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Hybridizing Micro - B₄C With Carbon nanotubes to Enhance The Mechanical Properties of Aluminium Matrix Composites.

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Abstract: In present work, the effects of hybridizing micron sized B₄C particles with multi walled carbon nanotubes on the microstructural and mechanical properties of Al - B₄C composite were investigated. Microstructure reveals grain refinement ascribed to the presence of uniformly distributed micron sized B₄C particles with multi walled carbon nanotubes. The Al - (B₄C + MWCNT) hybrid composite indicates the alliance of mechanical properties such as hardness, tensile strength and ductility. The enhanced attribute of Al - (B₄C + MWCNT) hybrid composite when compared to Al - B₄C is the increased content and uniform distribution of MWCNTs.

Keywords: Ductility, Hybrid composite, Hardness and Tensile strength.

1. INTRODUCTION

Aluminium being a light metal is studied with much attention as structural material, though they lack in rigidity and strength when compared with iron. Al2024 alloy has high strength to weight ratio, good fatigue resistance, average machinability and high strength. Its application involves wing structures in aircraft. Boron carbide is the hardest material and has properties such as low density and good chemical resistance. MWCNTs are used strength additives for polymer, ceramic and metallic composites due to high stiffness and strength. Metal matrix/ ceramic/ CNT composites have a great potential in automobile, space craft and VLSI industry due to high hardness, less coefficient of thermal expansion and high specific strength. Amal and Mostafa [1] investigated the attributes of Al- CNT strips and Al – 0.5wt% CNT strips exhibited improved yield strength, tensile strength and low density. Pulickel and Zhou [2] reported that CNT structures are remarkable and hence they are used in wide range of applications. Prabhu and Vinayagam [3] studied that MWCNTs helps improving the surface features from micro to nano level when used in grinding process. Yufeng Wu and Gap yong kim [4] obtained a hardness value of 87.5HV at 620°C for Al6061-CNT composite. Lai xue pang et al [5] developed Fe₃Al-CNT composite at 1273k and pressure 30 Mpa. The value for microhardness and compressive strength was 8.7 Gpa and 3175Mpa for 5% CNT in the composite. Bradbury et



al [6] studied aluminium composite with 6 wt% of CNT prepared by milling and concluded that maximum hardness was achieved due to MWCNTs. Dehong Lu et al [7] studied AZ31 composite reinforced with 0.1% Al_2O_3 and 0.2% CNTs and concluded that composite showed less wear for less load. Choi et al [8] investigated the aluminium nano composite reinforced with 5wt% Si alloy and 3 vol% MWCNTs and there was a improvement in % elongation and yield strength. Liu et al [9] reported that CNTs strength improved when ball milling time was 6 hours. Sebastian et al [10] fabricated Ni- MWCNT composite and was no improvement beyond 3 wt% of CNT because CNTs reagglomerated for large volume fraction. Bustamante et al [11] reported that when 5 wt% CNT content was added to Al 2024 composite it showed improved wear properties.

In the present work, hybrid composite is fabricated using stircasting technique and matrix used is Al2024 and reinforcements are micro B_4C and MWCNTs. The obtained composites are investigated for microstructure and mechanical properties such as hardness, tensile strength and ductility. Finally SEM is used for analyzing fractured specimens of composite.

2. EXPERIMENTAL PROCEDURE

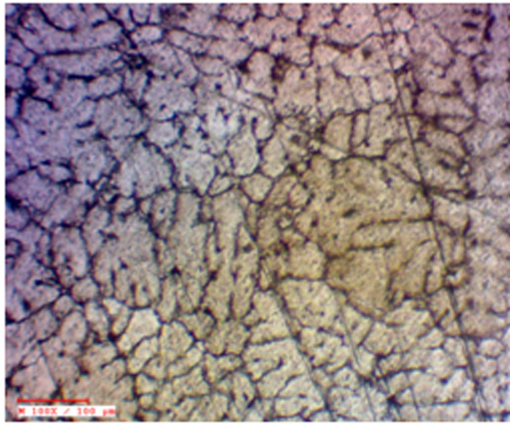
The material used for fabricating hybrid composite is Al2024 which is in form of billets, reinforcements such as B_4C of size 30 microns and MWCNTs. Initially Al2024 is made in to small billets and melted in a Electric resistance furnace at a temperature of 700°C. Degassing agent (hexachlore ethane) was used for reducing gas porosities. 10 wt% of Boron carbide particles and MWCNTs of 1wt% and 2wt% were mixed in ball mill and preheated for 3 to 4hours at 450°C. Preheated reinforcements was added in to melts and mixed for 5 mins using a stirring bar. Finally molten composite slurry is poured in to metallic mould and allowed to solidify.

3. RESULTS AND DISCUSSION

3.1 Microstructure

The presence and distribution of B_4C particles and MWCNTs in Al2024 matrix were studied using optical microscope. Fig 1 (a) shows the equiaxed grains in the Al2024 sample. Fig 1(b) shows the Al2024-10%B4C composite and it is seen that B_4C are uniformly distributed in the matrix.

Fig1(c) and Fig 1(d) shows the microstructure of Al2024-10%B4C-1%MWCNTs and Al2024-10%B4C-2%MWCNTs composite. It is seen that crystal grains of composite with 1% MWCNTs is coarser than 2% MWCNTs content.



(a) Al2024

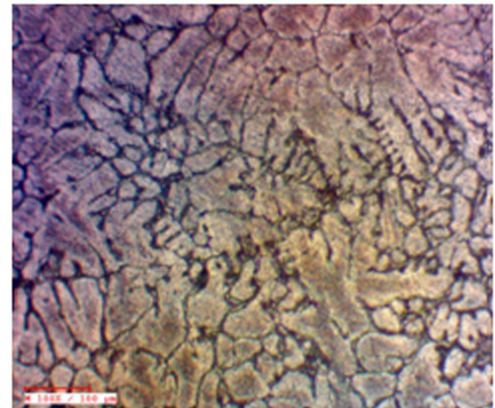
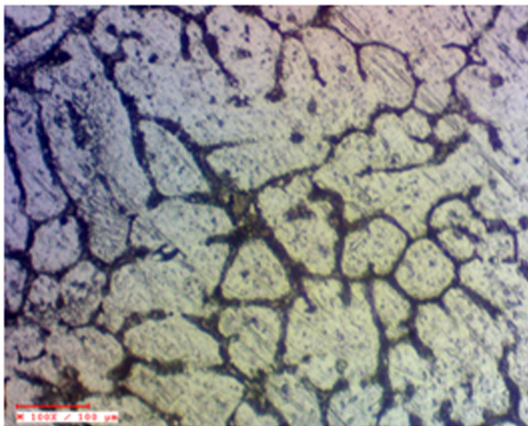
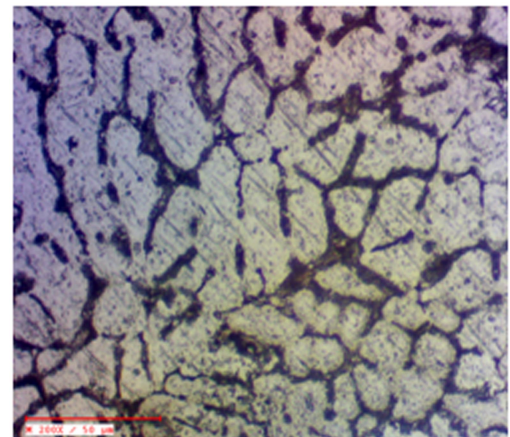
(b) Al2024+ 10% B₄C(c) Al2024+ 10% B₄C + 1%MWCNTs(d) Al2024+ 10% B₄C +2%MWCNTs

Fig.1 Microstructure of Al2024 hybrid composite

3.2 Hardness

Hardness of a composite is determined as per ASTM E10 standards. A test load of 500Kg is enforced on the specimens for 30sec. The average of all the eight readings is taken as hardness of the sample. The diameter of the steel ball indenter is 10mm. Fig 2 shows the hardness of Al2024 hybrid composite. It is seen that by addition of 10wt% of B₄C particles the hardness of the composite is increased because of the high hardness value of boron carbide as a ceramic and protects the specimen surface. It is also seen that with the increased content of MWCNTs the hardness is increased since they are uniformly distributed and MWCNTs provide deformation resistance to the movement of dislocation. The Brinell hardness for Al2024 sample is 100.35 BHN and for only 10%B₄C sample has 113.13 BHN and for 1% MWCNTs and 2% MWCNTs with 10%B₄C has 116.59 and 125.03 BHN respectively.

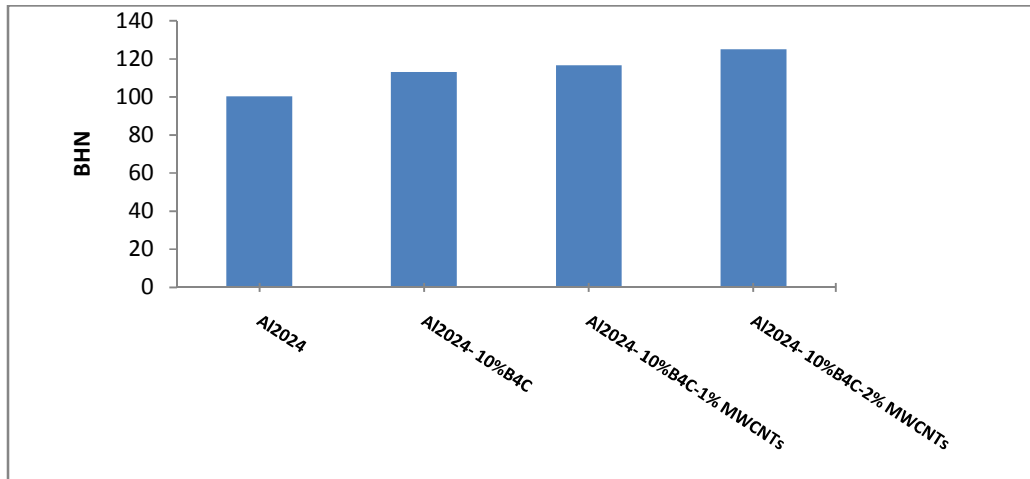


Fig. 2 Hardness of Al2024 hybrid composite

3.3 Tensile strength

Fig 3 shows the results of tensile test for hybrid composite reinforced with 10wt% B₄C and different wt% of MWCNTs. Tensile test was conducted from tensometer according to ASTM E8 standards and four readings was taken as a average. It is observed that 10wt% B₄C + 2%MWCNTs provides the most significant strengthening (+43%) followed by 10wt% B₄C + 1%MWCNTs provides 32% and finally 10wt% B₄C provides 20% in compare to Al2024 alloy. Improvement in tensile strength is mainly due to better dispersion of CNTs and B₄C provided by ball milling and in addition to the strain hardening which contributes to the final strength of the composite there is a mismatch of elastic and thermal expansion coefficients between matrix and reinforcements ($\alpha_{Al2024} = 22.8 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$, $\alpha_{B4C} = 5 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$, $\alpha_{MWCNTs} = 0.73 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$) which contributes to the strength of composite.

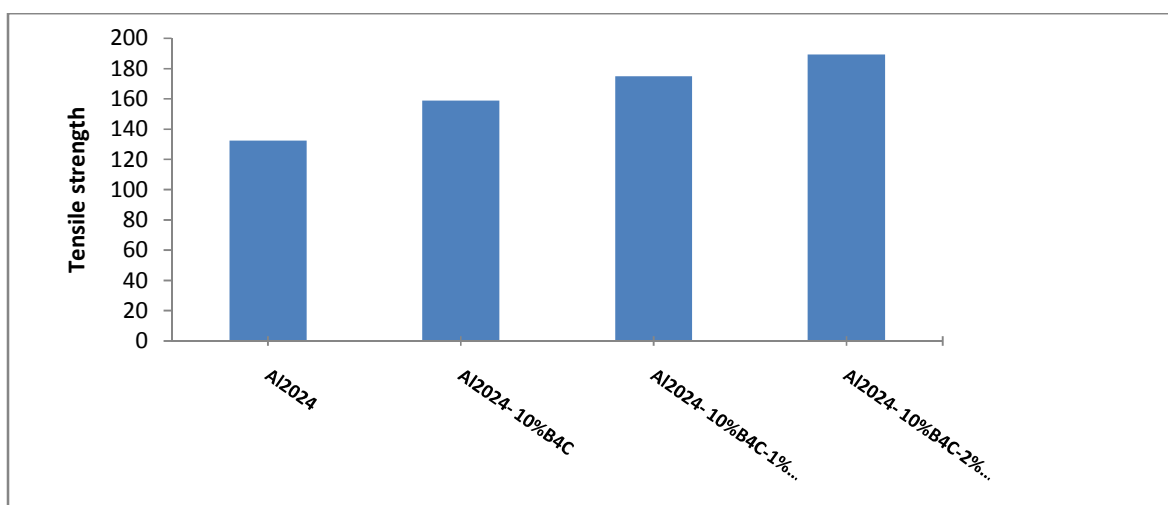


Fig. 3 Tensile strength of Al2024 hybrid composite

3.4 Ductility and fractography

Fig 4 shows the % elongation for Al2024 hybrid composite. There is larger elongation for Al2024 alloy and as 10wt% B₄C is added to base alloy the ductility decreases because of presence of hard ceramic phase which leads to localized crack initiation and stress concentration sites at the matrix- reinforcement interface. Addition of different wt% of MWCNTs with 10wt% B₄C to Al2024 alloy leads to improvement in ductility because in a stressed state there is a resistance to plastic deformation which is due to difficulty in rearranging of dislocations and it increases for nano structures which have less generated dislocation.

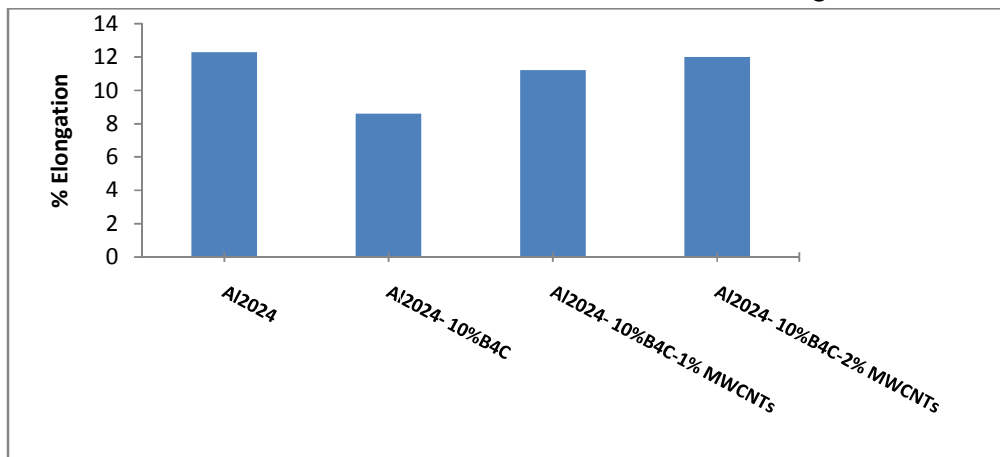
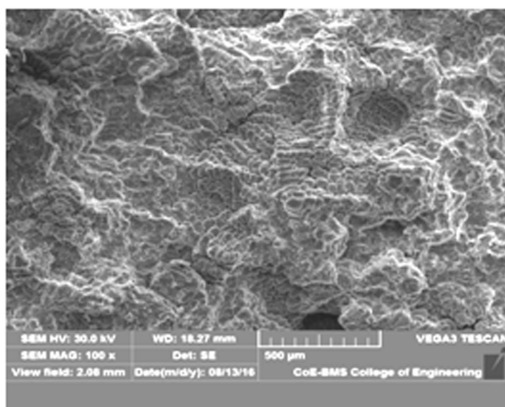
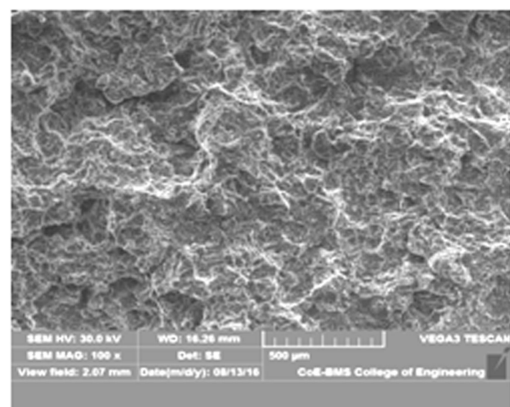


Fig. 4 % Elongation of Al2024 hybrid composite

Fig 5 shows the SEM fractographs of Al2024 hybrid composite. The Al2024 alloy shows large and deep dimples on the fracture surface which indicates ductile fracture. Fig 5 (b) shows the composite reinforced with 10wt% B₄C which has areas of brittle fracture which is due to the decohesion of B₄C particles from Al2024 matrix. The fracture surfaces of Fig 5(c) and 5(d) show a lot of dimples indicating the ductile nature of fracture which means that interfaces between the matrix, B₄C particles and MWCNTs are very strongly bonded.



(a) Al2024



(b) Al2024+ 10% B₄C

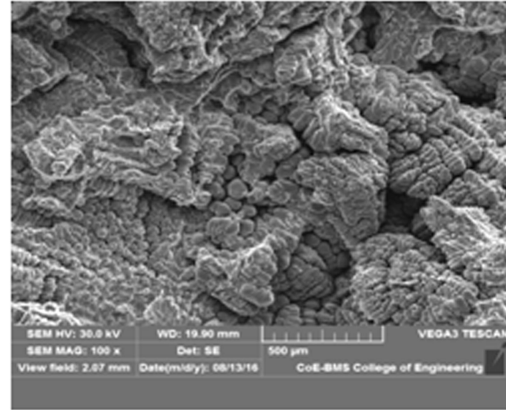
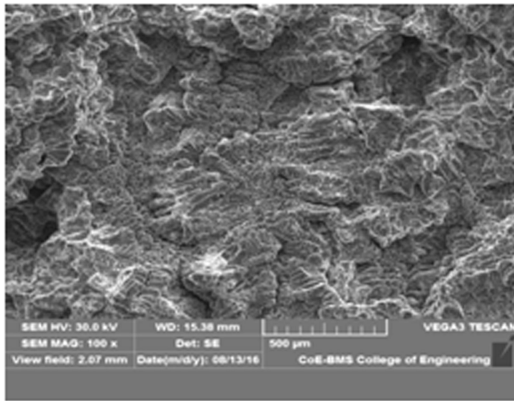
(c) Al2024+ 10% B₄C + 1%MWCNTs(d) Al2024+ 10% B₄C +2%MWCNTs

Fig. 5 Fracture surface of Al2024 hybrid composite

4. CONCLUSIONS

In this study, composites with B₄C particles and 1% - 2% MWCNTs were successfully prepared by using stir casting technique. The samples was subjected to mechanical tests and the various results are as follows

- 1) B₄C particles and MWCNTs are uniformly distributed in the Al2024 matrix and there is no agglomeration of MWCNTs in the composite.
- 2) The max Brinell hardness number was obtained for Al2024-10%B₄C-2%MWCNTs and the value is 125.03 BHN.
- 3) Al2024-10wt% B₄C + 2%MWCNTs provides strengthening (+43%) in compare to Al2024 alloy.
- 4) The fracture surface of composite reinforced with B₄C particles and MWCNTs indicates a ductile fracture which means that interfaces between the matrix, B₄C particles and MWCNTs are very strongly bonded.

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