preferred method for fabrication of aluminum matrix composites due to its low cost, simplicity, flexibility and capability of mass production. However, this method has always been accompanied by the formation of lots of structural defects in composite materials. Poor wettability and nonuniform distribution of reinforcing particles, segregation and agglomeration of the reinforcement particles in the matrix, weak matrix-reinforcement interface and presence of porosity and destructive phases are some important structural defects of stir casted composites [2].
Poor wettability of reinforcements in the melt means that the molten matrix cannot wet the surface of reinforcement particles. Therefore, when the reinforcement particles are added into the molten matrix, they float on the melt surface [3, 4]. Poor wettability of reinforcing particles in the molten metal could be a cause of oxide films on the melt surface or presence of a gas layer on the ceramic particles surface. More importantly, very large specific surface area and increased surface energy during combining two different phases lead to reducing the wettability of ceramic particles within the molten matrix [5].
Various techniques are used for increasing the wettability of reinforcing ceramic particles inmolten metal. Modification of surface oxide layer on the molten metal by addition of some alloying elements such as magnesium and calcium and heat-treating the particles for desorption of gases adsorbed on the particles are appropriate techniques for improving the reinforcement's wettability [6]. Metal coating of the reinforcement particles is known as the most favorite techniques for improving the ceramic particulates wettability trough modification of surface tension. A considerable focus of studies on fabrication of metal matrix composites using coated reinforcing particles were carried out in recent years. In this study, nickel coating of B_4C reinforcement particles is considered for successful fabrication of aluminum matrix composites, free of any structural defects.
Coatings enhance the mechanical and tribological properties of the base material. Electroless Ni coating is one of the popular techniques used in scientific as well as in industrial domains [7, 8]. Recently the electroless coatings have gained wide popularity in automobile, chemical, mechanical, and aerospace industries due its ability to produce hard, wear resistant, friction resistant, and corrosion resistant surface. Completely new material concepts are successfully used, especially for coatings, to implement key optimizations of properties often with reduced material consumption, with low technical effort, and at low process costs. The electroless

deposition of metallic nickel from aqueous solution in the presence of hypophosphite was first noted as a chemical accident by Wurtz in 1844 (Mallory and Hajdu 1990). Electroless plating is an autocatalytic process, where the substrate develops a potential when it is dipped in electroless solution called electroless bath, which contains a source of metallic ions, reducing agent, complexing agent, stabilizer, additives, and wetting agents etc.

The present study is to synthesize Al7020-B_4C particulate MMC using stir casting method, by taking uncoated and nickel coated B_4C particulates as the reinforcement material. In order to improve wettability and distribution of reinforcing particles a novel two stage mixing combined with preheating of the reinforcing particles is being adopted and the as cast Al7020 and 6 and 8wt. % of B_4Cparticulates of the prepared composites were subjected to metallographic studies, hardness and tensile behavior as per ASTM standards.

II. EXPERIMENTAL DETAILS

Materials Used

In the present study Al7020 is used as the matrix material, most of the applications in areas such as aerospace, automobile, marine make use of 7xxx series, aluminium zinc series alloys. Al7020 normally has 5% zinc. The theoretical density of Al7020 is taken as 2.84 g/cm^3.

Table 1: Chemical composition of Al7020 Alloy

Element	Si	Cu	Mg	Mn	Fe	Zn	Cr	Al
Wt. (%)	0.35	0.2	1.2	0.50	0.40	5.0	0.30	Balance

In the present work, micro B_4C particulates are used as the reinforcement materials, 80 to 90 micron particulates were used procured from Speedfam Ltd., Chennai. The density of boron carbide is lesser than the matrix material, which is 2.52 g/cm^3.

III. METHODOLOGY

In the present study B_4C particulates were used as the reinforcement particles. These B_4C particles were coated by nickel by using the electroless coating process to enhance the wettability between the matrix and the reinforcement. The fabrication of Al7020-B_4C composites were carried out by liquid metallurgy route via stir casting technique.Calculated amount of the Al7020alloy ingots are charged into the furnace for melting. The melting point of aluminium alloy is 660 °C. The melt superheated to a temperature of 730°C. The temperature was recorded using achrome-alumel thermocouple. The molten metal is then degassed using solid hexachloroethane (C_2Cl_6) for 3 min. A stainless-steel impeller coated with zirconium is used to stir the molten metal to create a vortex. The stirrer will be rotated at a speed of 300rpm and the depth of immersion of the impeller was 60 percent of the height of the molten metal from the surface of the melt. Further, the nickel coated B_4C particulates were preheated in a furnace upto500 °C will be introduced into the vortex. Stirring is continued until interface interactions between the reinforcement particulates and the matrix promotes wetting. Then, Al7020- 6wt. %B_4C mixture was poured into permanent cast iron mold having dimensions 120mm length and 15mm diameter. Similarly, composites are prepared for 8weight percentage of nickel coated B_4C particles reinforced composites.

Evaluation of Properties

The castings thus obtained were cut to appropriate size of 15 mm diameter and 5 mm thickness which is then subjected to different levels of polishing to get required sample piece for microstructure study. Initially, the sliced samples were polished with emery paper upto 1000grit size followed by polishing with Al_2O_3 suspension on apolishing disc using velvet cloth. This was followed by polishing with 0.3 microns diamond paste. The polished surface of the samples etched with Keller’s reagent and finally subjected to microstructure study under the scanning electron microscope.

Hardness test was conducted by using Brinell hardness testing machine as per ASTM E10 standard. The tensilestudy was carried out on the cut specimens as per ASTM E8 [9]standards using Electronic Universal Testing machine at room temperature to study properties like tensile strength, yield stress and percentage of elongation.

IV. RESULTS AND DISCUSSION

Microstructural Study

Figure 1a and b-c shows the SEM micrographs of as cast alloy Al7020 and the composites of 6 and 8 wt. % of nickel coated B_4C reinforced with Al7020 alloy composites. These two examined samples were chosen from the middle segment from the cylindrical specimens. The microstructure of as cast Al7020 alloy comprises of fine grains of aluminium solid solution with an enough dispersion of inter-metallic precipitates.

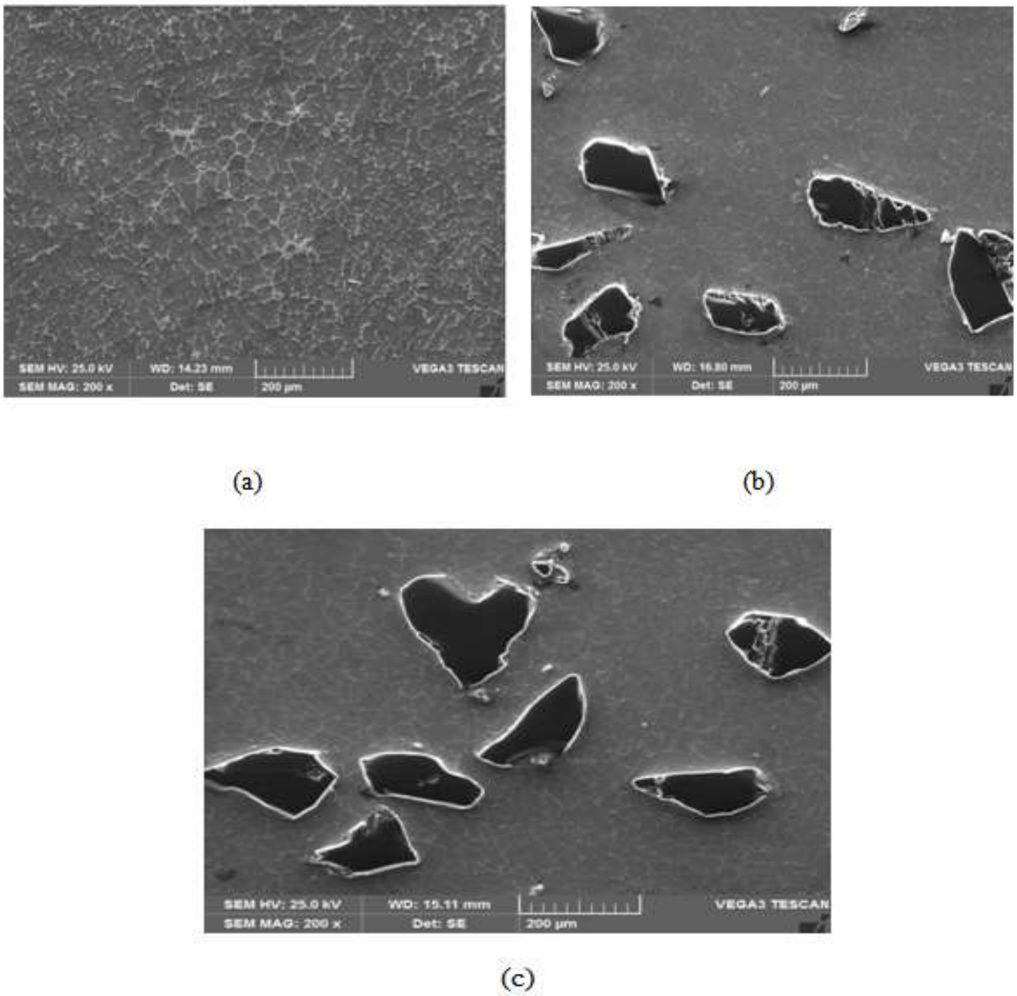


Fig. 1 Scanning electron micrographs of (a) as cast Al7020 alloy (b) Al7020-6 wt. % Nickel coated B_4C (c) Al7020-8 wt.% Nickel coated B_4C particles reinforced composites

The strong interfacial bonding between the Al7020 alloy and B_4C particulates obtained due to the addition of nickel coated B_4C particles. Fig. 1b-c represents the SEM micrographs of 6 and 8 wt. % nickel coated B_4C particulates reinforced composites. From the micrographs, it is revealed that the composites are free from pores and other surface damages. Nickel coated particles are uniformly distributed all over the Al7020 alloy matrix. This is mainly due to the enhanced wettability of the B_4C particulates due to the nickel coating.

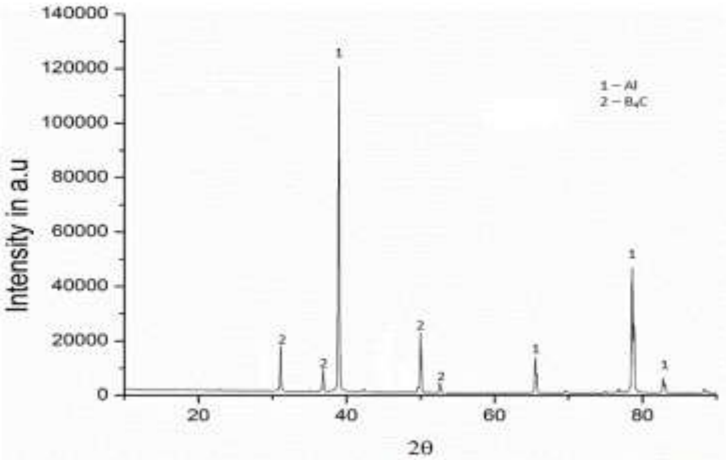


Fig.2: X-ray diffraction pattern of Al7020-8 wt.% of Nickel coated B_4C particulates reinforced composites

Fig. 2 shows the X-ray diffraction (XRD) pattern taken for Al7020 alloy with 8 wt.% of B_4C particulates reinforced composites It can be observed that peak height increases and then decreases on 2-theta scale indicating the presence of different phases of material. In fig. 2 it is visible that X-ray intensities of peak are higher at 38°, 65°, 78° & 83° indicating the presence of aluminium phase. Similarly, B_4C particulates phases are identified at 31°, 37°, 50° and 53°.

Hardness Measurements

From the fig.3, it is observed that there is an increase in the hardness of Al7020 with addition of 6 and 8wt % of nickel coated B_4C particulates addition. The graph shows the variation of hardness of Al7020 alloy with B_4C reinforcement particulate. It can be concluded that the addition of wt. % of B_4C particulate results in increasing the hardness. The hardness of a soft material such as Aluminum matrix is increased when it is reinforced with a hard particulate i.e., B_4C [10, 11].

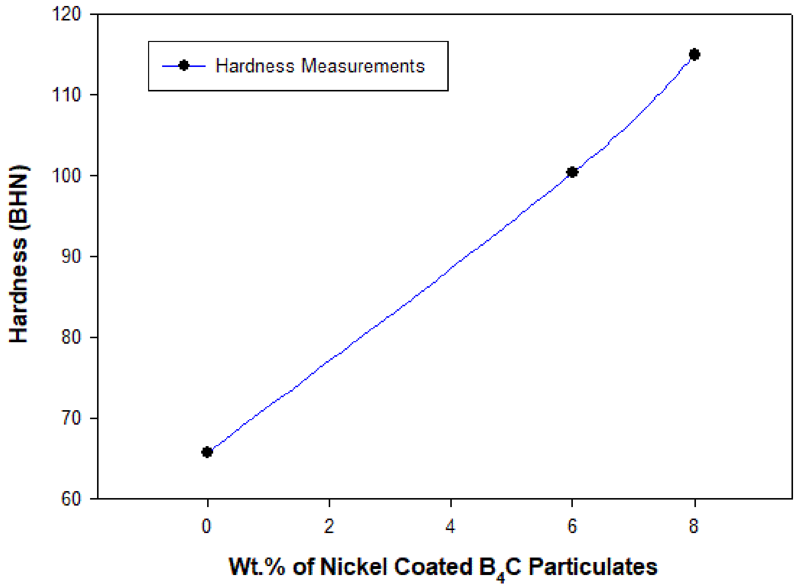
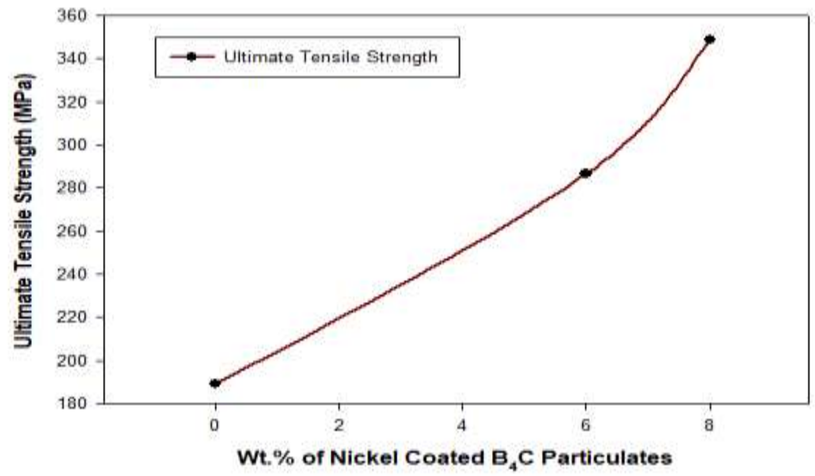


Fig. 3: Hardness measurements of Al7020-6 and 8 wt.% of Nickel coated B_4C composites

Ultimate Tensile Strength

Fig.4 shows the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 6 and 8 wt. % of nickel coatedB_4C particulates. The ultimate tensile strength of Al7020- B_4C composite material increases as compared to the cast base Al7020 alloy. The microstructure and properties of hard ceramic B_4C particulates control the deformation of the composites. Due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. This increase in ultimate tensile strength mainly is due to presence of B_4Cparticleswhich are acting as barrier to dislocations in the microstructure [12]. The improvement in ultimate tensile strength may also be due to alloy strengthening of the matrix, followed with a reduction in grain size of the composites, and the formation of a high dislocation density in the Al7020 alloy matrix due to the difference in the thermal expansion between the metal matrix and the B_4C reinforcement. Further, the enhanced strength is mainly due to the addition of nickel coated B_4C particulates, which created the strong interfacial bonding between the Al7020 alloy and the 90 micron size nickel coated B_4C particles.

Fig. 4:Showing the ultimate tensile strength of Al7020 alloy-6 and 8 wt.% of nickel coated B_4C composites



Yield Strength

Fig.5 shows variation of yield strength (YS) of Al7020 alloy matrix with 6 and 8 wt. % of micro B_4C particulate reinforced composite. By adding 6 and 8 wt. % of nickel coatedB_4Cparticulates yield strength of the Al alloy increased from 162.80 MPa to 241.7MPa and 291.25 MPa respectively.This increase in yield strength is in agreement with the results obtained by several researchers, who have reported that the strength of the particle reinforced composites is highly dependent on the volume fraction of the reinforcement. The increase in YS of the composite is obviously due to presence of hard nickel coated B_4Cparticles which impart strength to the soft aluminum matrix resulting in greater resistance of the composite against the applied tensile load [13]. In the case of particle reinforced composites, the dispersed hard particles in the matrix create restriction to the plastic flow, thereby providing enhanced strength to the composite [14].

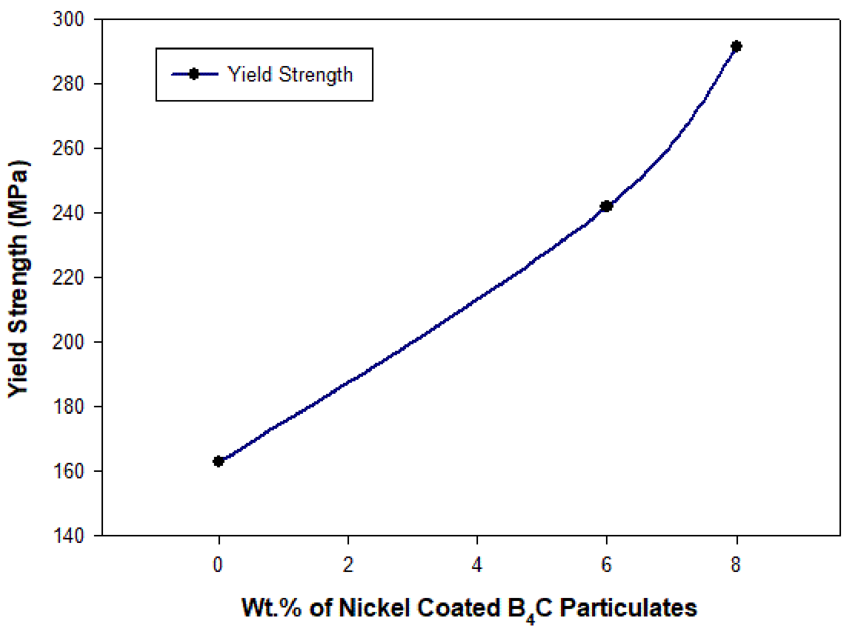


Fig. 5:Showing the yield strength of Al7020 alloy-6 and 8 wt.% of nickel coated B_4C composites

Percentage Elongation

Fig. 6 demonstrating the impact of microB_4C content on the elongation (ductility) of the composites. It can be seen from the chart that the flexibility of the composites diminish essentially with the 6 and 8 wt. % B_4C fortified composites. This diminishing in rate prolongation in correlation with the base amalgam is a most usually happening detriment in particulate fortified metal lattice composites [15]. The lessened pliability in composites can be ascribed to the nearness of B_4C particulates which may get broke and have sharp corners that make the composites inclined to restricted split start and proliferation [16].

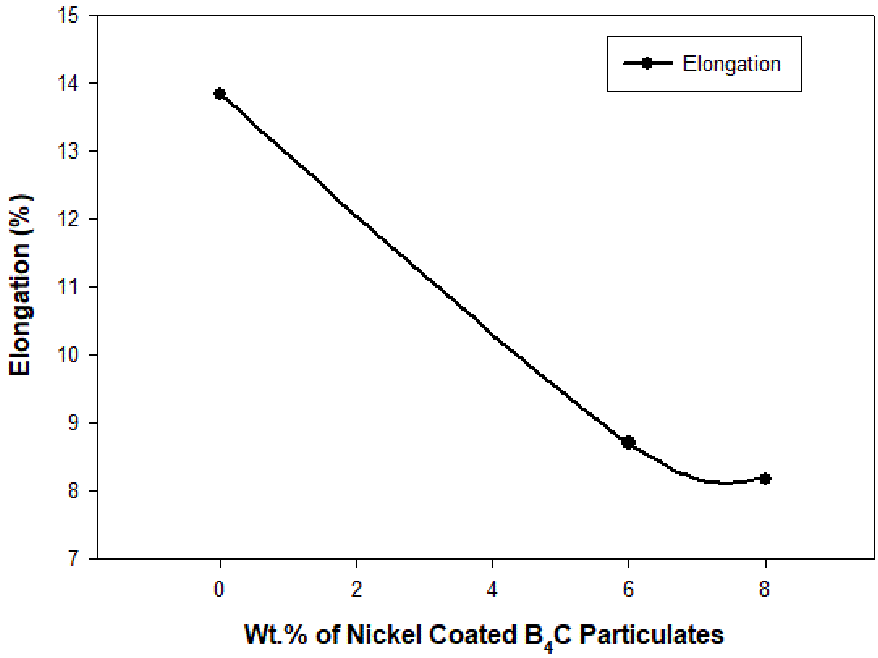


Fig. 6 Showing the percentage elongation of Al7020 alloy-6 and 8 wt.% nickel coated B_4C particulates reinforced composites

Fracture Studies

Fracture mechanisms of as cast alloy and composite samples after tensile testing were studied by using SEM images of fracture surfaces (figure 7a-c). The as cast Al7020 alloy fracture mode is a ductile fracture mode as shown in figure 7-a, which has large number of dimple shaped structures, no crack can be seen.

Figure 7b and 7c shows that 6 and 8 wt. % B_4C reinforced MMCs fracture structures have less ductile failure. During tensile test it is accepted that particle cracking along with matrix material fracture, de-bonding between the alumina particles and Al matrix alloy interface are some of the reasons for failure MMCs. Small voids observed in the case of 8 wt. % B_4C composites, fractured surfaces showed local stresses at the interfaces is more and so crack at reinforcement particles mechanism is observed.

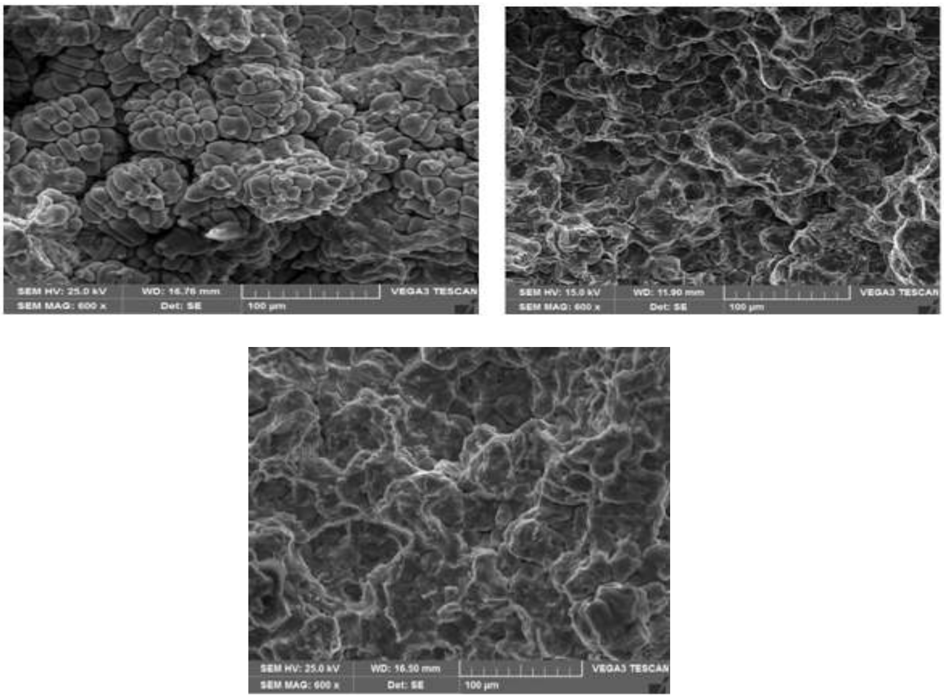


Fig. 7: Showing the SEM micrographs of tensile fractured surfaces of (a) as cast Al7020 alloy (b) Al7020-6 wt.% of Nickel coated B_4C (c) Al7020-8 wt.% of Nickel coated B_4C particulates reinforced composites

V. CONCLUSIONS

In this research, Al7020 alloy with 6 and 8 weight % of nickel coated B_4C particles reinforced composites have been fabricated by stir casting method. The microstructure, ultimate tensile strength, yield strength, percentage elongationand fractography of prepared samples are studied. The matrix is almost pore free and uniform distribution of micro particles, which is evident from SEM microphotographs. The XRD analysis confirms the presence of B_4C particles in the Al alloy matrix. The hardness andtensile properties of Al7020-6 and 8 wt. % nickel coated B_4C composites are superior to those of unreinforced material. There was slight decrease in the ductility of the composites as compared to the base Al7020 alloy matrix. The fracture surface of the composite material consists of voids which formed by the strain localization. These voids were then coalesced during tensile loading, resulting in the formation of dimple appearance at the fracture surface.

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