Interface Failure Analysis of TiB_2 Reinforced Aluminum Alloy Matrix Composites

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Abstract: *Hexagonal array unit cell/octagonal particle RVE models are modeled to find micromechanical properties of titanium boride/AA6061 alloy metal matrix composites. Interfacial and tangential traction distributions are also computed to know the debonding at the particle–matrix interface. The normal and tangential interfacial tractions are found to be nearly same for three volume fractions of titanium boride. No debonding has been noticed at the particle-matrix interfaces.*

Keywords: *AA6061 alloy, titanium boride, RVE model, finite element analysis, interfacial tractions, debonding.*

1. INTRODUCTION

Micromechanics have been a widely adopted approach for the prediction of effective properties of a composite material [1-15]. An abundance of research has been devoted to obtaining predictions of equivalent moduli of composite media [16-26]. The practical use of these models however, depends on the microtopology and material properties of the composite. The surface tractions applied to the inclusion will manifest as a layer of body forces spread over the interface between the inclusion and the matrix.

The purpose of this paper is to estimate the elastic moduli, major Poisson's ratio and interfacial tractions of titanium boride/AA6061 alloy metal matrix composites. Finite element analysis (FEA) of TiB_2/AA6061 alloy metal matrix composites was carried out RVE models comprising of square hexagonal cell/octagonal particle.

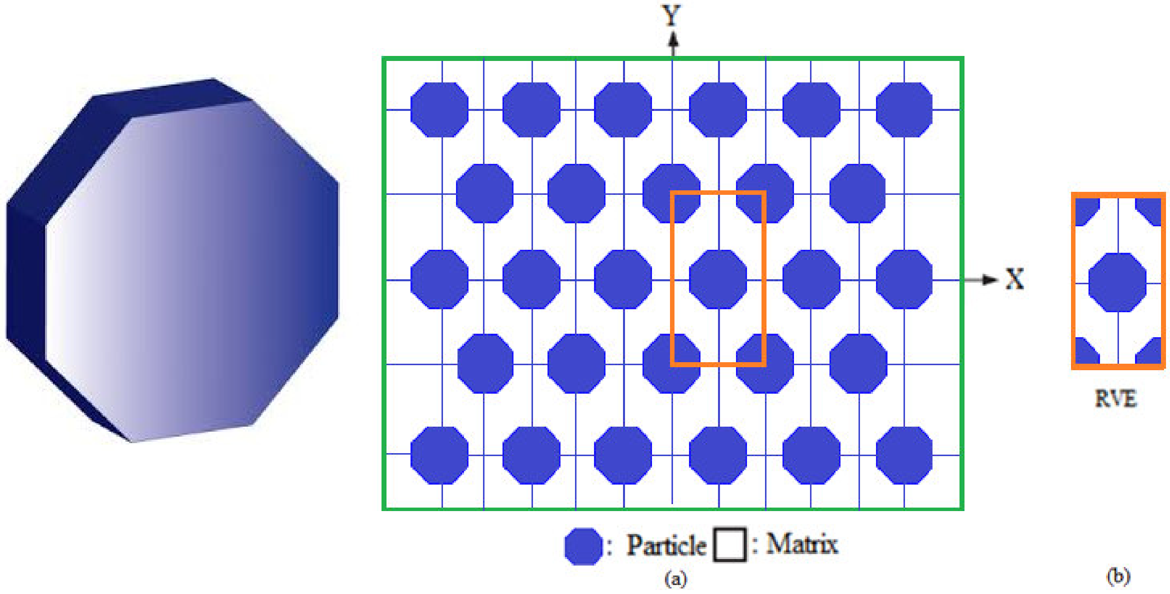

Figure 1: The RVE model: (a) particle distribution and (b) RVE scheme.

2. MATERIALS AND METHODS

The matrix material was AA6061 alloy. The volume fractions of titanium boride particulate reinforcement were 10%, 20%, and 30%. The representative volume element (RVE) scheme is shown in figure 1. The perfect adhesion was assumed between titanium boride particle and AA6061 alloy matrix. PLANE183 element was used for the matrix and the nanoparticle. The interface between particle and matrix was modeled using a COMBIN14 spring-damper element.

A linear stress–strain relation at the macro level can be formulated as follows:

$$\bar{\sigma} = \bar{C}\bar{\varepsilon} \tag{1}$$

where $\bar{\sigma}$ is macro stress, and $\bar{\varepsilon}$ represents macro total strain and $\bar{C}$ and is macro stiffness matrix.

For plane strain conditions, the macro stress- macro strain relation is as follows:

$$\begin{Bmatrix} \bar{\sigma}_x \\ \bar{\sigma}_y \\ \bar{\tau}_{xy} \end{Bmatrix} = \begin{bmatrix} \bar{C}_{11} & \bar{C}_{12} & 0 \\ \bar{C}_{21} & \bar{C}_{22} & 0 \\ 0 & 0 & \bar{C}_{33} \end{bmatrix} \times \begin{Bmatrix} \bar{\varepsilon}_x \\ \bar{\varepsilon}_y \\ \bar{\gamma}_{xy} \end{Bmatrix} \tag{2}$$

The interfacial tractions can be obtained by transforming the micro stresses at the interface as given in Eq. (3):

$$t = \begin{Bmatrix} t_z \\ t_n \\ t_t \end{Bmatrix} = T\sigma \tag{3}$$

$$\text{where, } T = \begin{bmatrix} 0 & 0 & 0 \\ cos^2\theta & sin^2\theta & 2sin\theta cos\theta \\ -sin\theta cos\theta & sin\theta cos\theta & cos^2\theta - sin^2\theta \end{bmatrix}$$

1. RESULTS AND DISCUSSION

Figure 2a exhibits a slight decrease in moduli with incrementally increasing volume fraction of titanium boride in the matrix AA6061 alloy. Figure 2b indicates that the major Poisson's ratio is not affected by the content of titanium boride. Figure 3c indicates that the shear modulus increases as volume fraction increases from 10%Vp to 30%Vp.

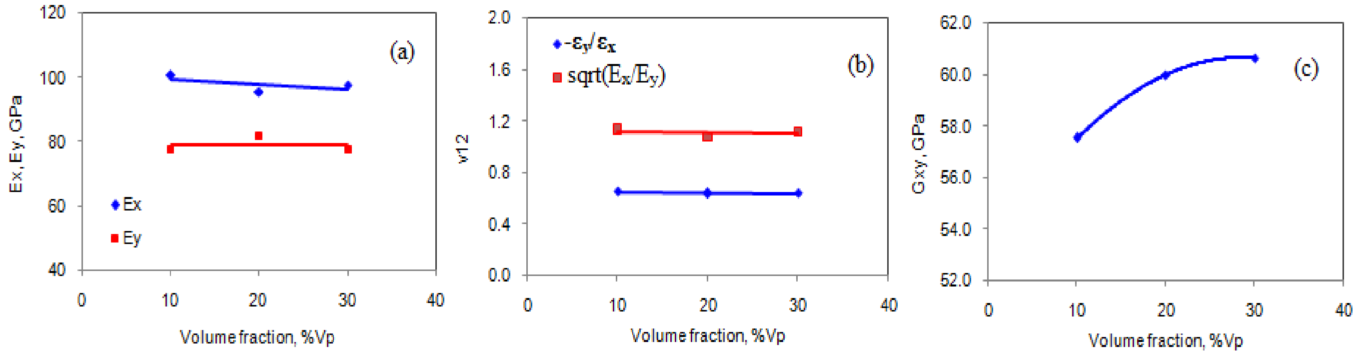

Figure 2: Effect of volume fraction on effective material properties.

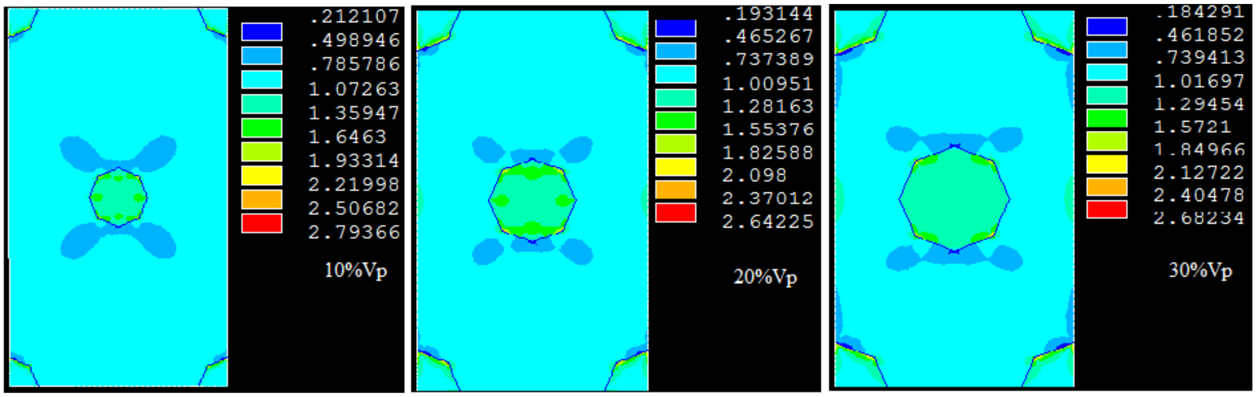

Figure 3: von Mises stresses induced in TiB_2/AA6061 alloy metal matrix composites.

Figure 3 shows von Mises stresses induced in a unit cell of square hexagonal array under tensile stress. The maximum stresses arise at the particle-matrix interface (red color) and in the titanium boride particle (green color). The regions of minimum stresses (blue color) are at the particle-matrix interface or in the matrix near to the interface in the transverse direction of tensile loading.

The normal and tangential interfacial stresses t_n and t_t are plotted from $\theta = 0°$ (the loading direction) to $\theta = 180°$, in figure 5. The interfacial normal traction, t_n decreases with as θ increases from 0^o to 135^o (figure 4a). The value of t_n attains its minimum at 135^o due to compression by the Poisson's effect. The tangential traction t_t, is shown in figure 4b. Its value decreases as θ increases from 0^o to 30^o, and then increases until $\theta = 105^o$. The normal and tangential tractions become zero at 75^o. The normal or tangential tractions are nearly same for three volume fractions of titanium boride in the matrix AA6061 alloy. Debonding of titanium boride particle is not observed in the three composites even though there is rise due to stress concentrations at the vertexes of octagonal particles.

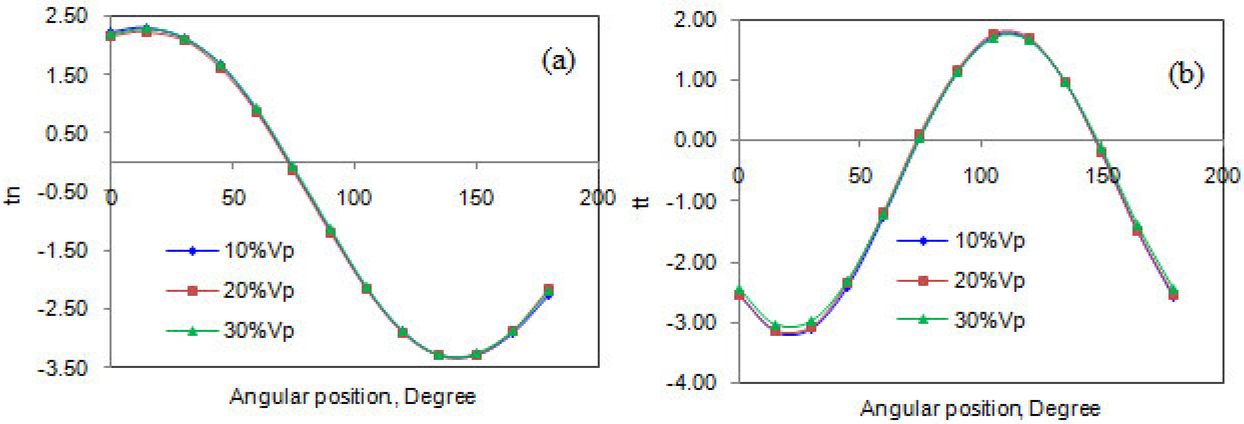

Figure 4: Interfacial tractions along the angle due to tensile loading: (a) normal and (b) tangential.

2. CONCLUSION

The interfacial normal and tangential tractions are nearly same for the inclusion octagonal titanium boride particles in the matrix AA6061 alloy. No debonding has been observed between the titanium boride and matrix AA6061 alloy.

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