TENSILE PERFORMANCE OF HEAT TREATED AA2024/Al_2O_3 METAL MATRIX COMPOSITES USING RVE MODELS: EXPERIMENTAL VALIDATION

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Abstract

The present work was aimed to predict the influence of heat treatment on the tensile behavior of the AA2024/Al_2O_3 metal matrix composites. The results obtained from the finite element analysis were verified with those of experimentation. The tensile strength and von Mises stress was greatly improved with the heat treatment, T6.

Keywords: *AA2024, Al_2O_3, heat treatment, tensile behavior, finite element analysis.*

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1. INTRODUCTION

Alumina Al_2O_3 is found as the mineral corundum. It provides superior abrasion, high temperature and chemical resistance, and is also electrically insulating. This material has an excellent cost-to-part life performance record. Purity Applications include wear- and heat-resistant liners, mechanical and pump seals, nozzles, semiconductor equipment components, insulators, etc. Alloy 2024 is Al-Cu-Mg alloy. With its relatively good fatigue resistance, alloy 2024 continues to be specified for many aerospace structural applications. The fracture of particle reinforced metal matrix composites is dependent on the particle strength and particle/matrix interface strength. The toughness decrease slightly with decreasing particle size, the effect of particle size is less because decreasing particle results in a lower inter-particle spacing [1-8].

The present work was focused on the effects of heat treatments such as T3, T4 and T6 on the properties of alumina (Al_2O_3) reinforced AA2024 composites. The results obtained the finite element analysis (FEA) were validated with those of experimentation.

2. MATERIALS AND METHODOLOGY

The matrix material used in the present work was AA2024 alloy. The reinforcement material was $_{Al2O3}$ at 30% volume fraction of the composites with average size 100nm. The matrix alloys and composites were prepared by stir casting process [2, 3].

In this research, a cubical representative volume element (RVE) was implemented to analyze the tensile behavior AA2024/Al_2O_3 nanocomposites. The loading on the RVE was defined as symmetric displacement, which provided equal displacements at both ends of the RVE. The large strain PLANE183 element was used in the matrix and the interphase regions in all the models. In order to model the adhesion between the interphase and the particle, a COMBIN14 spring-damper element was used. The stiffness of this element was taken as unity for perfect adhesion which could determine the interfacial strength for the interface region. It is equally important to set the strain rates of the finite element models based on the experimental tensile tests' setups to converge an exact nonlinear solution. Therefore, the rate of displacement in the RVEs was set to be 0.1 (1/min). The discretization of the RVE cell is shown in figure 1.

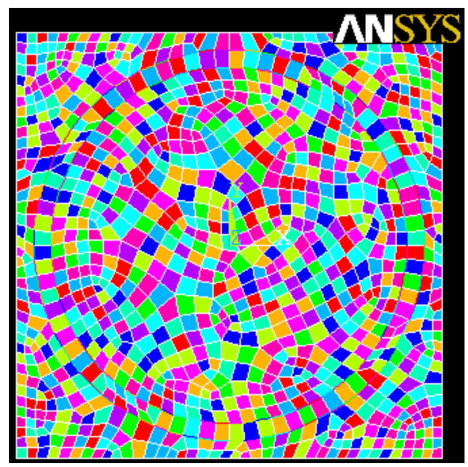

Figure 1: Discretization of RVE model.

3. RESULTS AND DISCUSSION

For the heat treatment T4, the tensile strength of AA2024/Al_2O_3 composite specimens had low tensile strength, whereas it was high for the heat treatment T6 (figure 2). The tensile strength of AA2024/Al_2O_3 composite specimens was intermediate for the heat treatment T3 as compared to the heat treatments T4 and T6. The experimental values are lower than those obtained from finite element analysis.

- T3 - Solution heat treated (493^{o}C), cold worked, and naturally aged to a substantially stable condition.
- T4 - Solution heat treated (493^{o}C), and naturally aged to a substantially stable condition.
- T6 - Solution heat treated (524^{o}C) then artificially aged.

The effect of heat treatment on the tensile strain is shown in figure 3. The trend is same that of the tensile strength. There was no much variation in the Young's modulus (91.45 < E < 92.36 GPa) as shown in figure 4.

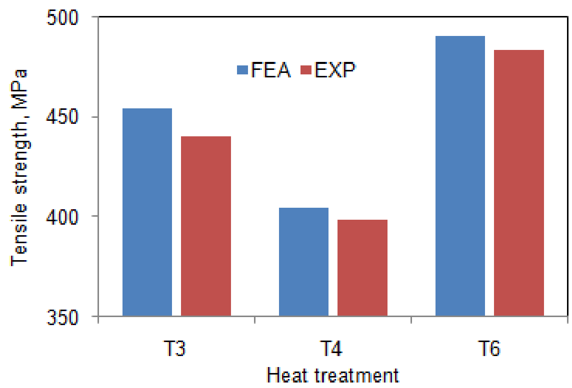

Figure 2: Effect of heat treatment on tensile strength.

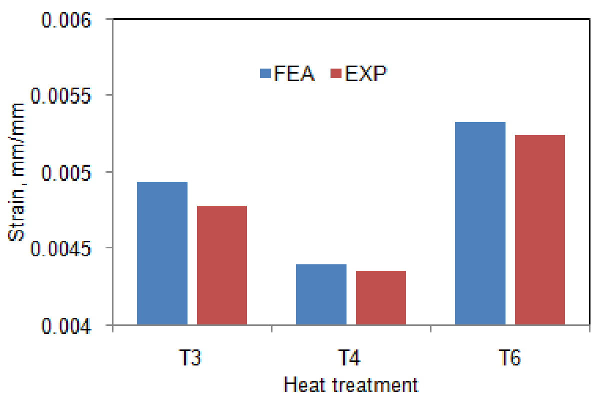

Figure 3: Effect of heat treatment on tensile strain.

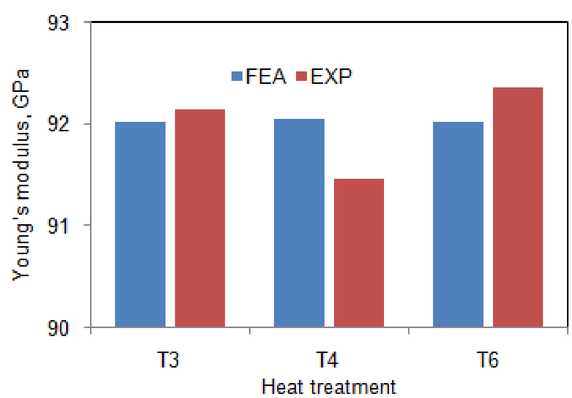

Figure 4: Effect of heat treatment on Young's modulus.

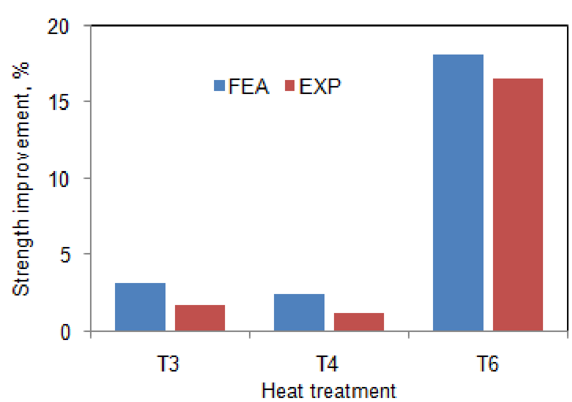

Figure 5: Effect of heat treatment on improvement of strength.

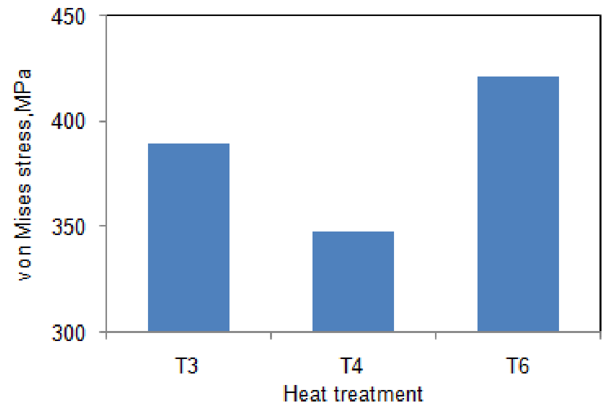

Figure 6: Effect of heat treatment on von Mises stress.

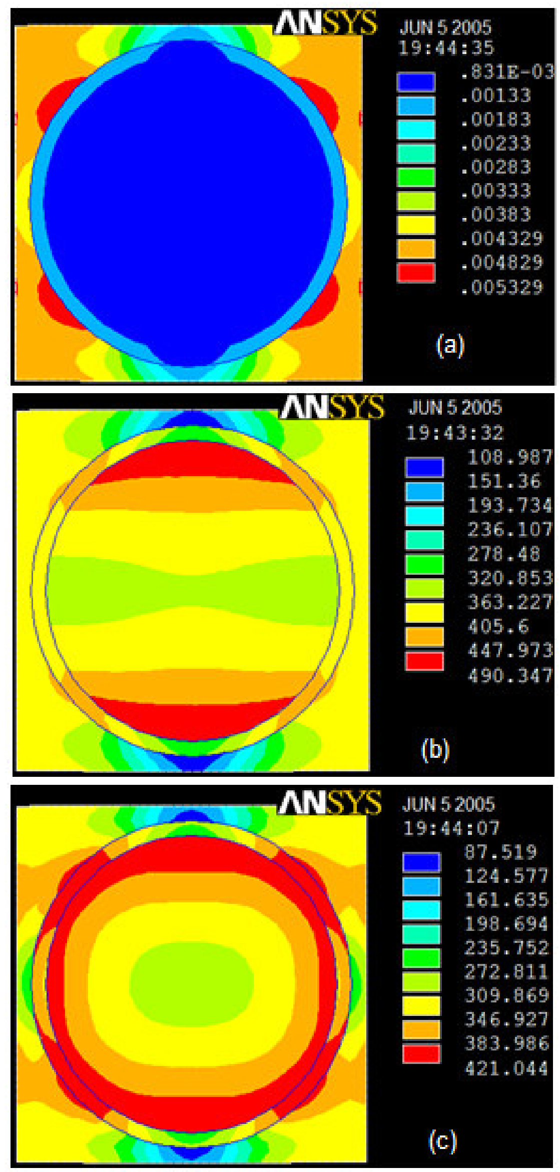

Figure 7: FEA results for heat treatment, T6 (a) tensile strain, (b) tensile strength and (c) von Mises stress.

The strength improvement in the metal matrix composite is computed as follows:

$$\% \text{ strength improvement (FEA)} = \left(\frac{\sigma_{ufea}-\sigma_{um}}{\sigma_{um}}\right) \times 100 \qquad (1)$$

$$\% \text{ strength improvement (Exp)} = \left(\frac{\sigma_{uexp}-\sigma_{um}}{\sigma_{um}}\right) \times 100 \qquad (2)$$

where, σ_{ufea}, σ_{ufea} *and* σ_{um} are, respectively, the tensile strength obtained FEA, the tensile strength obtained experimentation and the tensile strength of the matrix.

The improvement of tensile strength was high on account of Al_2O_3 reinforcement particle inclusion and heat treatment, T6 (figure 5). The von Mises stress was found to be high with heat treatment, T6 and it was low with heat treatment, T3 (figure 6). The FEA results for heat treatment condition are shown in figure 7.

4. CONCLUSION

The results obtained from FEA procedure were within the limits of experimental results. The strength improvement was highly appreciable with heat treatment, T6.

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