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Micro-Tensile Behavior of AA7020/Carbon Black Nanoparticle Metal Matrix Composites

[1]T.Prasad, [2]A.Chennakesava Reddy
[1]*Research Scholar, Department of Mechanical Engineering, JNTU University, Hyderabad, India*
[2]*Professor, Department of Mechanical Engineering, JNT University, Hyderabad-500 085, India*

Abstract : *The micro-tensile behavior of AA7020/carbon black nanoparticle composites was examined by using finite element analysis and representative volume element models for three different volume fractions. The uniform distributions of the nanoparticles were constructed to produce a representative volume element of the composites. The predicted mechanical properties and overall tensile stress-strain by finite element analysis corresponded well to the experimental results at the elastic region and near the yield surface, but the model slightly overestimated the strength of the composites at higher stress. This deviation possibly occurs from micro-mechanical factors, which were not considered in the RVE models. In contrast to FE analysis, fracture of the nanoparticle-matrix debonding occurred because of large localized stress. In the case of a high applied load, non-linear behavior of reinforcements and interfacial strength should be considered to obtain accurate results.*
Keywords: *AA7020, carbon black, RVE, micro-tensile behavior, finite element analysis.*

I. Introduction

Particle reinforced metal matrix composites have been the subject of extensive study due to a need for lightweight structural materials [1-2]. The basic concept of the micro-mechanics of failure (MMF) theory is to perform a hierarchy of micromechanical analyses, starting from mechanical behavior of constituents (the fiber, the matrix, and the interface), then going on to the mechanical behavior of a composite. Failed constituent envelopes are predicted by MMF but not by Tsai-Wu as shown in Fig. 1.

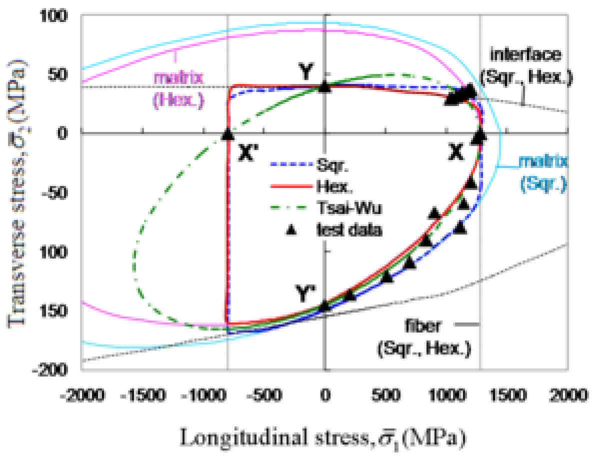

Fig. 1: Failure envelopes generated by MMF and the Tsai-Wu failure criterion for a carbon/epoxy UD ply, with test data superimposed.

The physical and mechanical properties are influenced by the distribution, size and shape parameters of the reinforced particles [3-5]. Since the theory for determining the overall elastic properties of two-phase composites is relatively well developed, the emphasis in this paper is the strength of the weakest zone and metallurgical phenomena in it. Considering adhesion, formation of precipitates, particle size, agglomeration, voids/porosity, obstacles to the dislocation, and the interfacial reaction of the particle/matrix, the formula [6-7] for the strength of composite is stated below:

$$\sigma_c = \left[\sigma_m \left\{\frac{1-(v_p - v_v)^{2/3}}{1-1.5(v_p - v_v)}\right\}\right] e^{m_p(v_p - v_v)} + k d_p^{-1/2} \quad (1)$$
$$k = E_m m_m / E_p m_p\,;$$

where, v_v and v_p are the volume fractions of voids/porosity and nanoparticles in the composite respectively, mp and mm are the possion's ratios of the nanoparticles and matrix respectively, d_p is the mean nanoparticle size (diameter) and E_m and E_p is elastic moduli of the matrix and the particle respectively. Anisotropy can be seen in many composites. The equation [6-7] to find Young's modulus including the effect of voids/porosity in the composite is given below:

$$\frac{E_c}{E_m} = \left(\frac{1-v_v^{2/3}}{1-v_v^{2/3}+v_v}\right) + \frac{1+(\delta-1)v_p^{2/3}}{1+(\delta-1)\left(v_p^{2/3}-v_p\right)} \quad (2)$$

$$\delta = E_p/E_m$$

where, E_c, E_m and E_p are the elastic moduli of composite, matrix and nanoparticles respectively.

Micro mechanics is a powerful tool compared with traditional macro-level methods since it provides insight to the micro stress distribution in each constituent. On the other hand, numerical micromechanical modeling analysis appears to be well-suited to describe the behavior of particle reinforced metal matrix composites [8, 9]. The finite element analysis was employed to examine the effect of the volume fraction and fiber aspect ratio on short, random, SiC fiber reinforced, metal matrix composites [10].

The 7XXX alloys are of special interest since in addition to meeting the needs of aerospace, industry, and transportation, they are extensively used or are being considered as protection materials for both welded structural and appliqué armor.

The objective the present paper is to investigate the effects of adhesive characteristics between the matrix and the reinforced nanoparticle of AA7020/carbon black nanocomposites through RVE models using finite element analysis software.

II. Materials And Methods

The matrix material was AA7020 aluminum alloy. The reinforcement material was carbon nanoparticles of average size 100nm. The matrix alloys and composites were prepared by the stir casting and low-pressure die casting process. The volume fractions of carbon black reinforcement were 10%, 20%, and 30%. Prior to the machining of composite samples, a solution treatment was applied at 500^0 C for 1 hour, followed by quenching in cold water. The samples were then naturally aged at room temperature for 100 hours.

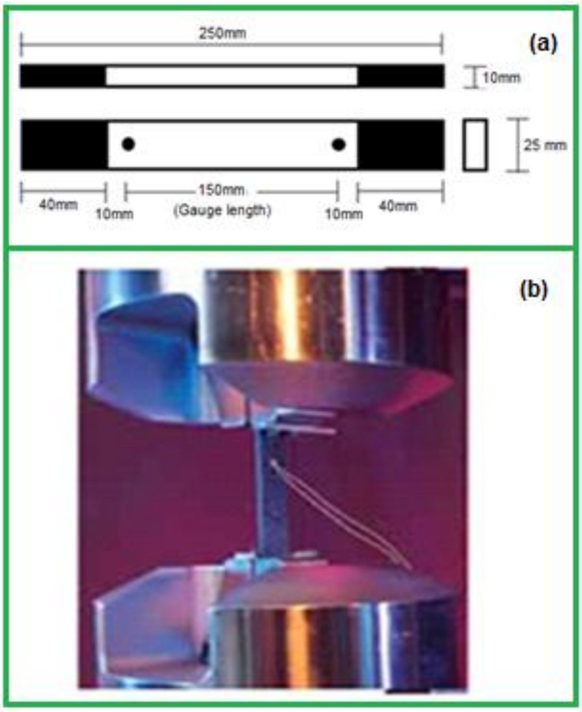

Fig. 2: Shape and dimensions of tensile specimen; (b) tensile testing.

The heat-treated samples were machined to get flat-rectangular specimens (Fig. 2) for the tensile tests. The tensile specimens were placed in the grips of 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). A strain gauge was used to determine elongation as shown in Fig. 2.

An image analyzer was used to study the distribution of the reinforcement particles within the AA7020 aluminum alloy matrix. The polished specimens were ringed with distilled water, and etched with 0.5% HF solution for optical microscopic analysis. Fracture surfaces of the test samples were analyzed with a scanning electron microscope (SEM) using S-3000N Toshiba SEM to define the macroscopic fracture mode and to establish the microscopic mechanisms governing fracture.

In this research, a cubical representative volume element (RVE) was implemented to analyze the tensile behavior AA7020/carbon black nanocomposites (Fig. 3). The RVE scheme with adhesion (without interphase) was applied between the matrix and the filler. The PLANE183 element was used in the matrix and the nanoparticle. In order to model the adhesion between the matrix and the particle, a COMBIN14 spring-damper element was used. The stiffness of this element was chosen to be unity, which determines the interfacial strength for the interface region.

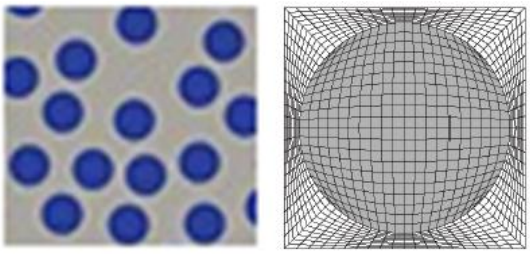

Fig. 3: The RVE model.

III. Results And Discussion

Fig. 4 reveals the optical microstructure of AA7020/carbon black nanocomposites. It is observed that the carbon black nanoparticles are randomly distributed in the AA7020 matrix. The micro-voids are also seen across the grain boundaries.

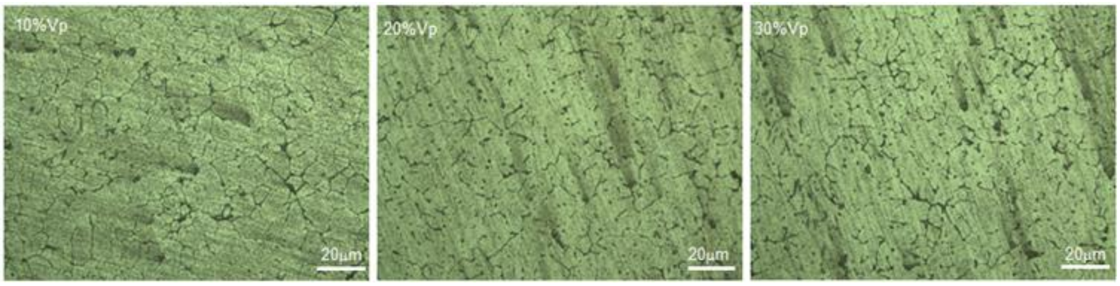

Fig. 4: Optical microstructures of AA7020/carbon black nanocomposites.

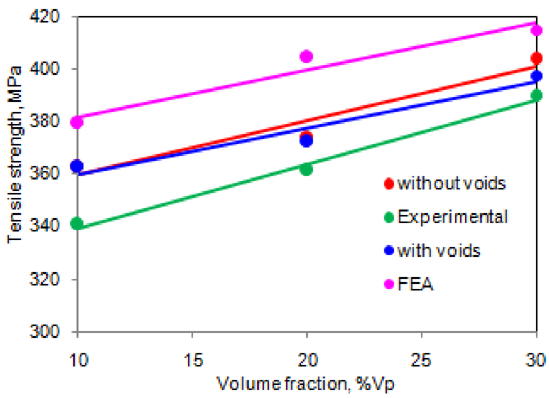

Fig. 5: Effect of volume fraction on tensile strength.

Fig.5 describes the tensile strengths of the nanocomposites obtained by FEA, Reddy model, and experimental procedure. In all the cases the tensile strength increases with an increase of carbon black content in the nano campsites. The tensile strength (without voids) obtained by the finite element analysis (FEA) were higher than the experimental and AC Reddy values. When voids were considered in the composites the tensile strength was decreased. This was on account of the failure which was occurred in the regions of voids or in the matrix.

The adhesive bond was broken between the carbon black nanoparticle and AA7020 alloy matrix in the nanocomposite when the stress was exceeded the ultimate tensile strength (350 MPa) of the matrix as shown in Fig. 6. The region of red color is the failure zone between the nanoparticle and the matrix. The load transfer from the matrix to the carbon particle increased with increasing content of carbon black nanoparticles in the composite. Fig. 7 illustrates the elastic strain contours of the RVE models. The elastic strain increased elastically with the content of carbon black in the direction of the tensile loading.

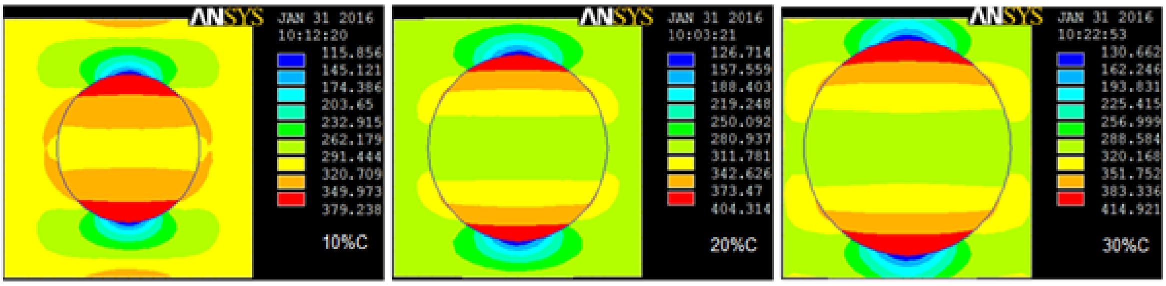

Fig. 6: Tensile stress.

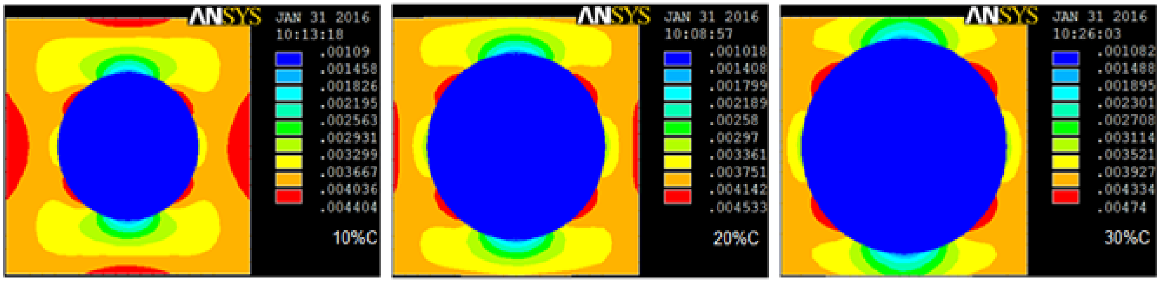

Fig. 7: Elastic strain in the direction of tensile loading.

Fig. 8 shows the variations of von Mises stress in the nanocomposites. The von Mises stress was found to be high for 30% carbon black content in the composites. It was low for 20% carbon black content in the composites. The local stress concentration around the nanoparticle increased with an increase in the volume fraction of carbon black.

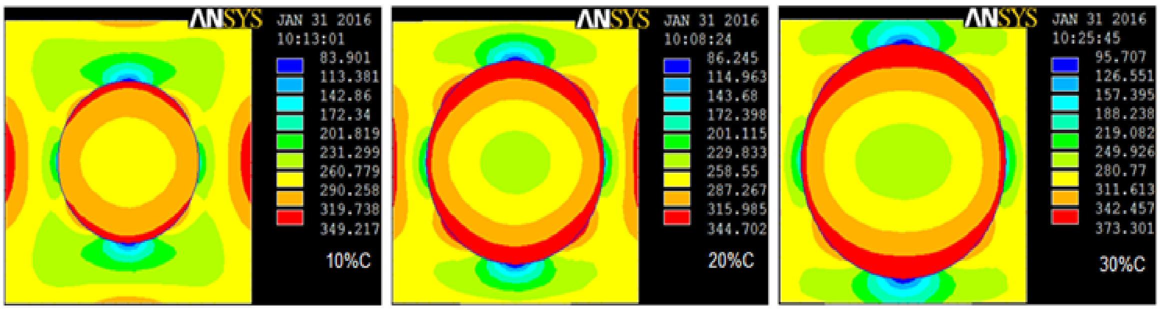

Fig. 8: von Mises stress.

Table 1 gives the elastic moduli of the AA7020/carbon black composites obtained by the Rule of Mixtures, FEA and Reddy model with respect to the volume fraction of carbon black nanoparticles. The lower limit values of Reddy model are lower than those obtained from FEA because the voids are not considered in the finite element analysis of the nanocomposites. This is due to the fact that the existence of voids in the nanocomposites. The presence of voids, even at a very low volume fraction, can significantly degrade the material properties [11-12].

Table 1: Elastic modulus AA7020/carbon black composite

Model	Elastic Modulus, GPa		
	10% Vp	20% Vp	30% Vp
Rule of Mixture	105.80	139.60	173.40
AC Reddy (UL)	165.58	183.69	202.59
AC Reddy (LL)	77.81	83.79	90.28
FEA	86.11	89.19	87.54

IV. Conclusions

The tensile strength was increased with an increase of carbon black content in the nanocomposites. By increasing the nanoparticles the elastic modulus was increased appreciably. The presence voids reduces the strength and stiffness of the nanocomposite.

References

[1]. A. C. Reddy and Essa Zitoun, Tensile properties and fracture behavior of 6061/Al_2O_3 metal matrix composites fabricated by low pressure die casting process, *International Journal of Materials Scie*nces, 6(2), 201, 147-157.

[2]. A. C. Reddy, Tensile fracture behavior of 7072/SiCp metal matrix composites fabricated by gravity die casting process, *Materials Technology: Advanced Performance Materials*, 26(5), 2011, 257-262.

[3]. A. C. Reddy, Influence of volume fraction, size, cracking, clustering of particulates and porosity on the strength and stiffness of 6063/SiCp metal matrix composites, *International Journal of Research in Engineering and Technology*, 4(1), 2015, 34-442.

[4]. A. C. Reddy, Studies on loading, cracking and clustering of particulates on the strength and stiffness of 7020/SiCp metal matrix composites, *International Journal of Metallurgical & Materials Science and Engineering*, 5(1), 2015, 53-66.

[5]. A. C. Reddy, Influence of Particle Size, Precipitates, Particle Cracking, Porosity and Clustering of Particles on Tensile Strength of 6061/SiCp Metal Matrix Composites and Validation Using FEA, *International Journal of Material Sciences and Manufacturing*, 42(1), 2015, 1176-1186.

[6]. A. C. Reddy, Estimation of Thermoelastic Behavior of Three-phase: AA1100/Ni-Coated Boron Carbide Nanoparticle Metal Matrix Composites, *International Journal of Scientific & Engineering Research*, 6(10), 2015, 662-667.

[7]. A. C. Reddy, Influence of Interphase on Tensile Behavior of Strain Hardened AA1100/AlN Nanocomposites Using RVE Models and Experimental Validation, *International Journal of Engineering, Science and Technology*, 7(7), 2015, 239-250.

[8]. A. C. Reddy, Consequences of Interphase between Matrix and Reinforced Nanoparticle on Behavior of AA6262/AlN Nanocomposites, *International Journal of Science and Research*, 4(9), 2015, 1045-1049.

[9]. A. C. Reddy, Cause and catastrophe of strengthening mechanisms in 7020/Al2O3 composites prepared by stir casting process and validation through FEA, *International Journal of Advanced Research*, 3(3), 2015, 603-614.

[10]. S. Kari, H. Berger, and U. Gabbert, Numerical evaluation of effective material properties of randomly distributed short cylindrical fibre composites, *Computational Materials Science*, 39, 2007, 198-204.

[11]. A. C. Reddy, Influence of strain rate and temperature on superplastic behavior of sinter forged Al6061/SiC metal matrix composites, *International Journal of Engineering Research & Technology*, 4(2), 2011, 189-198.

[12]. A. C. Reddy, Strengthening mechanisms and fracture behavior of 7072Al/Al2O3 metal matrix composites, *International Journal of Engineering Science and Technology*, 3(7), 2011, 6090-6100.