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Effect of Processing Temperature and Holding Time on Interface Bonding Of Al/Sic: Finite Element Method

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Abstract— The main aim of this analysis is to study the effect of bonding strength between metal and ceramic at different processing temperature and holding time. The Al/SiC bonding was modelled and analyzed using finite element analysis in ANSYS software. The different values of coefficients of linear thermal expansion (CTEs) of the metal and ceramic are induces more thermal stress at the interface. The mismatch of thermal stress at the interface region plays an important role in improving bonding strength. Hence, it is essential to study and evaluate the interface bonding in metal-ceramics joints.

Keywords— Bonding strength, Coefficient of thermal expansion, Thermal stress, Interface

I. INTRODUCTION

The growing interest in aluminium based metal matrix composites could be realized for the past decades because of its superior mechanical and physical properties. The mechanical properties are generally depending on the interface bonding between matrix and reinforcement. It is well known that the function of the interface is to transmit load from matrix to reinforcement due to the large stress gathering capability of the reinforcement and binding property of the matrix material [1]. The formation of interface bond was mainly affected by the factors such as processing temperature and holding time. The different processing temperature and holding time leads to thermal expansion in Al and SiC. Due to their difference in thermal expansion coefficient (CTEs) residual thermal stress will be induced at the interface [2]. This thermal stress will affect the interface bonding between Al/SiC, which is known as thermal mismatch stress. Metal-ceramic interfacial phenomena controls stress transfer between Al/SiC [5].

Generally composite materials with weak interfaces have relatively low strength and stiffness but high resistance to fracture, whereas materials with strong interfaces have high strength and stiffness but are somewhat brittle [6, 7]. S. Sozhamannan et al, (2009), studies the influence of processing temperature at constant holding time in the interface bonding of Al/SiC. The interfacial bonding strength increases with increase in processing temperature due to least formation of interfacial compounds. The structural morphologies of interface in Al/SiC interface region. The higher concentration of Si in the matrix region near the interface alters the interface bonding characteristics of Al/SiC. The diffusion rate of Si depends on the functions of temperature and time. The objective of this paper is to analyse the interface residual stress at different holding time and temperature.

II. FINITE ELEMENT MODELING

Three-dimensional rectangular model of Al/SiC were created in FEA to find the global and local stress and strain status. Al/SiC FEA model shown in Fig.1. The model adopted assumes that the SiC plate glued to aluminium, while the matrix deform elastically or elastic-plastically depending on the local effective stress level..The one end of contour was fixed, that is degrees of freedom at all direction x, y and z are arrested. The negative pressures were applied at other end of contour which showed in below diagram. The finite element modelling procedures are mentioned below in fig. 2. and material properties of Al/SiC are given in table 1

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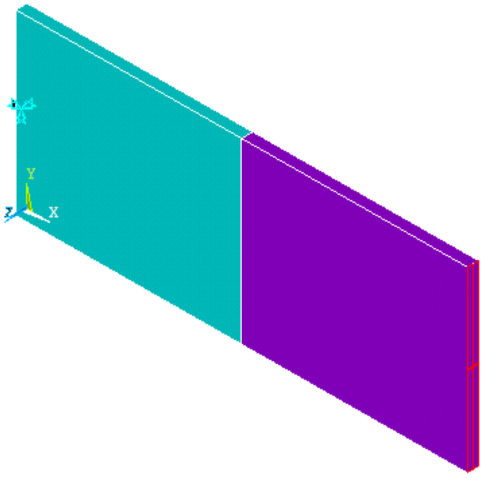


Figure 1. 3-D model of Al-SiC

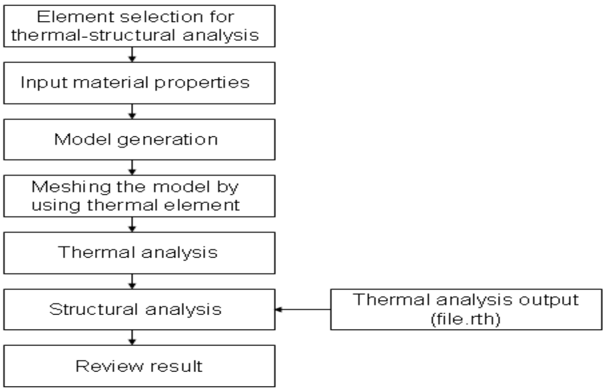
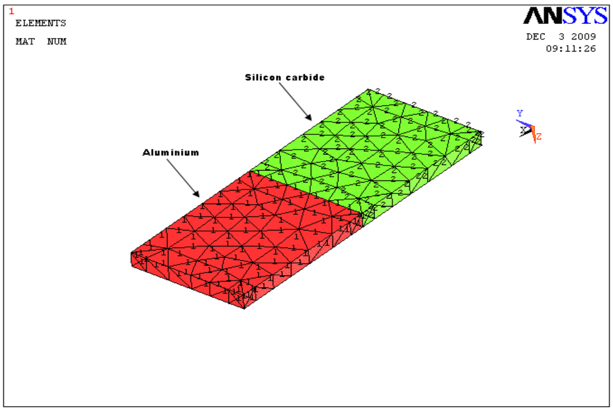


Figure 2.Flow chart for analysis procedure

Table 1. Material properties

Material	E(GPa)	γ	a(°K^{-1})	C(W/m°K)	c(J/Kg°K)
LM20 Al	71	0.3	21x10^{-6}	168	902
SiC	410	0.16	4x10^{-6}	120	750

III. FINITE ELEMENT MODELING OF AL-SIC AND LINE PATH DIAGRAM



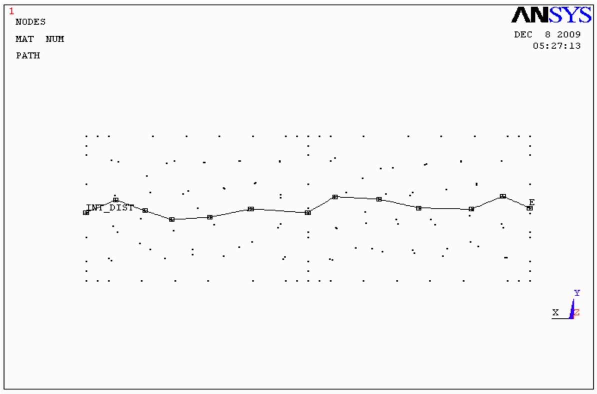


Fig.3. Line path diagram

IV. THERMAL STRESS DISTRIBUTION

The thermal stress distribution across the interface region is shows in fig.4 to fig.6 revealed that the maximum thermal stress were present at the interface region. It is clear evident that the thermal stresses at the interface region increases when increasing processing temperature with holding time. At lower temperature, the thermal stress are low in the range from (-69.717 to -169.93 MPa). At higher temperature (>800°C),more thermal stress were accumulated in interface region due to the different thermal expansion value between SiC and Al alloy, and also SiC thermo-dynamically unstable. The presence of higher thermal stress may lead to debonding at the interface and it reduce the load transferring across the interface.

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V.THERMAL STRESS DISTRIBUTION DIAGRAM

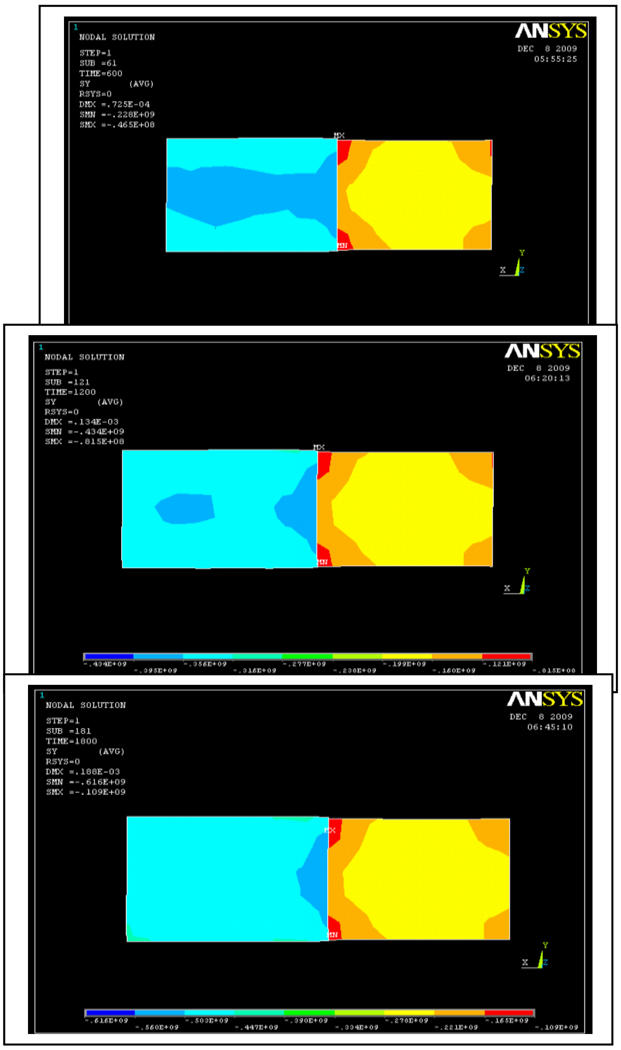

Fig 6.Thermal stress distribution at 30 min

VI. THERMAL STRESS DISTRIBUTION BETWEEN Al-SiC (X-DIRECTION)

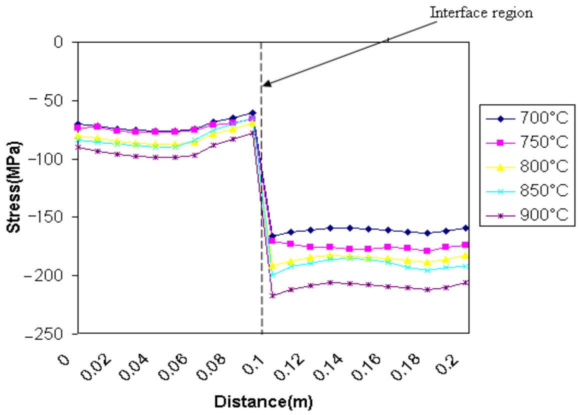

Fig 7. At 10 min

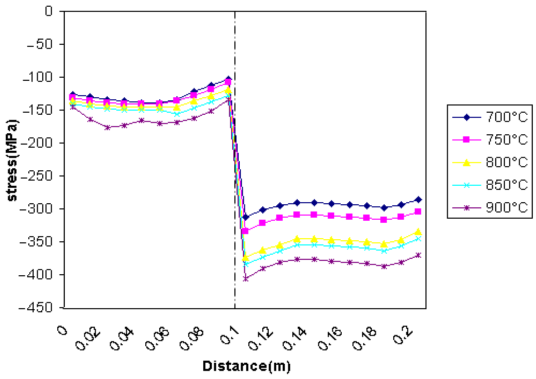

Fig 8. At 20 min

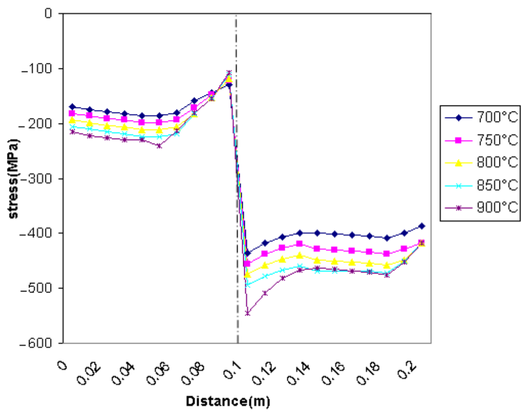

Fig 9. At 30 min

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VII. THERMAL STRAIN DISTRIBUTION DIAGRAM

The thermal strain characteristics are plotted in fig: 10to 12. The strain distribution shows that a maximum thermal strain has been found in the Al region and also the strain distributions are very low in the SiC side. There is a strain relaxed by the SiC are transferred to the matrix, which results a matrix are fractured as thermal strain increases. It was found that thermal strains are increased when increase in processing temperature and holding time between Al matrix and SiC reinforcement. The presence of high strain at the interface region cause the interface bond strength. Since the matrix (Al) and reinforcement (SiC) have different thermal and mechanical properties, they exhibit different thermal strain distributions along the interface region.

VIII. THERMAL STRAIN BETWEEN Al-SiC (X-DIRECTION)

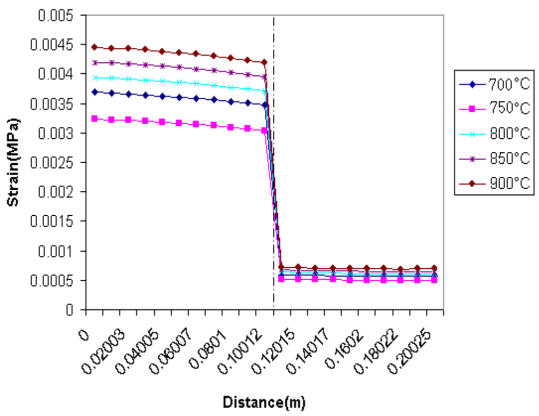

Fig 10. At 10 min

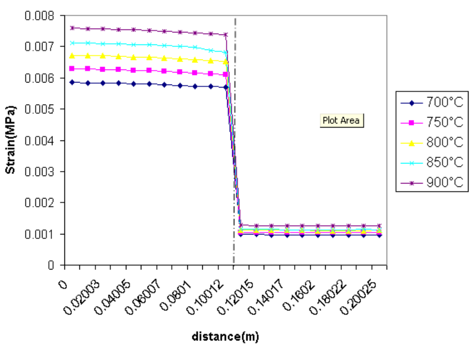

Fig 11. At 20 min

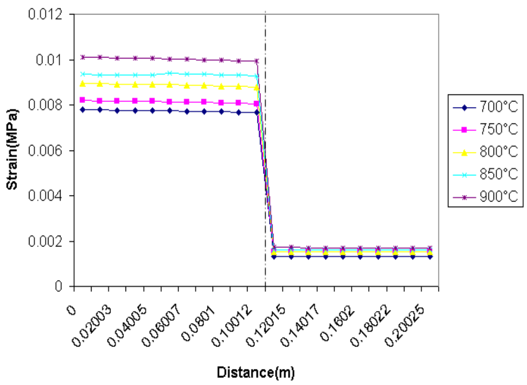

Fig 12. At 30 min

IX. THERMAL STRESS DISTRIBUTION AT INTERFACE REGION (Y-DIRECTION)

The plot shows the thermal stress distribution along the interface region (y-direction).From this plot ,it shows the higher thermal stress induced at the corner of the interface region and this phenomena gradually increase with change in temperature and time. The compressive thermal stress act on this interface region between Al and SiC. Increase in thermal stress at corner of the interface region induce thermal strain at the reinforcement (SiC) side. There is a strain relaxed by the SiC are transferred to the matrix which results a matrix are fractured as thermal strain increases.

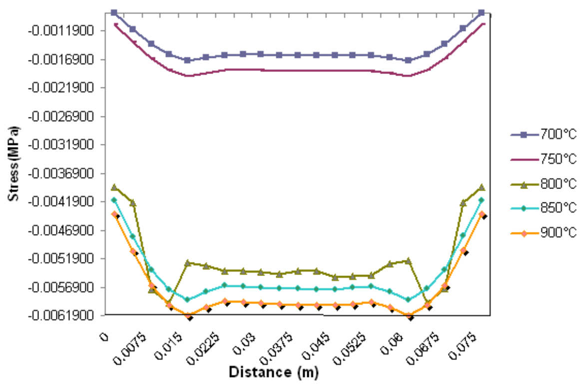

Fig 13. At 10 min

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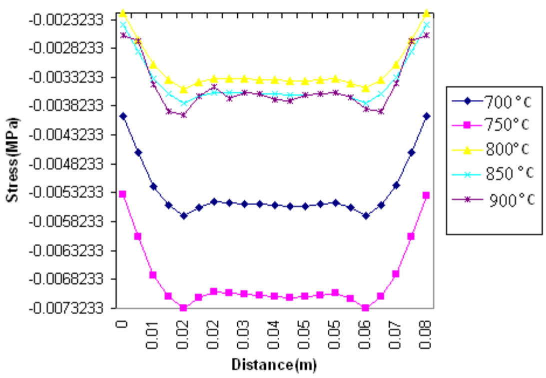

Fig 14. At 20 min

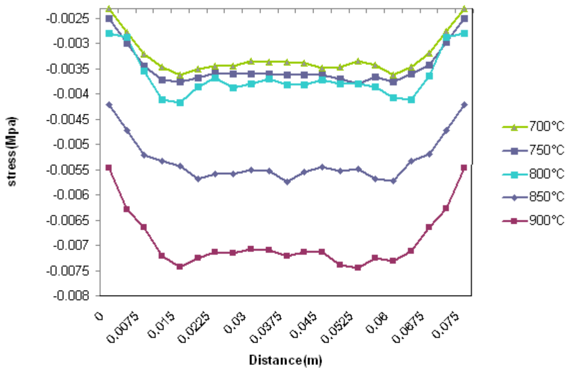

Fig 15. At 30 min

X. CONCLUSIONS

- Increase in various processing temperature with holding time, thermal expansion between Al and SiC were increased. This phenomena increase thermal stress at the interface region.
- The higher thermal stresses induce more residual stress at the interface region. This may leads to create debonding between Al and SiC.
- Increase in thermal stress will leads to increase thermal strain at the interface region between Al and SiC. The higher thermal strain cause interface bonding strength between Al-SiC.
- In the interface region, increases in temperature with time, thermal stress were induced at the corner (top and bottom) side.
- The presence of higher thermal stress along the interface leads to induce thermal strain in that region, which results matrix fractured as thermal strain increases

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