# Reckoning of Micro-stresses and interfacial Tractions in Titanium Boride/AA2024 Alloy Metal Matrix Composites

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**Abstract:** A micromechanical approach is developed to compute the micro stress within a metal matrix composite under various particle loading conditions. Diamond unit cell/hexagonal particle RVE models are analyzed and compared using two-dimensional finite element methods. Subsequently, effective material properties, the distribution of micro stress in the particle/matrix, as well as traction distribution at the particle–matrix interface, and the effect of different interfacial stiffness, are obtained. Shear modulus decreases as volume fraction increases from 10%Vp to 20%Vp and later on it increase from 20%Vp to 30%Vo of titanium boride in the matrix of AA2024 alloy.

**Keywords:** AA2024 alloy, titanium boride, RVE model, finite element analysis, interfacial tractions, hexagonal shaped particle.

## 1. INTRODUCTION

Two-phase materials such as metal matrix composites have been exploited for decades in engineering design, and they have proved to be of great applicability and high performance. A model that can estimate elastic properties of these materials as a function of simple macrophysical observables is wanted. The effective properties of the RVE are obtained by various analytical models such as finite element methods [1, 2]. The heterogeneity in the metal matrix composites can be attributed to the presence of dispersed particulates in a matrix and the mechanical behavior of these composites largely depends on the size, shape and properties of these particulates (figure 1).

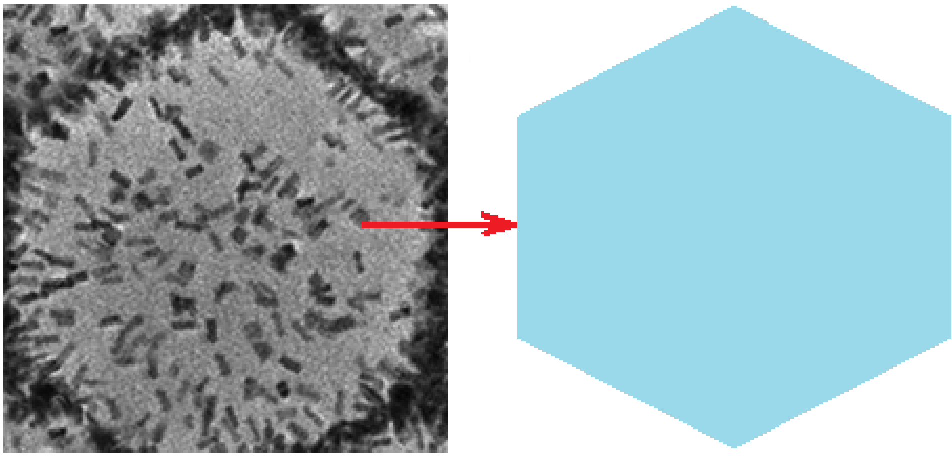

**Figure 1:** Reinforced particle in a metal matrix composite.

The aim of the present paper is to evaluate micro stresses and interfacial tractions of titanium boride/AA2024 alloy metal matrix composites. Finite element analysis (FEA) of $B_4C$/AA2024 alloy metal matrix composites was executed RVE models comprising of hexagonal cell/hexagonal particle. The shape of titanium boride particle was assumed to be hexagonal.

## 2. MATERIALS AND METHODS

The matrix material was AA2024 alloy. The volume fractions of titanium boride particulate reinforcement were 10%, 20%, and 30%. The RVE scheme was employed to estimate micro stresses and interfacial tractions through finite element analysis as shown in figure 2. The perfect adhesion was assumed between titanium boride particle and AA2024 alloy matrix. PLANE183 element was employed for the matrix and the nanoparticle. The interface between particle and matrix was discretized using a COMBIN14 spring-damper element.

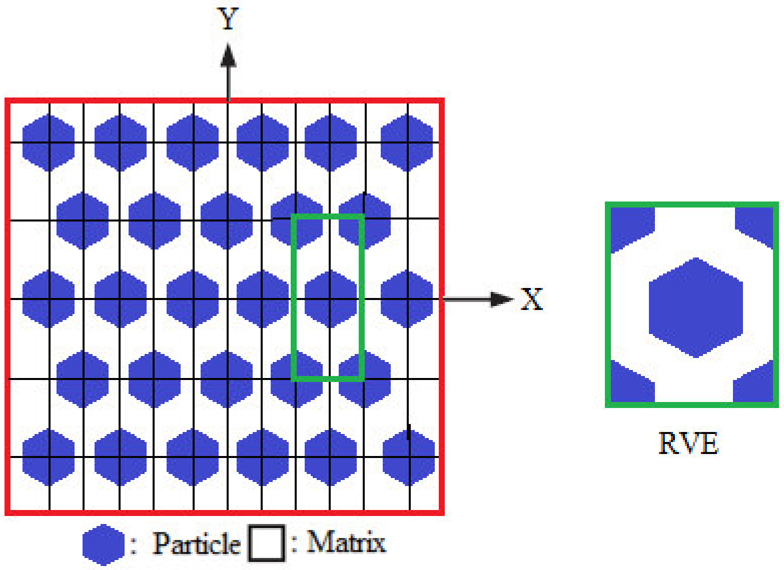

**Figure 2:** The RVE model: (a) particle distribution and (b) RVE scheme.

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

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

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:

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

The traction t at any point on the interface can always be decomposed into three components: normal traction $t_n$, which is perpendicular to the interface at the current point, tangential traction $t_t$ which is tangent to the circumference of the particle at the current point, and longitudinal traction $t_z$ which is parallel to the longitudinal direction of the particle. The interfacial tractions can be obtained by transforming the micro stresses at the interface as given in Eq. (3):

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

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

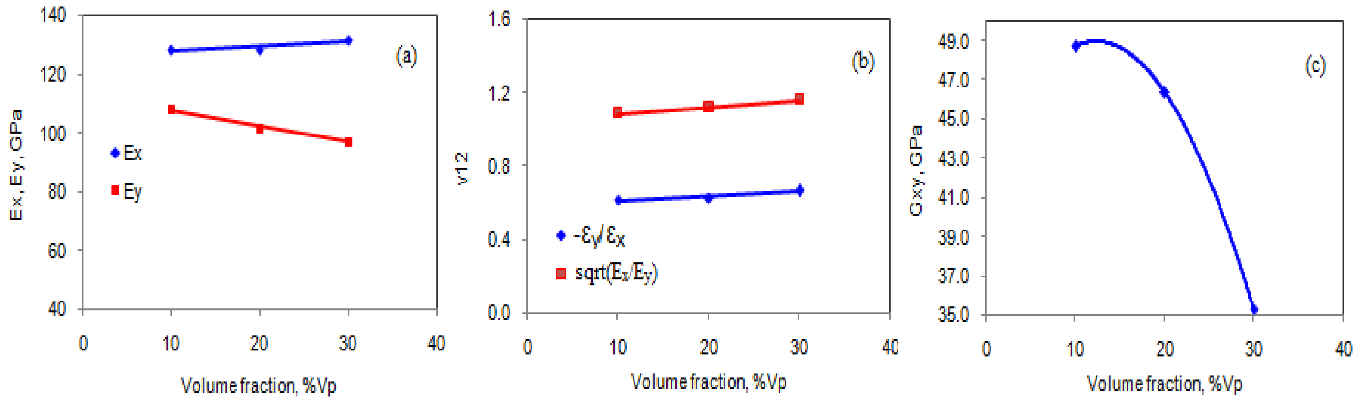

**Figure 4:** Effect of volume fraction on effective material properties.

## 3. RESULTS AND DISCUSSION

Elastic moduli, $E_x$ and $E_y$ increase with volume fraction increases, as shown in figure 3a. The major Poisson's ratio increases with increase of volume fraction of titanium boride in the metal matrix composites (figure 3b). Shear modulus decreases as volume fraction increases from 10%Vp to 20%Vp and later on it increase from 20%Vp to 30%Vo of titanium boride in the matrix of AA2024 alloy (figure 3c).

Figure 4 shows stress concentrations induced in a unit cell of square diagonal array under tensile stress. In a unit cell of square diagonal array under tensile stress, maximum stress concentrations are observed in the titanium boride particle (green color) or at the vertices of the hexagonal particle (red color). The regions of minimum stress (blue color) concentrations occur at the particle-matrix interface in transverse direction of tensile loading.

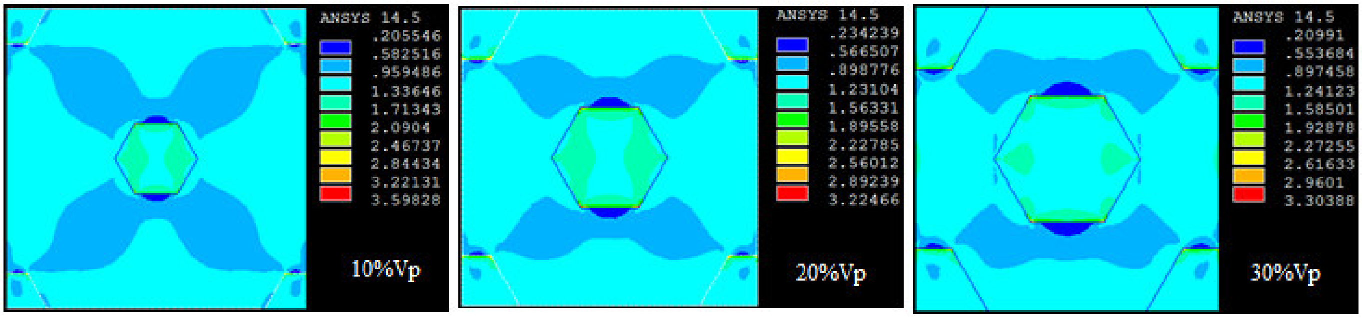

**Figure 4:** Stress concentrations in $TiB_2$/AA2024 alloy metal matrix composites.

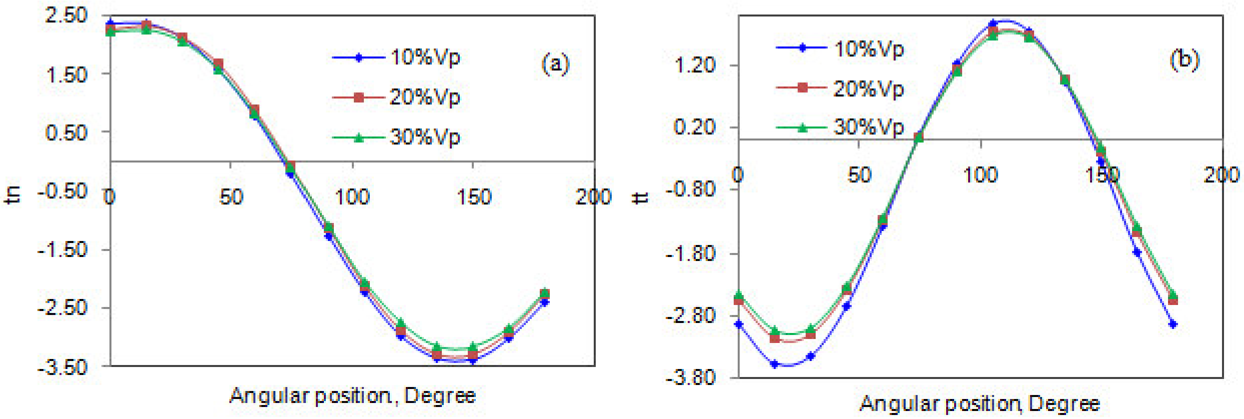

**Figure 5:** Interfacial tractions along the angle due to tensile loading: (a) normal and (b) tangential.

The interfacial normal traction, $t_n$ decreases with as θ increases from $0^o$ to $135^o$ (figure 5a). The direction of macro load coincides with the direction of $t_n$ at $\theta = 0^o$, so $t_n$ attains its minimum at $135^o$ due to compression by the Poisson's effect. The major Poisson's ratio increases with increase of volume fraction of titanium boride in the metal matrix composites. The Interfacial tangential traction increases from $30^o$ to $105^o$ (figure 5b).

## 4. CONCLUSION

For effective material properties, variations of Ex, $E_y$, $G_{xy}$ and $v_{12}$ with respect to $V_p$, are predicted. Additionally, in unit cells with different particle volume fractions, variations of interfacial tractions along particle perimeter under tension loading. For titanium boride/AA2024 alloy metal matrix composites, interfacial normal traction decreases due to Poisson's effect.

## REFERENCES

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