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Thermoelastic Behavior of Nanoparticulate BN/AA5050 Alloy Metal Matrix Composites

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Abstract— **The present work was proposed to predict thermoelastic behavior of AA5050/boron nitride nanoparticle metal matrix composites. BN has excellent thermal and chemical stability. The RVE models were used to evaluate thermo-elastic behavior. The stiffness of AA5050/boron nitride nanoparticle metal matrix composites decreased with increases in the loading of BN nanoparticles. The stiffness was raised steeply at 100^{o}C which is very interesting phenomena to be scientifically. A higher modulus characteristically indicates that the material is harder to deform.**

Index Terms— **AA5050 alloy, boron nitride, RVE model, thermoelastic, finite element analysis.**

I. INTRODUCTION

Nanoparticle reinforced metal matrix composites are of concern for a diversity of industrial applications due to their higher stiffness and strength than the matrix alloys [1]. Aluminum alloy metal matrix composites [2] were fabricated by reinforcing with nanoparticulates of stronger and stiffer material such as silicon carbide [3, 4], boron carbide [5], alumina [6, 7], aluminum nitride [8], alumina trihydrate [9] or carbon [10]. Thermal decomposition kinetics and interaction of thermal energy between particulate and matrix are crucial for high temperature applications of metal matrix composites [11-13]. Boron nitride (BN) has excellent thermal and chemical stability. Boron nitride has potential use in nanotechnology for high temperature applications.

The present work was designed to examine the thermoelastic behavior of nanoparticulate BN/AA5050 alloy matrix composites. Finite element analysis (FEA) was implemented to measure the local response of the material using representative volume element (RVE) reinforced by a single particle subjected to hydrostatic and isothermal loading.

II. MATERIAL AND METHODS

The matrix material was AA5050 alloy. The reinforcement nanoparticulate was BN of average size 100nm. The mechanical properties of materials used in the current work are given in table 1. The volume fractions of BN nanoparticles were 20% and 30%.

In this investigation, a square RVE (Fig. 1) was used to understand the thermo-elastic (compressive) behavior AA5050/ BN nanocomposites. The matrix and nanoparticle were discretized with PLANE183. The interphase between nanoparticle and matrix was discretized with CONTACT172 element [14]. Both uniform thermal and hydrostatic pressure loads were applied simultaneously on the RVE model.

Table 1. Mechanical properties of AA5050 matrix and BN nanoparticles.

Property	AA5050	BN
Density, g/cc	2.69	2.29
Elastic modulus, GPa	68.9	100
Ultimate tensile strength, MPa	145	83.3
Poisson's ratio	0.33	0.27
CTE, μm/m-^{o}C	21.8	6.0
Thermal Conductivity, W/m-K	193.0	52.0
Specific heat, J/kg-K	900	1150

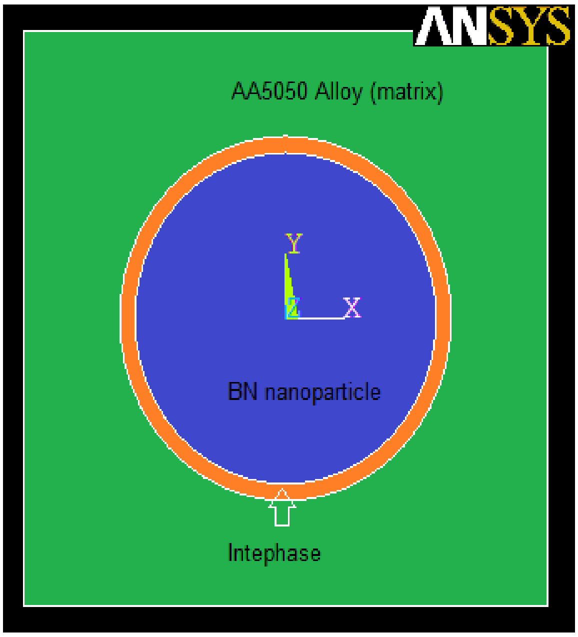

Fig. 1 The RVE model.

III. RESULTS AND DISCUSSION

The finite element analysis (FEA) was carried out at 0^{o}C to 300^{o}C. The hydrostatic pressure and isothermal loads were applied on RVE models to explore thermo-elastic compressive behavior of AA5050/BN nanoparticulate composites.

A. *Micromechanics of thermo-elastic behavior*

Thermo-elastic strains as a function of temperature are showed in Fig. 2. The increase of temperature increased the compressive strains along the load direction. The positive nature was due to the dominant role of thermal strains over the elastic strains. The thermal conductivity and CTE of matrix alloy are nearly four times those of BN nanoparticle. Along the transverse direction, the tensile strains were also increased with increase of temperature.

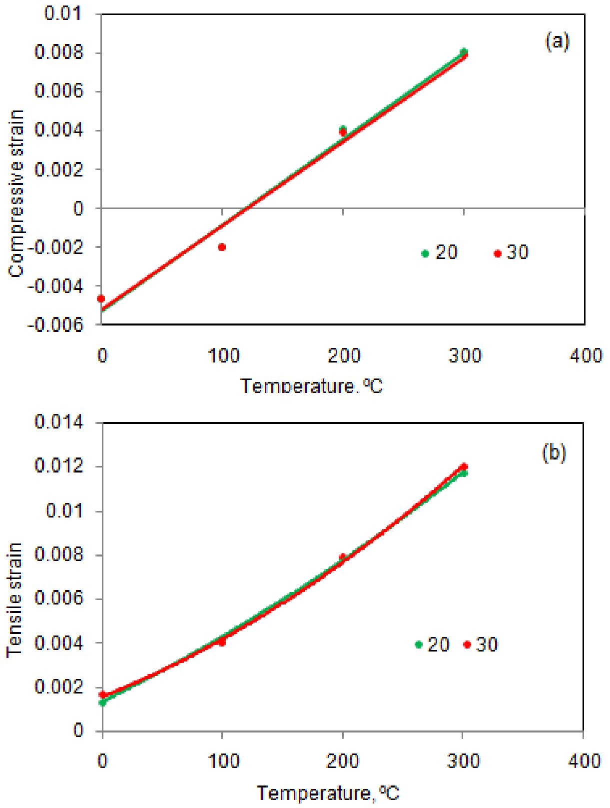

Fig. 2 Influence of temperature on thermoelastic strain.

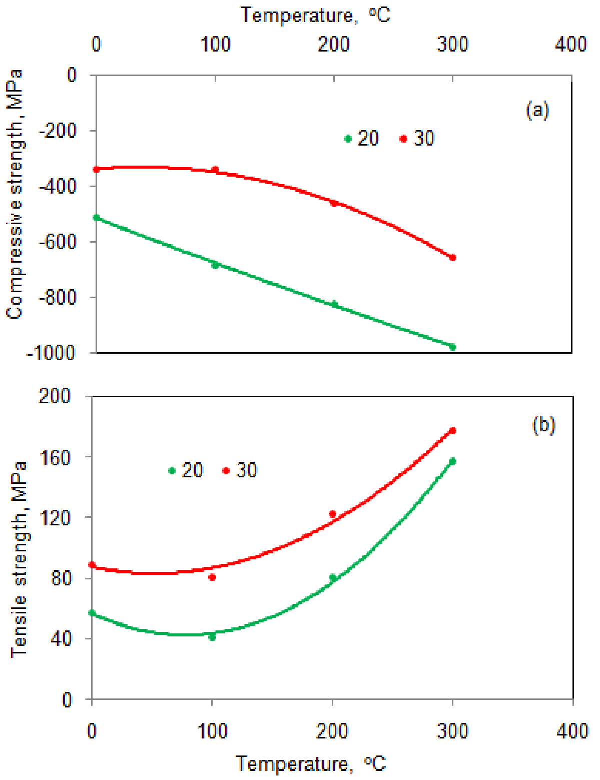

Fig. 3 Influence of temperature on tensile and compressive stresses of AA5050/BN composites.

Tensile and compressive strengths as a function of temperature are depicted in Fig. 3. The compressive strength decreased with the increase of temperature as showed in Fig. 3(a). The compressive strength deteriorated with increase in the volume fraction of BN. High compressive stresses were induced in the composites having 20% BN nanoparticles. The tensile strength increased with increase of temperature from 0°C to 300°C (Fig. 3(b)).

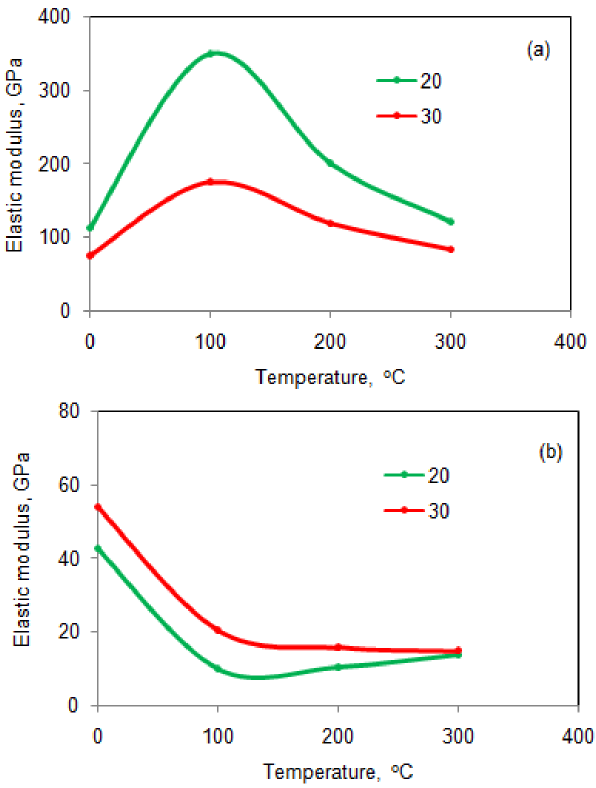

Fig. 4 Influence of temperature on elastic modulus: (a) E_x and (b) E_y.

The compressive elastic modulus increased initially with the increase of temperature as showed in Fig. 4(a) and later on from 100°C it decreased with increase of temperature. The BN nanoparticles are very stiffer to undergo deformation under compressive loading below 100°C. The tensile elastic modulus decreased with increase of temperature (Fig. 4(b)). This phenomenon is also confirmed with the variation of major Poisson's ratio with the temperature (Fig. 5). A higher modulus indicates that the AA5050 matrix was no longer to carry hydrostatic and thermal loads. Because of load transferred from matrix to BN nanoparticles, very large hydrostatic force was required for small deformation of BN [15].

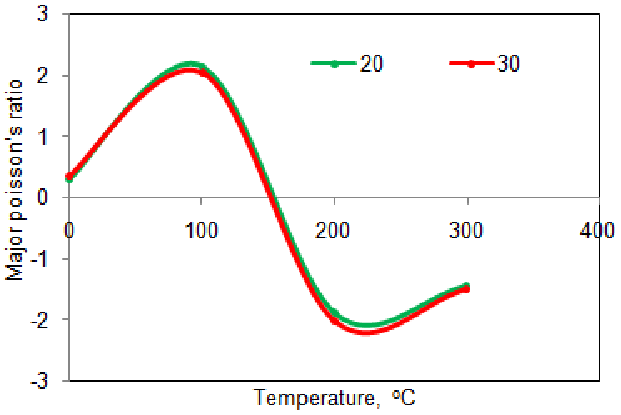

Fig. 5 Influence of temperature on major Poisson's ratio.

B. Fracture behavior

Fig. 6 describes the von Mises stress induced in the composites. The von Mises stress increased with the increase of temperature from 0^{o}C to 300^{o}C. The von Mises stress was higher in the composites having 20% BN nanoparticles than that in the composites consisting of 30% BN. Only interphase was ruptured in the case of AA5050/10% BN composites while both BN nanoparticle and interphase were fractured in the case of AA5050/30% BN composites (Fig. 7).

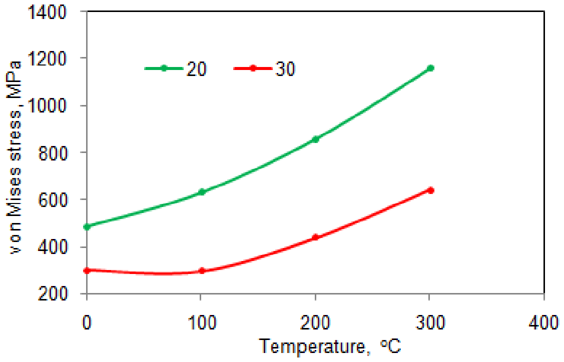

Figure 6: Influence of temperature on von Mises stress.

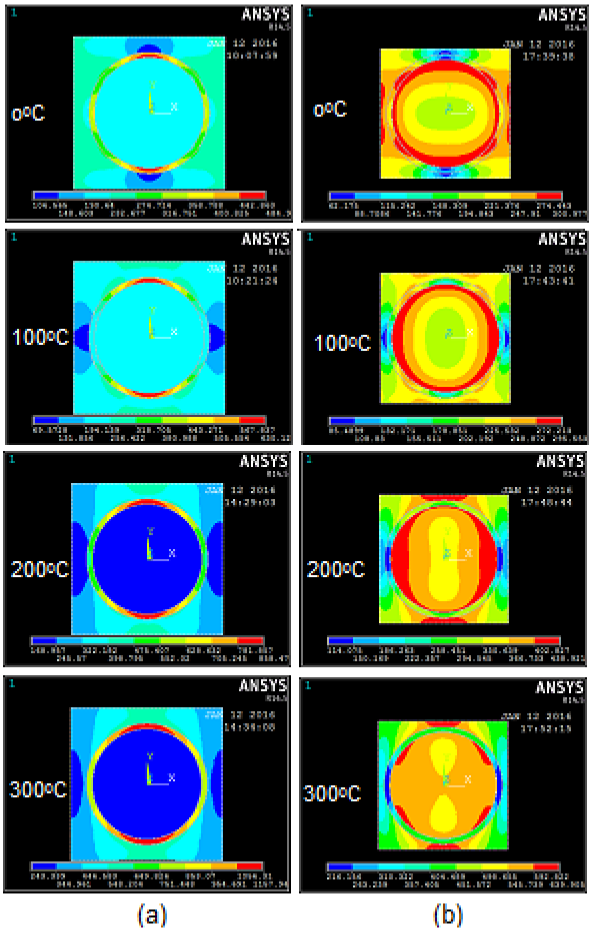

Fig. 7 Raster images of von Mises stress of AA5050/BN composites.

IV. CONCLUSIONS

The thermoelastic strains increased with the increase of temperature. The compressive strength decreased with the increase of temperature. Interestingly, the stiffness was high at 100^{o}C for AA5050/BN nanoparticulate metal matrix composites.

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