Prediction of Tensile Behavior of Boron Carbide/AA3003 Alloy Metal Matrix Composites

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Abstract: The present work was planned to predict the consequence of boron carbide particle loading on the tensile behavior of B_4C/AA3003 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 AA3003 alloy matrix in the composite when the stress exceeded 110 MPa (tensile strength) of the matrix.

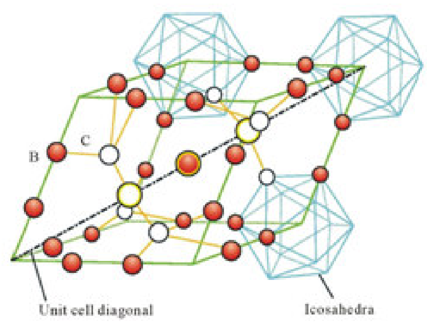
Keywords: AA3003 alloy, boron carbide, RVE model, finite element analysis, stir casting process.

1. INTRODUCTION

In particulate reinforced metal matrix composites (MMCs), the matrix is the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite through prevention of matrix deformation by mechanical restraint. Aluminum MMCs are widely used in aircraft, aerospace, auto- mobiles and various other fields [1]. Boron carbide (B_4C) has high elastic modulus and fracture toughness. There exists a rich literature of theoretical models in estimating overall elastic properties of MMCs when reinforcements are assumed to be perfectly bonded [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.

The aim of the present paper is to determine the influence of particle size and loading of boron carbide as a reinforcement material in AA3003 alloy matrix. Finite element analysis (FEA) of B_4C/AA3003 alloy metal matrix composites was implemented through RVE models. The results acquired from the FEA were entrenched with those found from experiential tests. B_4C/AA3003 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 AA3003 alloy. The loading of boron carbide particulate reinforcement were 10%, 20%, and 30%. The morphology of boron carbide particles is shown in figure 1. Boron carbide has a complex crystal structure typical of icosahedron-based borides. Boron carbide/AA3003 alloy metal matrix composites were produced by 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. The heat-treated samples were machined to get flat-rectangular specimens 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).

The RVE scheme with adhesion (without interphase) was applied between the matrix and the filler as shown in figure 2. The PLANE183 element was used for the matrix and the nanoparticle. The interphase was discretized using a COMBIN14 spring-damper element.

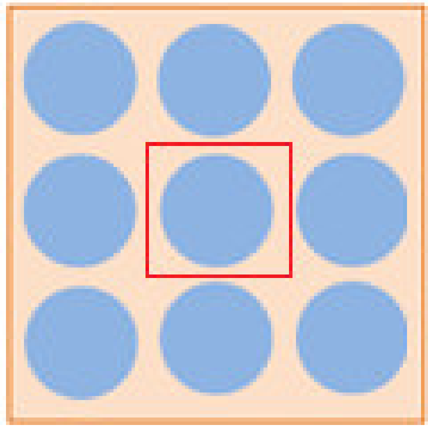


Figure 2: The RVE model.

3. RESULTS AND DISCUSSION

Figure 3 represents the tensile properties of B_4C/AA3003 alloy metal matrix composites attained by FEA and experimental tests. The tensile strain (figure 4a), tensile strength (figure 4b) and elastic module increased with increased content of boron carbide content in the composites. 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.

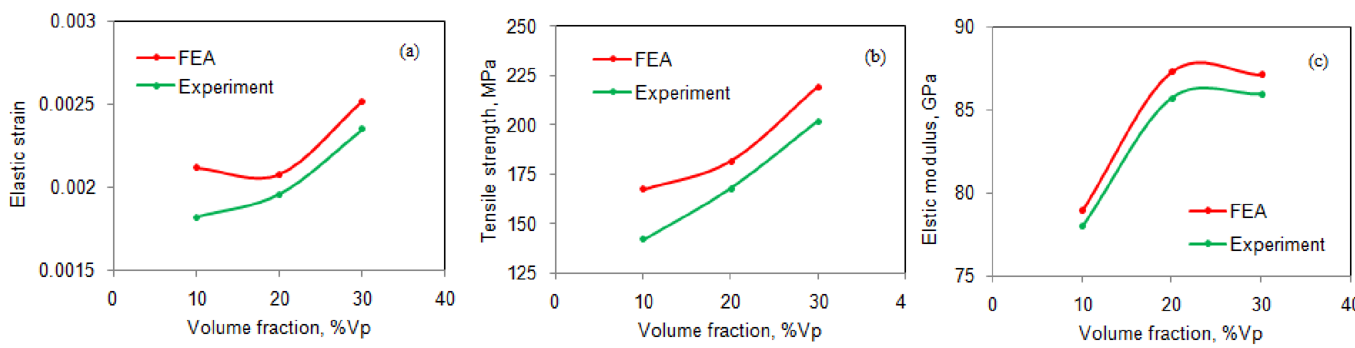


Figure 3: Effect of volume fraction on tensile strength.

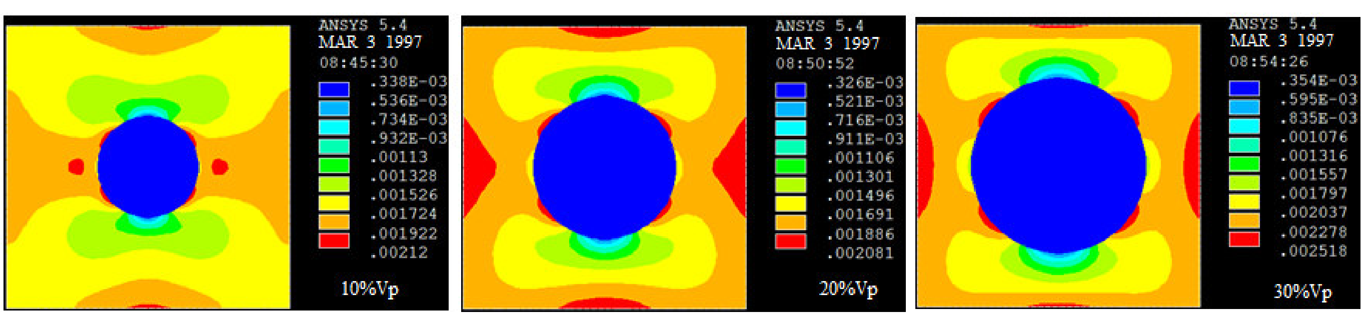


Figure 5: Elastic strain developed in B_4C/AA3003 alloy metal matrix composites.

The tensile strengths of AA3003 alloy and B_4C particles, are, respectively, 110 MPa and 417 MPa. The stress in the AA3003 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.

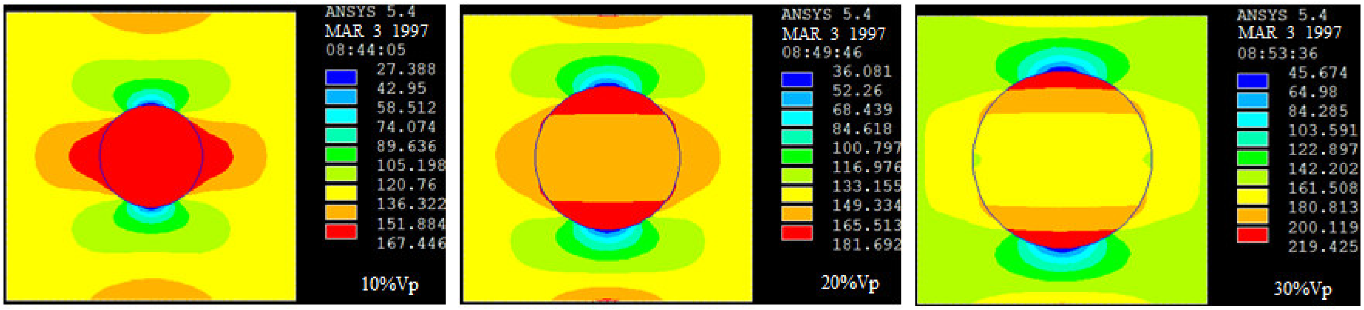


Figure 6: Tensile stress induced in B_4C/AA3003 alloy metal matrix composites.

Figure 7 illustrates the variation of von Mises stress in B_4C/AA3003 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/AA3003 alloy metal matrix composite had experienced interfacial debonding (red color band around the particle).

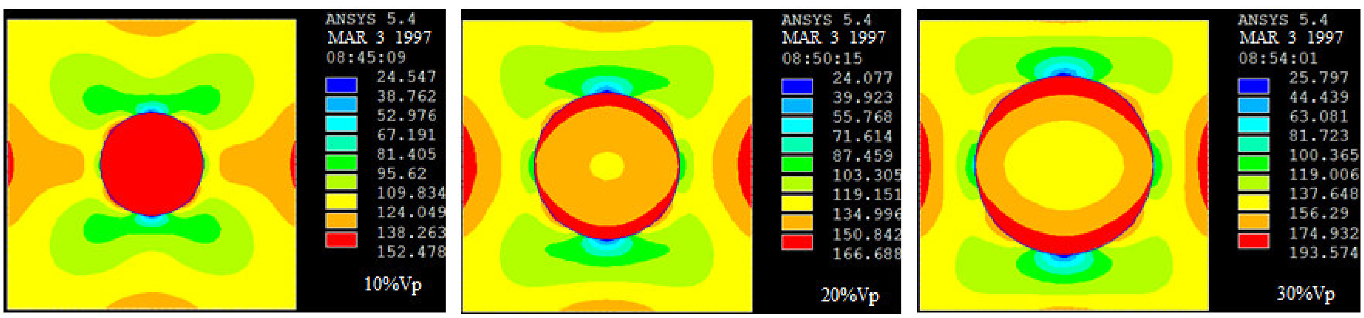


Figure 7: von Mises stress induced in B_4C/AA3003 alloy metal matrix composites.

4. CONCLUSION

The tensile strength increased with an increase of boron carbide content. The adhesive bond was broken between the boron carbide particle and AA3003 alloy matrix in the composite when the stress exceeded the tensile strength (110 MPa) of the matrix.

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