Evaluation of Tensile Behavior of Boron Carbide/AA1100 Alloy Metal Matrix Composites

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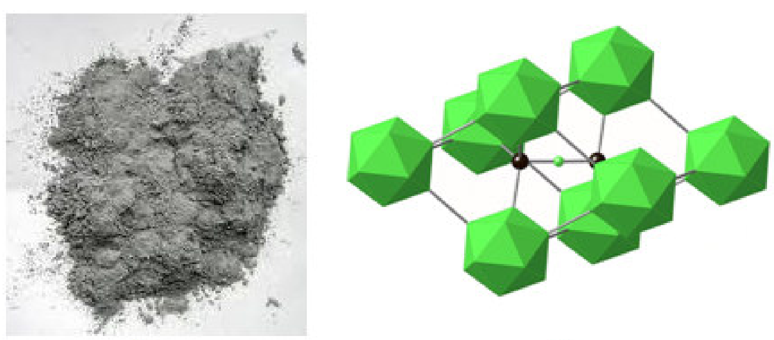
Abstract: The present work was planned to evaluate the consequence of boron carbide particle loading on the tensile behavior of B_4C/AA1100 alloy metal matrix composites. Both, experimental and finite element analyses were carried out to establish tensile behavior of the composites fabricated by the stir casting process. The adhesive bond was broken between the boron carbide particle and AA1100 alloy matrix in the composite when the stress exceeded 110 MPa (tensile strength) of the matrix.

Keywords: AA1100 alloy, boron carbide, RVE model, finite element analysis, stir casting process.

1. INTRODUCTION

Reinforcement materials in MMCs are second phase addition to a metallic matrix that results in some net properties improvement such as specific strength and stiffness. Generally, most reinforcement materials for MMCs are ceramics (oxides, carbides, nitrides, and so on), which are characterized by their high strength and stiffness both at ambient and elevated temperatures. Examples of common MMC reinforcements are SiC, Al_2O_3, TiB_2, BN, and graphite [1, 2]. Presently, the use of a representative volume element (RVE) or a unit cell [3] of the composite microstructure, in conjunction with a finite element (FE) analysis tool is well recognized for determining the effective material properties and understanding the micromechanics of the composite materials. Boron carbide is (B_4C) is an extremely hard boron–carbon ceramic, and Ionic material used in tank armor, bullet proof vests and engine sabotage powders.

The aim the present paper is to determine the influence of particle size and volume fraction of boron carbide as a reinforcement material in AA1100 alloy matrix. Finite element analysis (FEA) of B_4C/AA1100 alloy metal matrix composites was executed through RVE models. The results acquired from the FEA were confirmed with those found from experimentation. B_4C/AA1100 alloy metal matrix composites were made-up using stir casting process.



(a) (b)

Figure 1: Boron carbide powder (a); a unit cell of B_4C (b).

2. MATERIALS AND METHODS

The matrix material was AA1100 alloy. Boron carbide (B_4C) particles of average size 200 nm were employed as reinforcement fillers. The morphology of boron carbide particles is shown in figure 1. Boron carbide has a complex crystal structure typical of icosahedron-based borides.

The volume fractions of boron carbide reinforcement were 10%, 20%, and 30%. AA1100 matrix alloy was melted in a resistance furnace. Boron carbide/AA1100 alloy metal matrix composites were manufactures using stir casting process. The preheated cast iron die was filled with dross-removed melt by the compressed (3.0 bar) argon gas. All the samples were given H12 heat treatment prior to the machining of composite samples for tensile testing.

The heat-treated samples were machined to get flat-rectangular specimens (figure 2a) for the tensile tests. The tensile specimens were tested for tensile properties a Universal Test Machine (UTM) at a specified grip separation and pulled until failure. The test speed was 2 mm/min (as for ASTM D3039). A strain gauge was used to determine elongation as shown in figure 2b.

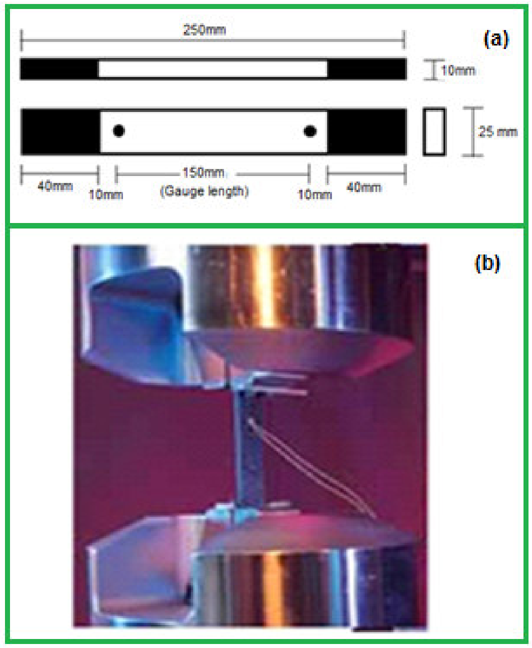


Figure 2: Shape and dimensions of tensile specimen; (b) tensile testing.

The RVE scheme with adhesion (without interphase) was applied between the matrix and the filler as shown in figure 3. The PLANE183 element was used for the matrix and the nanoparticle. The interphase was discretized using a COMBIN14 spring-damper element.

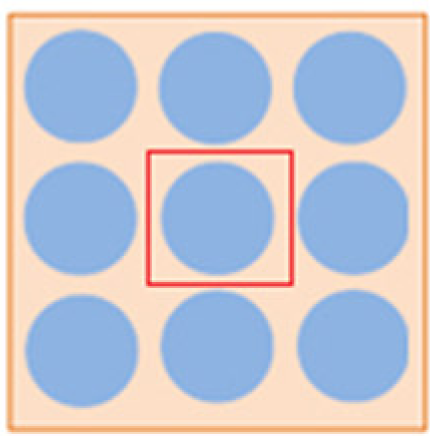


Figure 3: The RVE model.

3. RESULTS AND DISCUSSION

Figure 4 depicts the tensile properties of B_4C/AA1100 alloy metal matrix composites attained by FEA and experimental tests. The tensile strain (figure 4a) and tensile strength (figure 4b) increased with increased content of boron carbide content in the composites. The elastic moduli of composites having 20%Vp and 30%Vp of boron carbide have nearly the same value. The results obtained from experimental procedure were lower than those computed from the finite element analysis owing to the presence of the agglomeration of B_4C particles and porosity due to stir casting process in the composites.

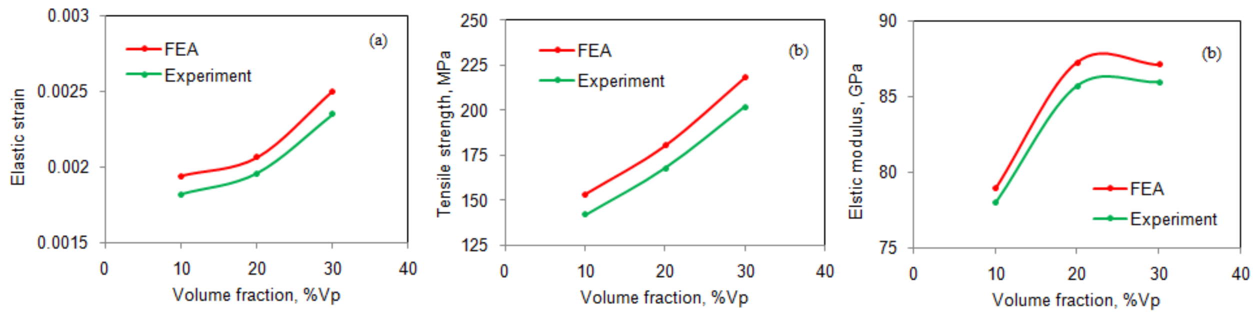


Figure 4: Effect of volume fraction on tensile strength.

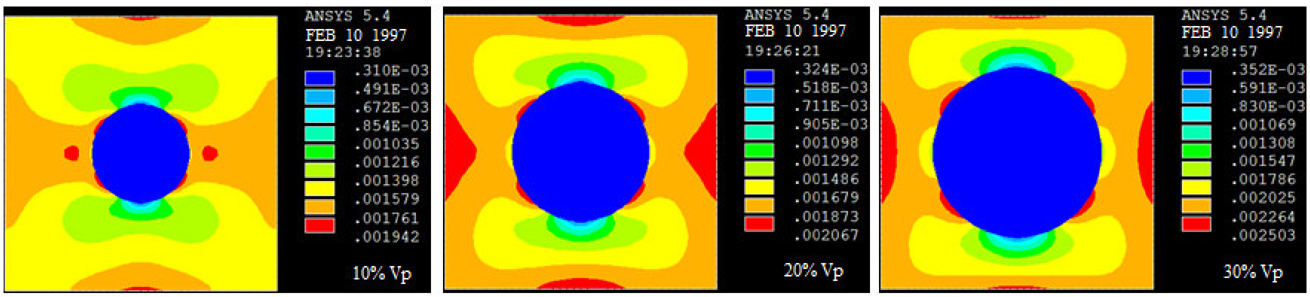


Figure 5: Elastic strain developed in B_4C/AA1100 alloy metal matrix composites.

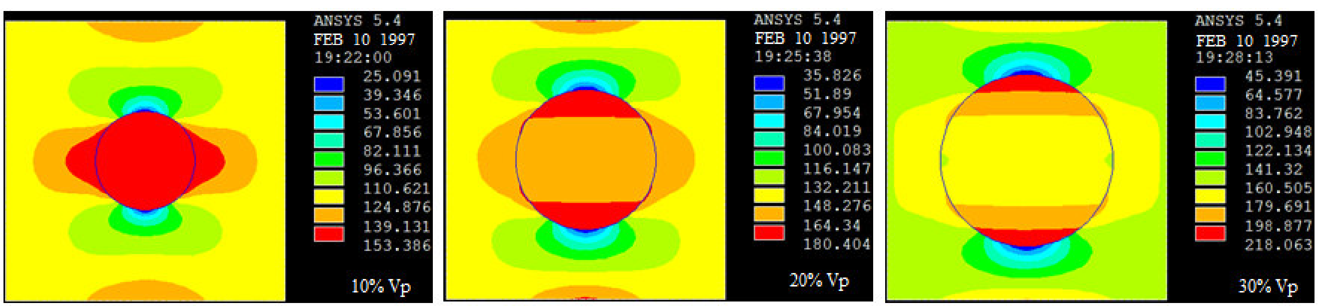


Figure 6: Tensile stress induced in B_4C/AA1100 alloy metal matrix composites.

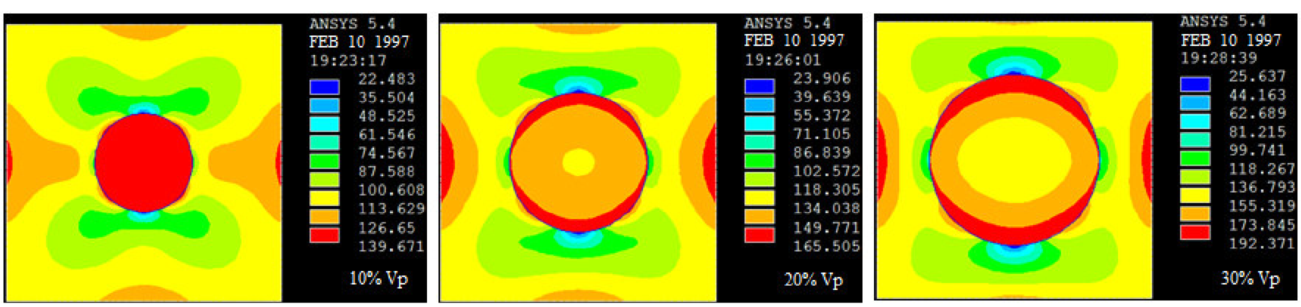


Figure 7: von Mises stress induced in B_4C/AA1100 alloy metal matrix composites.

The tensile strengths of AA1100 alloy and B_4C particles, are, respectively, 110 MPa and 417 MPa. The stress in the AA1100 alloy matrix is exceeded 110 MPa (yellow or green bands). Reinforcing B_4C particles or interface had experienced stress value in the range of 153 MPa to 218 MPa which is lower than the tensile strength of B_4C. This indicates that the B_4C particles were ruptured due to transfer of load from the matrix. Figure 7 illustrates the variation of von Mises stress in B_4C/AA1100 alloy metal matrix composites. The von Mises stress increased from 139.67MPa to 192.37 MPa with an increase of boron carbide content from 10%Vp to 30%Vp. B_4C/AA1100 alloy metal matrix composite had experienced interfacial debonding (red color band around the particle).

4. CONCLUSION

The tensile strength increased with an increase of boron carbide content. The adhesive bond was broken between the boron carbide particle and AA1100 alloy matrix in the composite when the stress exceeded the tensile strength (110 MPa) of the matrix.

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