High Temperature Micromechanical Behaviour of Mo-Coated B_4C/3003 Al Alloy Nanocomposites

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***Abstract*— 3003 is a general-purpose alloy with moderate strength, good workability, and good corrosion resistance. High hardness makes the application of boron carbide possible as an abrasive and cutting material. The aim of the current work was to investigate the influence of combined thermo-structural loading on the behaviour of B_4C/3003 metal matrix composites. A numerical analysis was carried out using ANSYS code. The major conclusion of the current work was that the interphase between the nanoparticles ant matrix 3003 Al alloy was ruptured at 300^0C due to thermal mismatch between B_4C and 3003 Al alloy.**

Keywords- 3003 Al alloy; boron carbide, thermo-structural loading; numerical analysis.

I. INTRODUCTION

In recent years, there has been a promising perception in using Al-based metal matrix composites for high temperature applications wherein thermal stability is major requirement such as in aircraft and automobile applications [1-19]. However, the dimensional stability depends upon the thermal mismatch between the matrix alloy and the reinforced material.

3003 aluminium alloy is an alloy in the wrought aluminium-manganese family. It can be cold worked (but not, unlike some other types of aluminium alloys, heat-treated) to produce tempers with a higher strength but a lower ductility. Like most other aluminium-manganese alloys, 3003 is a general-purpose alloy with moderate strength, good workability, and good corrosion resistance. It is commonly rolled and extruded, but typically not forged. A variety of chemical, physical, and mechanical properties of boron carbide ensure its wide range of applications in modern technology. In nuclear reactors, boron carbide is used as a material for rods that controls the kinetics of nuclear fusion. Boron carbide is highly stable chemically in various aggressive environments. It is important to know the resultant influence of thermal mismatch and thermal boundary resistance between 3003-aluminium alloy matrix and B_4C reinforcement on the micromechanical behaviour of B_4C reinforced aluminium alloy composites. This paper describes the micromechanical behaviour subjected to both temperature and tensile loading to investigate thermal stability of B_4C/3003-aluminium alloy composites.

II. MATERIALS AND METHODS

3003-aluminium (Al) alloy and boron carbide were used, respectively, for matrix and reinforcement. ANSYS software was employed for the numerical analysis of RVE (representative volume element) models of B_4C/3003 Al alloy metal matrix nanocomposites. The boron carbide nanoparticles were coated molybdenum layer. The boron carbide nanoparticles were assumed to be spherical in the present study. The volume fraction of B_4C nanoparticles was 20%. The plane strain boundary conditions were imposed on RVE models for the numerical analysis [20]. The reinforcement and the matrix were discretised with plane 183 element. The interphase was discretised with contact 172 element. The operating temperatures were 0^0C, 100^oC. 200^oC and 300^oC. The RVE models were numerically tested for the yield strength of the 3003 Al alloy at different temperatures. The numerical results were validated with experimentally tested samples of the B_4C/3003 Al alloy nanocomposites.

III. RESULTS AND DISCUSSION

The average diameter of B_4C nanoparticle was 90 nm. The thickness of molybdenum layer on B_4C nanoparticles was 5 nm. The effect of temperature and structural loading on the linear dimension of RVE cell along the loading direction is shown in figure 1 and normal to the load direction is shown in figure 2. It is observed that the dimension along the loading direction increases with increasing temperature of the RVE cell. The combined effect of thermal expansion and structural elongation has been observed along the loading direction. Normal to loading direction the thermal expansion dominates the structural contraction.

The influence of temperature on strains induced parallel and normal to the loading direction is shown in figure 3 and 4. The strain increases with an increase in the temperature in the regions of the 3003 Al alloy matrix in the directions parallel and normal to the loading. The strains are tensile in the parallel direction of tensile loading, while they are compressive in the normal direction of loading at zero degree of temperature. The strain induced in the B4C nanoparticle is negligible either raise or fall in temperature along parallel and perpendicular directions of the applied tensile load.

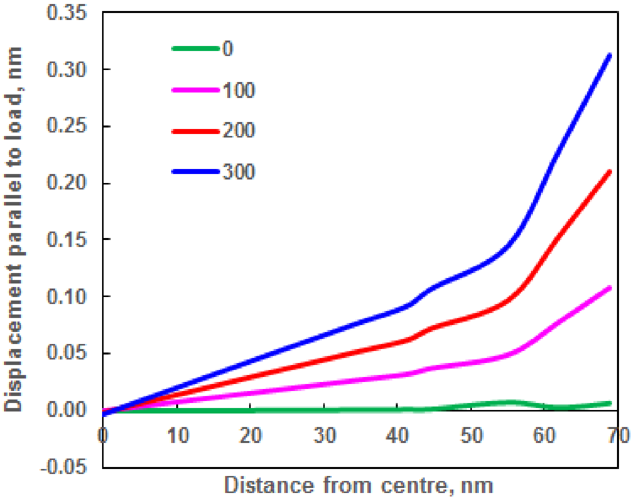

Figure 1. Effect of temperature on deformation behaviour of B_4C/2024 Al alloy nanocomposites along load direction.

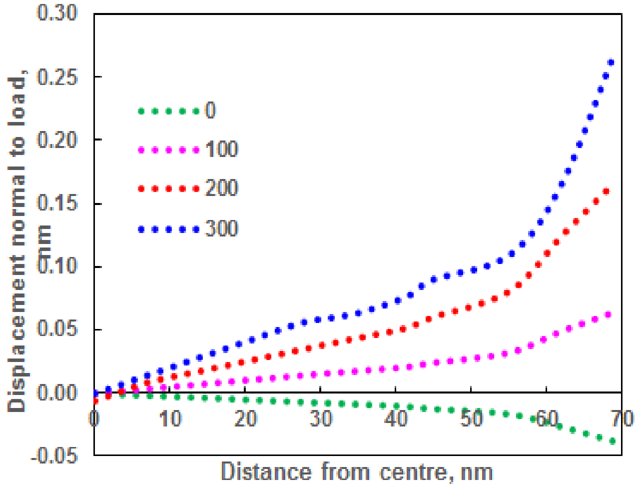

Figure 2. Effect of temperature on deformation behaviour of B_4C/2024 Al alloy nanocomposites normal to load direction.

The stresses induced in the B4C decrease with increase in the temperature as shown in figure 5 and 6. It is clearly understood that the load transfer take place from the matrix to the reinforced nanoparticle via interphase. It is observed that the interface is likely to fracture at 3000C. The same observation can be from the raster images of von Mises stresses obtain from ANSYS software code are illustrated in figure 7.

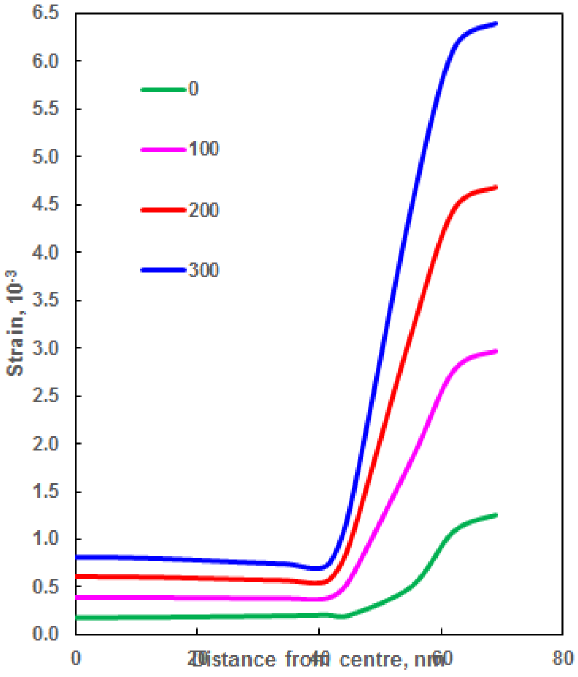

Figure 3. Effect of temperature on strains induced in B_4C/2024 Al alloy nanocomposites along load direction.

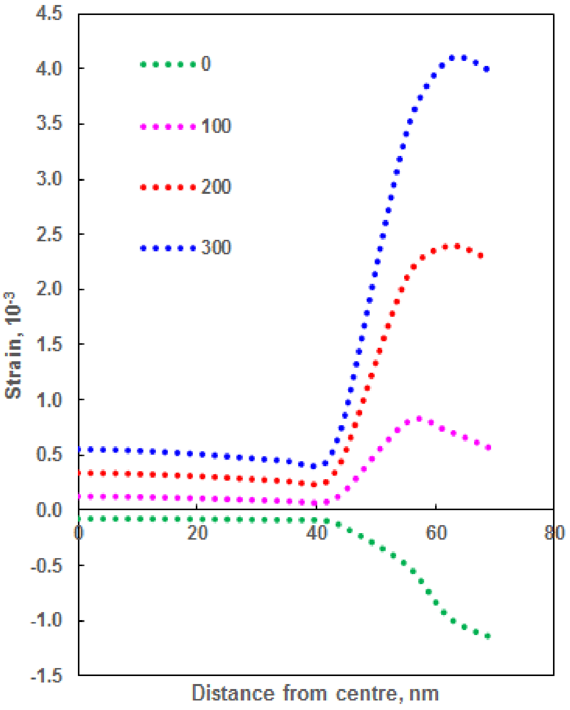

Figure 4. Effect of temperature on strains induced in B_4C/2024 Al alloy nanocomposites along normal direction to loading.

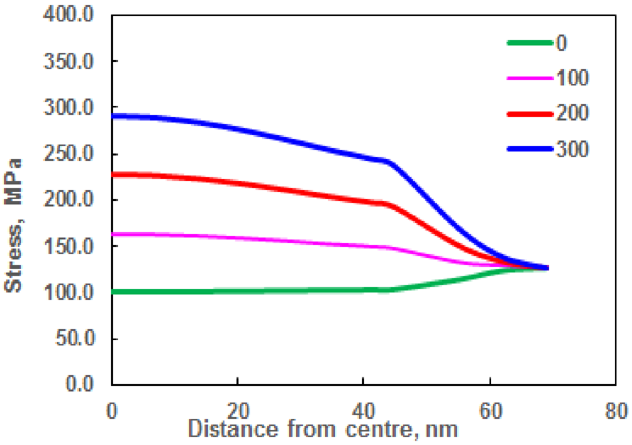

Figure 5. Effect of temperature on stresses induced in B_4C/2024 Al alloy nanocomposites along load direction.

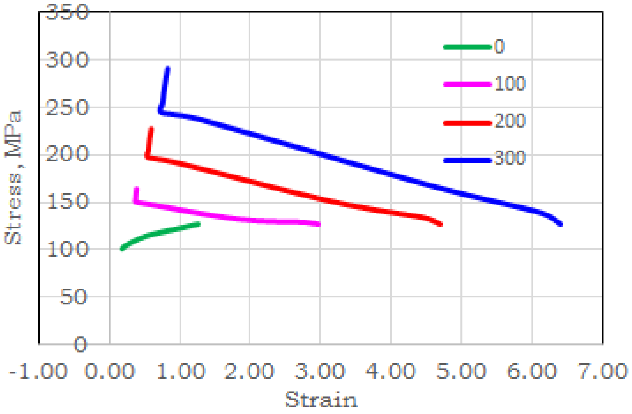

Figure6. Stress-strain diagram of B_4C/2024 Al alloy nanocomposites along load direction.

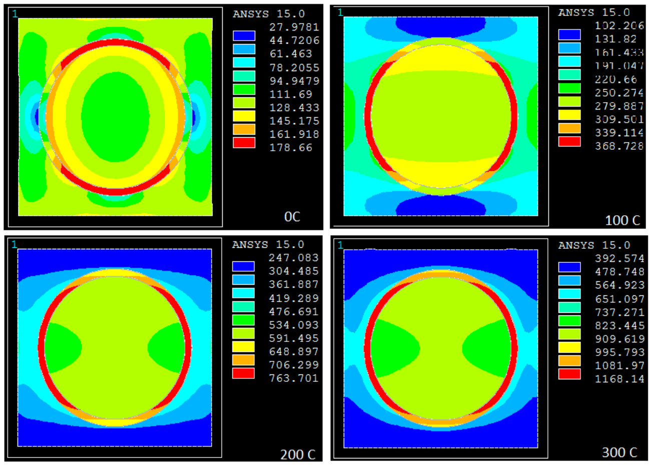

Figure 7. Raster images of von Mises stresses.

IV. CONCLUSION

The thermo-strucutral induced micromechanics of B_4C/3003 Al alloy have been computed numerically using ANSYS code. The critical conclusion of this work is that the intherphae are likely fracture at high temperautres along with applied stuctural loading.

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