Cohesive Zone Modelling for Interface Debonding in AA8090/Silicon Nitride Nanoparticulate Metal Matrix Composites

[1]P. M. Jebaraj and A. Chennakesava Reddy[2]

[1]Professor, Department of Mechanical Engineering, Dr. Ambdekar Institute of Technology, Bangalore, India
[2]Assistant Professor, Department of Mechanical Engineering, MJ College of Engineering and Technology, Hyderabad, India
dr_acreddy@yahoo.com

Abstract: *Diamond array unit cell/2-D elliptical particulate RVE models were employed to predict interface debonding using two-dimensional finite element methods under plane strain conditions. The particulate metal matrix composites are silicon nitride/AA8090 alloy at different volume fractions of silicon nitride. There is strong probability of interface debonding at all volume fractions in the AA8090 alloy matrix.*

Keywords: AA8090*, silicon nitride, elliptical particle, RVE model, finite element analysis, debonding.*

1. INTRODUCTION

Numerical modeling of the behavior of multiphase materials has typically been conducted by assuming a single fiber, whisker, or particle of simple geometry in a unit cell model. Unit cell models have been employed to model fracture of the ceramic reinforcement [1-6]. Modeling of damage in the composite was conducted on 2D sections by approximating the particle morphology as ellipsoids, so the deformation assumed a two-dimensional stress state (plane stress or plane strain). A number of research endeavors have continued to advance the use of cohesive zones in modeling fracture [7-10].

The paper is intended to predict debonding in AA8090 alloy/silicon nitride particulate metal matrix composites. Finite element method was employed to construct and analyze representative volume elements (RVEs) models of periodic 2-D elliptical particulates in a diamond array distribution.

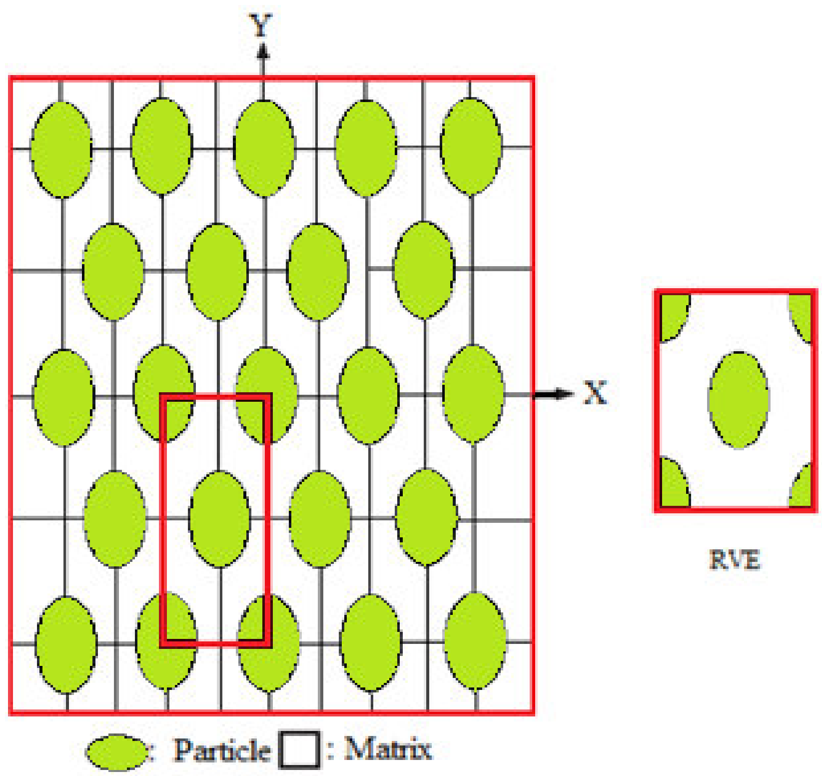

Figure 1: The RVE model: (a) particle distribution and (b) RVE scheme.

2. MATERIALS AND METHODS

The AA8090 alloy/silicon nitride nanoparticulate metal matrix composites were used in the present work with 10%, 20%, and 30% volume fractions of silicon nitride. The periodic model for the representative volume element (RVE) scheme as shown in figure 1 was used to analyze the composites with finite element software code. The RVE scheme was constructed from 2-D elliptical particulates in a diamond array particulate distribution. The perfect adhesion was assumed between silicon nitride particle and AA8090 alloy matrix. PLANE183 element was used for the matrix and the nanoparticle. The interface between particle and matrix was modeled using CONTACT -172 elements.

If particle fracture occurs when the stress in the particle reaches its ultimate tensile strength, $\sigma_{p,uts}$, then setting the boundary condition at

$$\sigma_p = \sigma_{p,\,uts} \tag{1}$$

and substituting into Eq.(1) gives a relationship between the strength of the particle and the interfacial shear stress such that if

$$\sigma_{P,uts} < \frac{2\tau}{n} \tag{2}$$

Then the particle will fracture. Similarly if interfacial debonding/yielding is considered to occur when the interfacial shear stress reaches its shear strength

$$\tau = \tau_{max} \tag{3}$$

Then by substituting Eq. (5) into Eq.(1) a boundary condition for particle/matrix interfacial fracture can be established where-by,

$$\tau_{max} < \frac{n\sigma_p}{2} \tag{4}$$

This approach suggests that the outcome of a matrix crack impinging on an embedded particle depends on the balance between the particle strength and the shear strength of the interface.

3. RESULTS AND DISCUSSION

The effect of volume fraction of silicon nitride on the elastic moduli, E_x, E_y and G_{xy} is shown figure 2a. The tensile elastic modulus and compressive modulus were decreased with the increase of silicon nitride content in the composites. The shear modulus decreased with the increase of silicon nitride in the matrix AA8090 alloy. The major Poisson's ratio decreased with increase of volume fraction of silicon nitride (figure 2b).

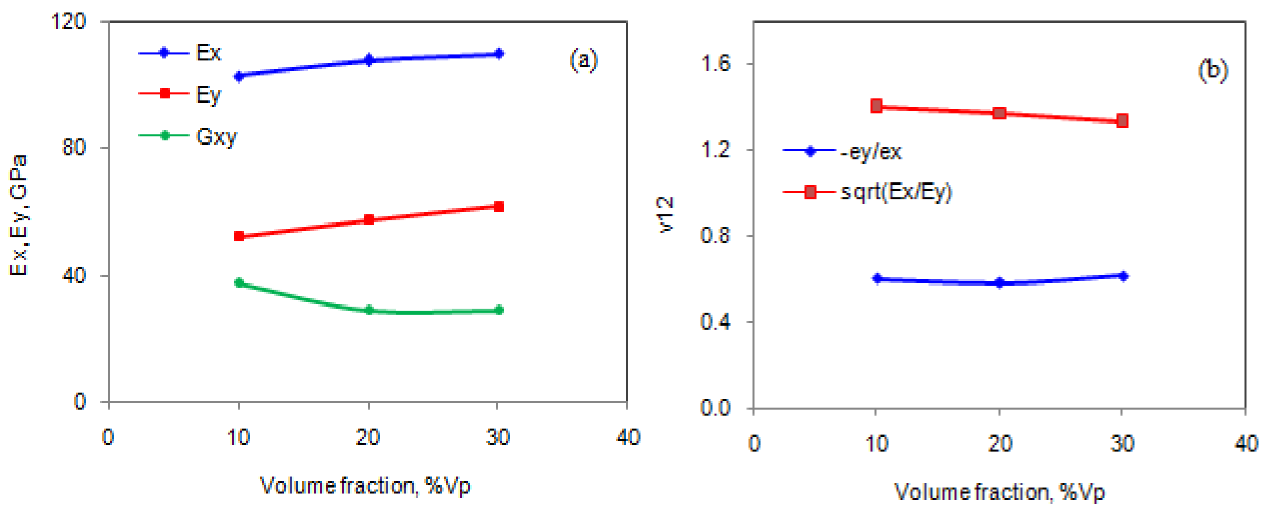

Figure 2: Effect of volume fraction on effective material properties.

The silicon nitride particulate fracture was not noticed as the condition $\sigma_p \leq 2\tau/n$ is not satisfied as shown in figure 3a. The strength of silicon nitride is higher than the shear stress required for fracturing silicon nitride particulates. The debonding was occurred in all the composites as shown in figure 3b. The debonding was due to heavy load transfer from the AA8090 matrix alloy to the silicon nitride particulates. The shear stress developed at the interface increased with the increase of silicon nitride content in the composites as shown in figure 4. The interface debonding had occurred in the direction of tensile loading and along the direction of maximum shear stress. The debonding phenomenon is clearly observed in the composite having 30% silicon nitride (figure 5).

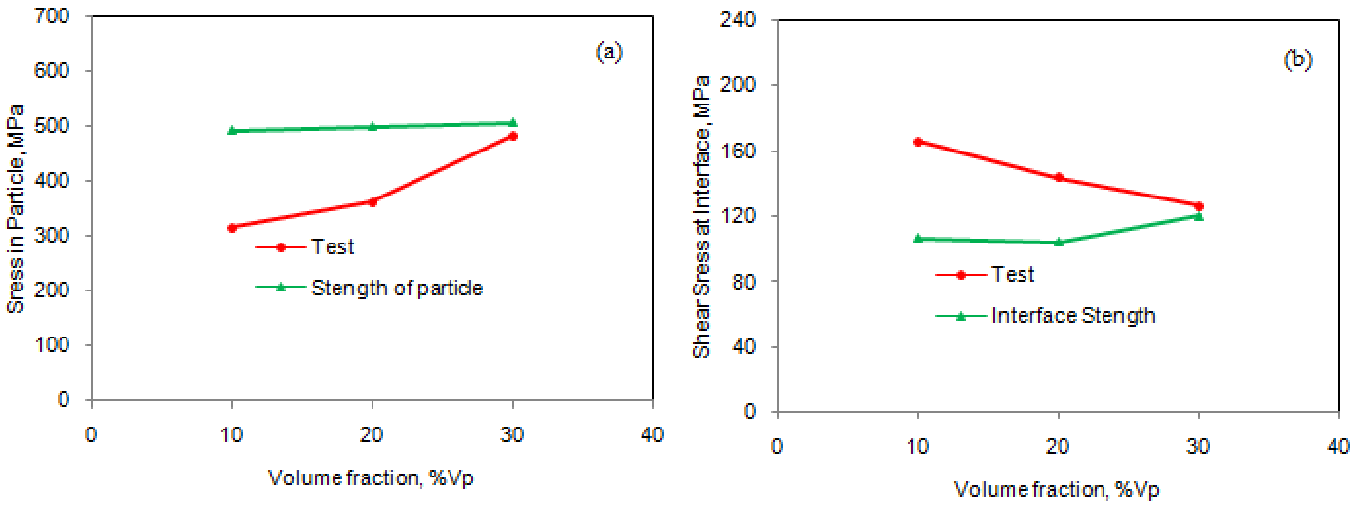

Figure 3: Fracture criteria of: (a) particulate fracture and (b) interface debonding.

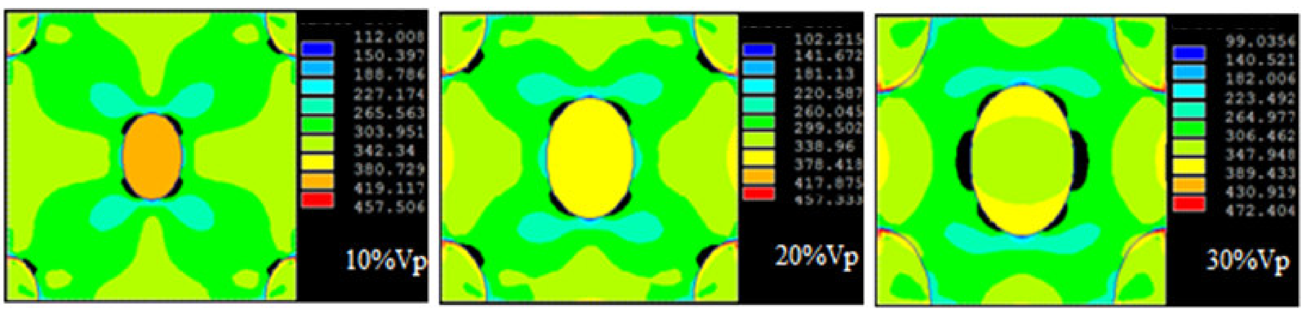

Figure 4: Results obtained from finite element analysis: von Mises stresses.

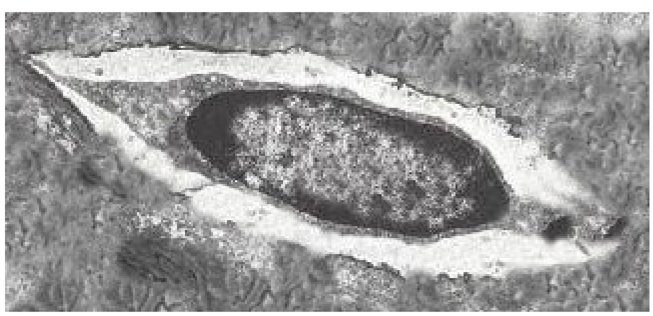

Figure 5: Interface debonding in the composite AA8090/30%silicon nitride.

4. CONCLUSION

The interface debonding took place at volume fractions of SiN in the composite. The debonding was highly predominant in the composites having 30% silicon nitride.

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