# Effect of Interfacial Tractions of Rectangular Titanium Boride Particulate/AA8090 Alloy Metal Matrix Composites

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**Abstract:** A micromechanical modeling is carried out to assess of debonding evolution by normal and tangential separation within titanium boride/AA8090 alloy metal matrix composite under various particle loading conditions. Square diagonal array unit cell/rectangular particle RVE models are worked out using two-dimensional finite element methods. The debonding has taken place at the particle-matrix interface.

**Keywords:** AA8090 alloy, titanium boride, rectangular particle, RVE model, finite element analysis, interfacial tractions, debonding.

## 1. INTRODUCTION

The micro-mechanisms of failure in metal matrix composite materials are generally known. They involve either particle crushing or particulate-matrix interface decohesion, followed by matrix cracking. The decohesion mechanisms are sensitive to local morphological parameters like volume fraction, size, shape and spatial distribution of reinforcements, interfacial strength and process-related defects as shown in figure 1. The effect of weak bonding or debonded interface on the mechanical properties has been studied by several investigators [1-3]. Among the important contributions to the field of damage evolution by normal and tangential separation are those by Needleman [4], Tvegaard [5], and Allen et al. [6]. A majority of these studies have used unit cell models, which assume that the material is constituted of periodic repetition of single cells. In the context of the debonding behavior, the most frequent and versatile approach is based on the primal variant of the Finite Element Method (FEM) [7-16].

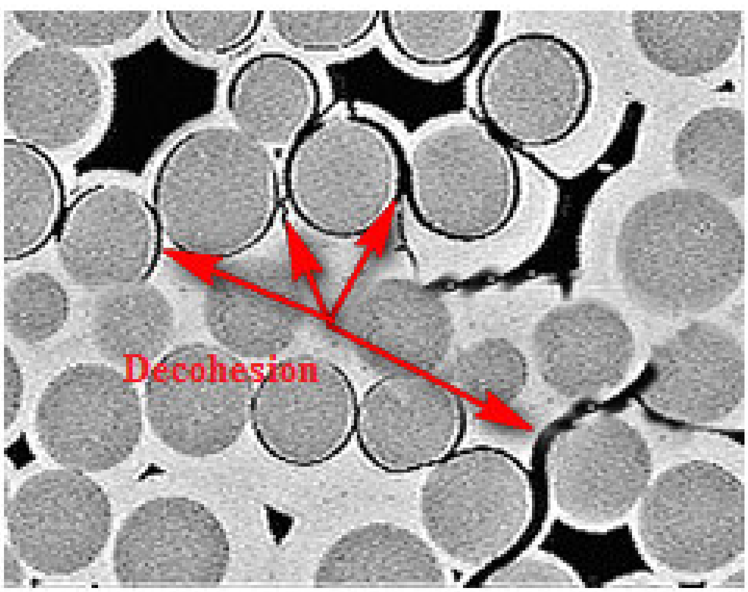


Figure 1: Decohesion in a metal matrix composite.

Therefore, the current investigation aims to cohesiveness interface between the particle and the matrix in titanium boride/AA8090 alloy particulate metal matrix composites by calculating interfacial tractions. Finite element method is used to construct and analyze the different (representative volume elements (RVEs) models of periodic rectangular particulates having diagonal square array of periodical distribution of particulates.

## 2. MATERIALS AND METHODS

The volume fractions of titanium boride particulate reinforcement were 10%, 20%, and 30% in the matrix AA8090 alloy. The periodic model for the representative volume element (RVE) scheme is shown in figure 2. The perfect adhesion was assumed between titanium boride particle and AA8090 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.

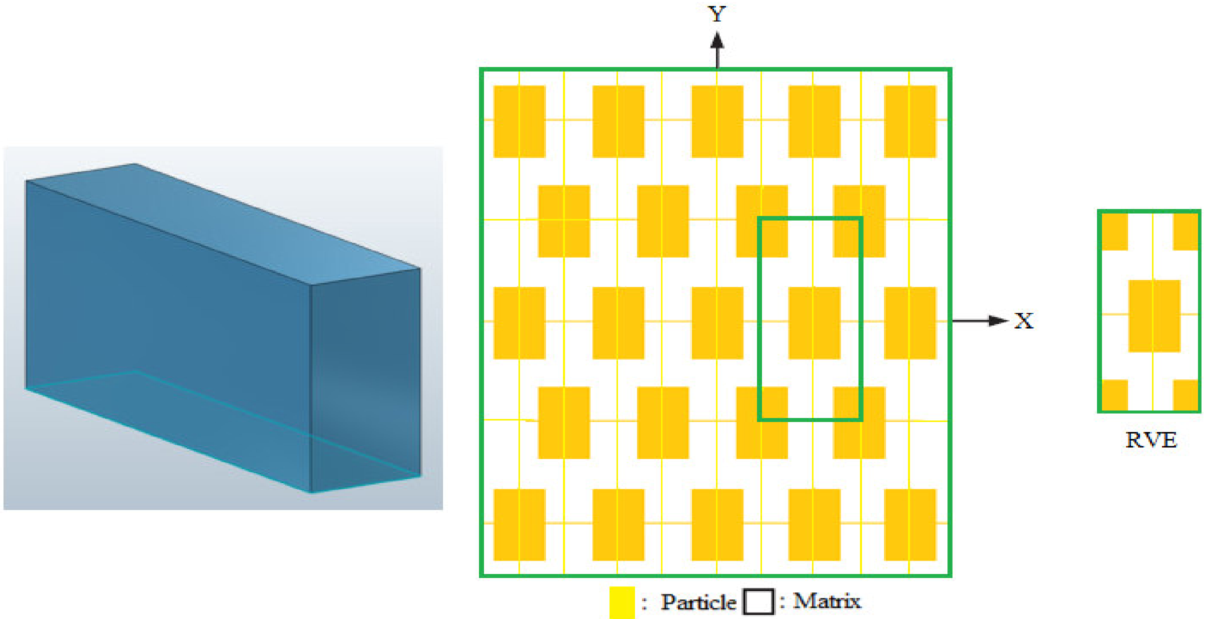


**Figure 2:** The RVE model: (a) particle distribution and (b) RVE scheme.

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

$$\bar{\sigma} = \overline{C}\bar{\varepsilon} \quad (1)$$

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

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

$$\begin{Bmatrix} \overline{\sigma_x} \\ \overline{\sigma_y} \\ \overline{\tau_{xy}} \end{Bmatrix} = \begin{bmatrix} \overline{C_{11}} & \overline{C_{12}} & 0 \\ \overline{C_{21}} & \overline{C_{22}} & 0 \\ 0 & 0 & \overline{C_{33}} \end{bmatrix} \times \begin{Bmatrix} \overline{\varepsilon_x} \\ \overline{\varepsilon_y} \\ \overline{\gamma_{xy}} \end{Bmatrix} \quad (2)$$

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

$$t = \begin{Bmatrix} t_z \\ t_n \\ t_t \end{Bmatrix} = T\sigma \quad (3)$$

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

## 3. RESULTS AND DISCUSSION

Influence of volume fraction on the elastic moduli, $E_x$, $E_y$ and Gxy are shown figure 3a. The tensile elastic modulus, $E_x$ increases with increase of volume fraction titanium boride. The compressive elastic modulus, $E_y$ and shear modulus, $G_{xy}$ decrease with increase of volume fraction titanium boride. The major Poisson's ratio increases with increase of volume fraction titanium boride for $TiB_2$/AA8090 alloy metal matrix composites (figure 3b). Figure 4 shows shear stresses induced in a unit cell of square diagonal array RVE under tensile stress. The maximum shear stress occurs at 45$^o$ and 135$^o$ from the axis of tensile loading. The stress bridging is high in high volume fraction of titanium boride.

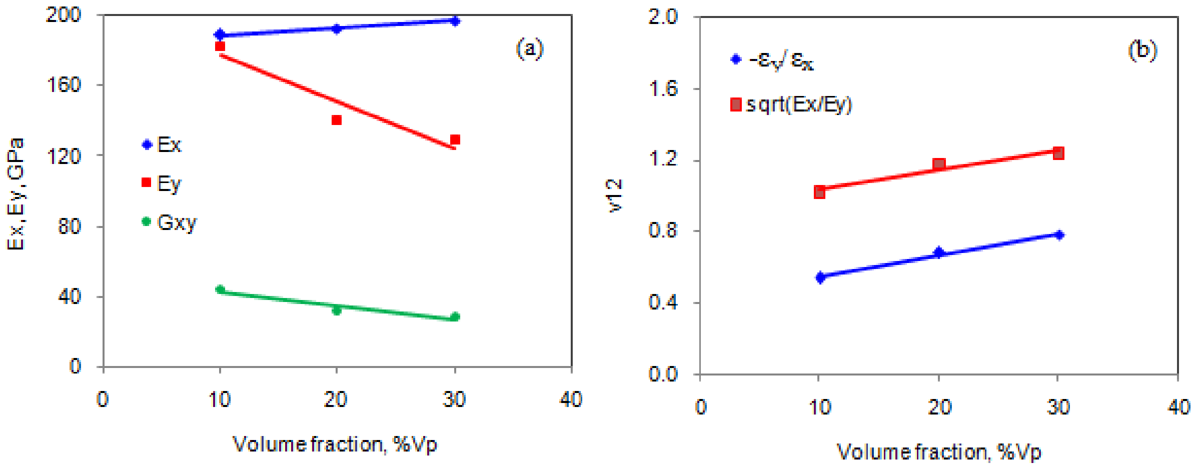


**Figure 3:** Effect of volume fraction on effective material properties.

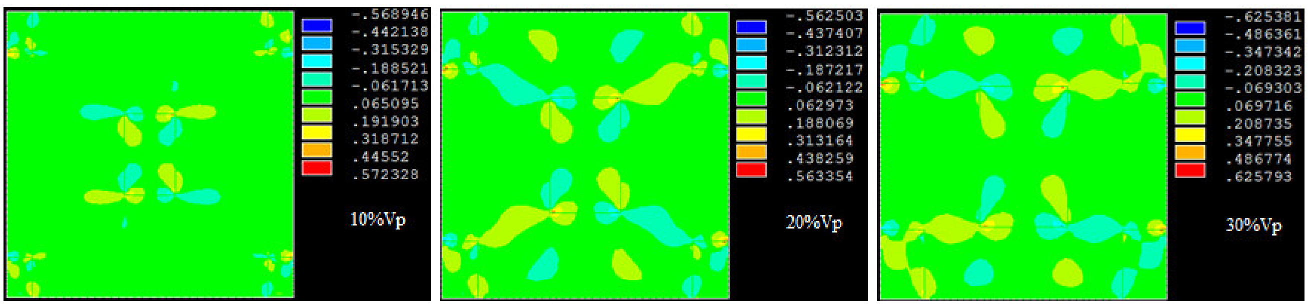


**Figure 4:** Stress concentrations in $TiB_2$/AA8090 alloy metal matrix composites.

The interfacial normal traction, $t_n$ decreases with as θ increases from 0° to 135° (figure 5a) and it becomes zero at 75° and maximum at 0°. The normal traction $t_n$ turns into negatively maximum at 135° due to compression of Poisson's effect. The tangential traction $t_t$, increases as θ increases from 15° to 105°, and it reaches zero value at θ =75°. The incidence of zero value of normal and tangential traction coincides for square diagonal array of periodic distribution of titanium boride particles. There is likelihood of debonding at 75° from the axis of loading as the zero values of interfacial tractions indicate no load transfer from the matrix to the particle. Prior to debonding, the normal stress is maximum at θ = 0°. While debonding in progress, the normal traction, $t_n$ decreases in magnitude gradually and becomes zero at 75°. Similarly, the tangential traction, $t_t$ increases in magnitude gradually and becomes zero at 75°.

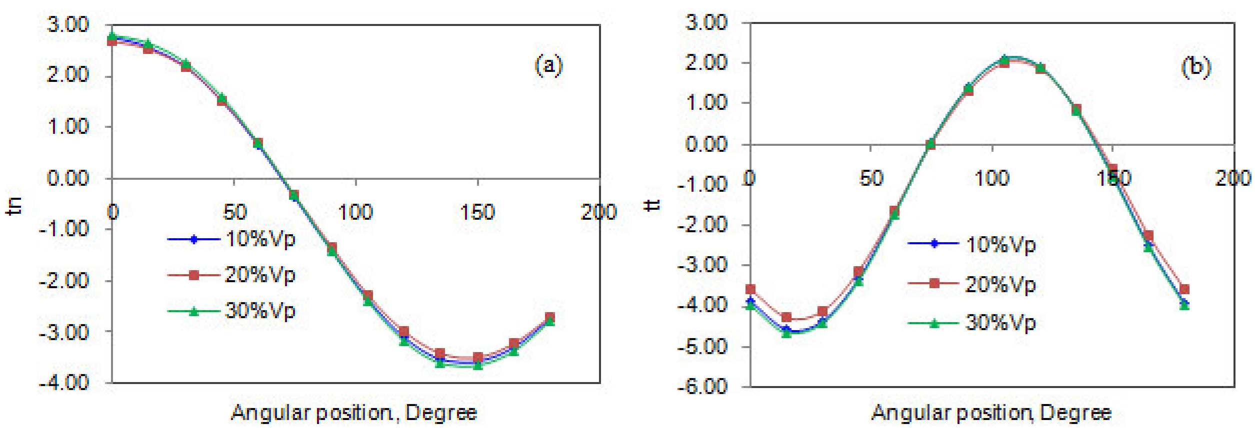

**Figure 5:** Interfacial tractions along the angle due to tensile loading: (a) normal and (b) tangential.

## 4. CONCLUSION

Tensile elastic modulus increases while compressive elastic modulus and shear modulus decrease with increase of volume fraction of titanium boride. The normal and tangential tractions are coincidental at 75°. The deboning between particle and matrix take place at 75° from the axis of loading.

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