TEMPERATURE DISTRIBUTION IN COMPOSITE LAMINATES

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ABSTRACT -To estimate the behavior of composites under thermal loading, it is required to predict the accurate temperature distribution within the laminate. Most of the literature in this area assumes linear or parabolic variation of temperature. In this work an attempt is made to study the temperature distribution and temperature discontinuity across the debonding for different thermal conductivity ratios, different length of debonding and at different debonding locations. The problem of heat conduction in an anisotropic slab and composite laminates containing an interfacial debonding is considered. The present model considered is validated with the existing results and extended work to various parameters mentioned above.

KEYWORDS - Temperature distribution, temperature discontinuity, orthotropy, laminate, interfacial debond

NOMENCLATURE

a, L_h – Length of heated portion of slab, laminate
h – Thickness of slab, laminate
L_p – Length of slab, laminate
K_L – Thermal conductivity along longitudinal direction
K_T – Thermal conductivity along transverse direction
Z – Thickness direction of slab, laminate

I. INTRODUCTION

Advanced composite materials are widely used in various engineering applications such as electronic devices, turbines, aircraft components ,etc., Laminated and fiber reinforced composites in many engineering materials are exposed to high temperature environments during manufacturing process and service conditions. The evaluation of thermal stresses in composite laminated plates demands an accurate temperature distribution due to thermal loading. The temperature distribution of composite laminates mainly depends on plate dimensions, debonding size and location and Lamina orthotropy. Two-dimensional steady state heat conduction in a laminated anisotropic slab containing interfacial debonding is considered to study the effect of orthotropy and debond. Tauchert and Akoz [1] used displacement potentials to find the thermal stresses in orthotropicslabs with varying boundary conditions. B.Raghava rao ,K.M.Rao and V.Ramachandra Raju [2] obtained the temperature distribution in thick cross-ply composite laminates using finite element analysis and proved the assumption of linear temperature variation in thick composite laminates is no longer valid. Erasmo carrera [3] studied the temperature profile influence on layered plates response considering classical and advanced theories. S.Brischetta and E.CarreraHeat [4] studied the conduction and thermal analysis in multi layered plates and shells. Nilanjan mukharjee and P.K.sinha [5] studied the effects of different stacking sequences on the temperature field of the plate. D.L.Clements and T.R.Tauchert [6] studied the temperature distributions in isotropic and orthotropic slabs containing debonds. Hyung Jip Choi, Surot Thangjitham [7] investigated the disturbances in a laminated anisotropic slab containing an interfacial debonding. P.D.Soden, M.J.Hinton and A.S.Kaddour [8] studied the Lamina properties, lay-up configurations and loading conditions for a range of fiber-reinforced composite laminates. The present work aims at the prediction of temperature distributions and discontinuities through in composite laminates with different fiber orientations containing debond of different sizes and at different locations. The laminate is subjected to sinusoidal temperature loading on top and bottom surfaces and the sides are insulated. ANSYS software is used for the analysis. Erasmo Carrera [3] considered a three-layered sandwich plate which is subjected to sinusoidal loading obtained the exact temperature distribution. The present model is compared with the exact solution for its validity and good similarity is observed between the results.

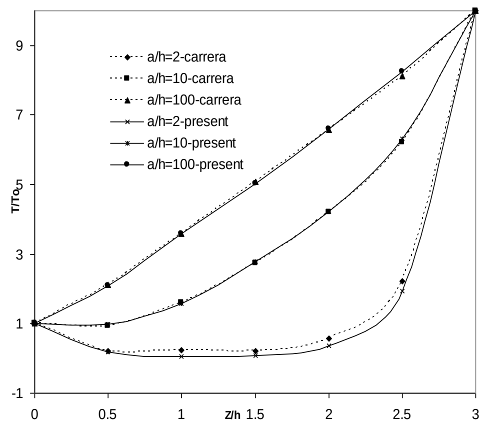

Fig.1. Comparison of present FE Model with Analytical solution [3]

II. MODELING AND ANALYSIS

An anisotropic slab with infinite plate dimensions with interfacial debonding is considered. The width of heated region, debonding length and thickness of slab are considered as equal. For solving the temperature distribution numerical method FEM/ANSYS is used. The laminate is generated for different layers and is meshed with ANSYS-Thermal solid55. The connectivity between the layers is obtained by gluing the areas created. The debonding can be regarded as line crack. Constant temperature loading is applied at particular portion and the remaining sides are insulated. For the above conditions the temperature distribution and discontinuities are predicted and the normalized temperature distribution is plotted in the graphs. Later the above model is extended to predict the temperature distributions and discontinuities for different anisotropic materials and different sizes and locations of debonding. Fig.2 shows the physical model of the slab considered and fig.3 shows the physical model of the laminate considered. For all the cases considered in the present work, same loading is used.

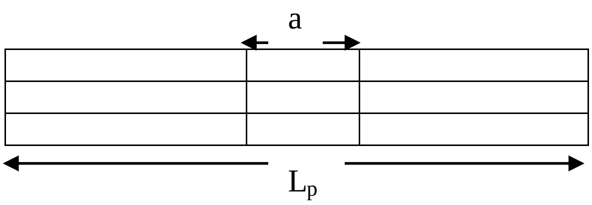

Fig.2. Physical model of slab

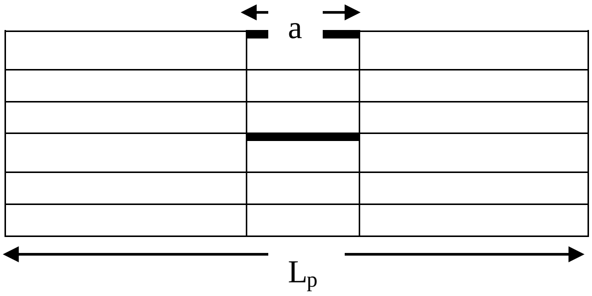

Fig.3. Physical model of laminate

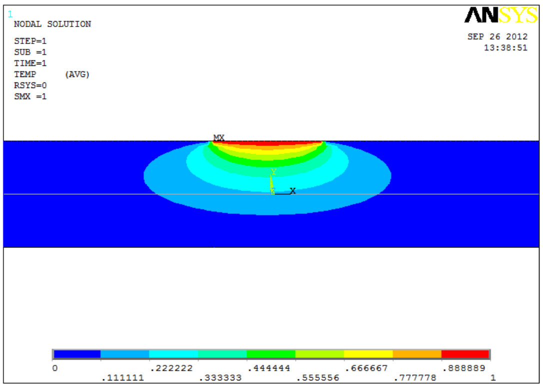

Fig.4. Temperature distribution in anisotropic slab with out debond

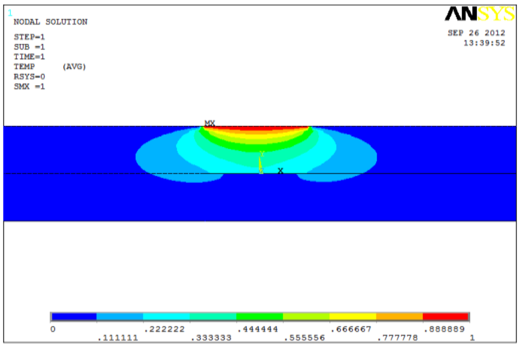

Fig.5 Temperature distribution in anisotropic slab with debond

figs 4,5 shows the temperature contours of isotropic and anisotropic slabs which are subjected to heating at a particular portion. It is observed that whenever there is debond exists in between the layers, it restricts the flow of heat through it.

III. RESULTS AND DISCUSSIONS

Temperature distribution in an isotropic slab depends on the boundary conditions fig.6 shows the deviation of temperature distribution for different boundary conditions. In order to obtain the temperature distribution of a slab it is necessary to obtain the infinite dimensions of that slab. Fig.7 shows the infinite plate dimensions for different anisotropic materials.

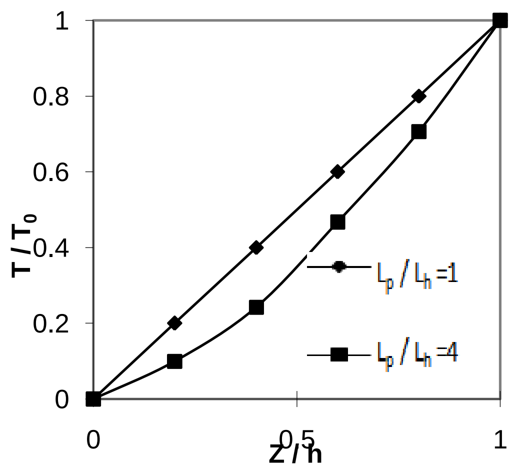

Fig.6 temperature distribution in isotropic slab at different boundary conditions.

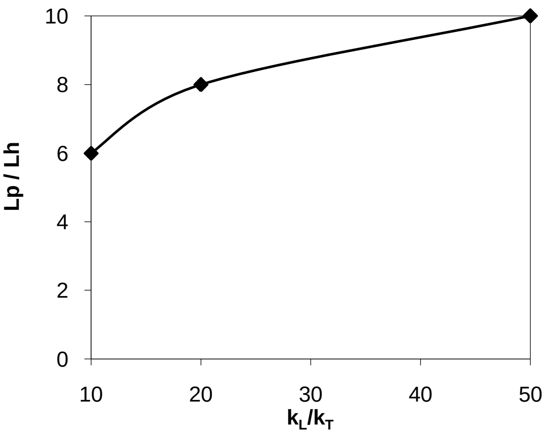

Fig.7 infinite plate dimensions for different k_L/k_T values.

The temperature distribution of slab depends on plate orthotropy. Fig.8 shows the temperature distribution in different orthotropic slabs. As discussed earlier when a debond occurs in between the layers the temperature distribution varies. This effect is shown in fig.9.

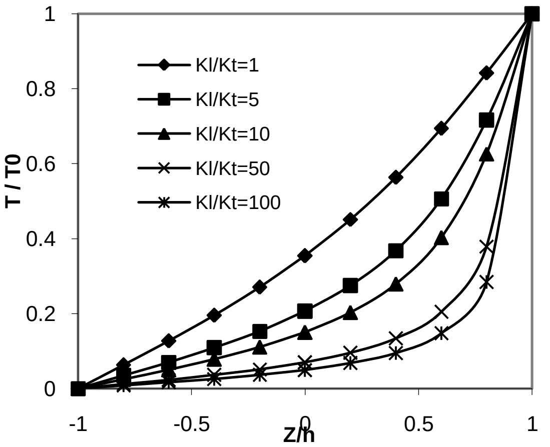

Fig.8. temperature distribution in different orthotropic slabs

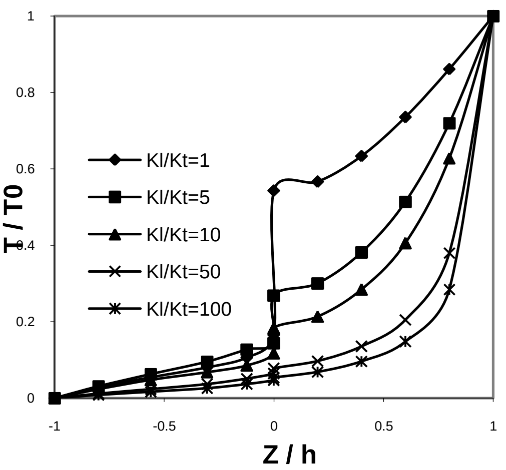

Fig.9. temperature distribution in anisotropic slabs with debond a/h=1

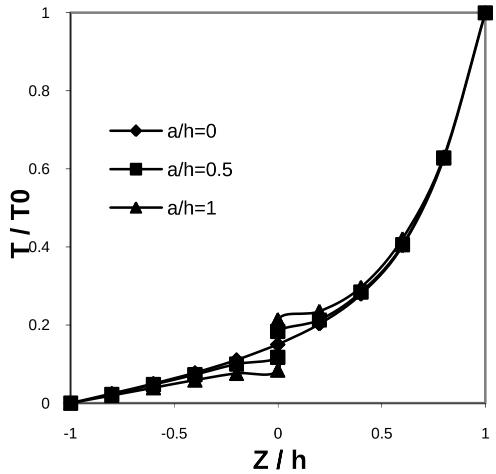

Fig.10. temperature distribution in a slab (k_L/k_T =10) for different sizes of debond.

It is observed that the temperature distribution in anisotropic slabs varies with the size of debond and this is effect is shown in fig.10.

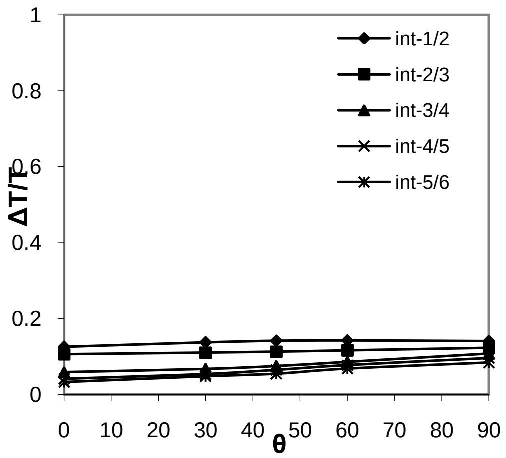

Fig.11. temperature discontinuities at different interfaces with debond a/h=0.25 in ($0^0/90^0/\theta^0$) laminate

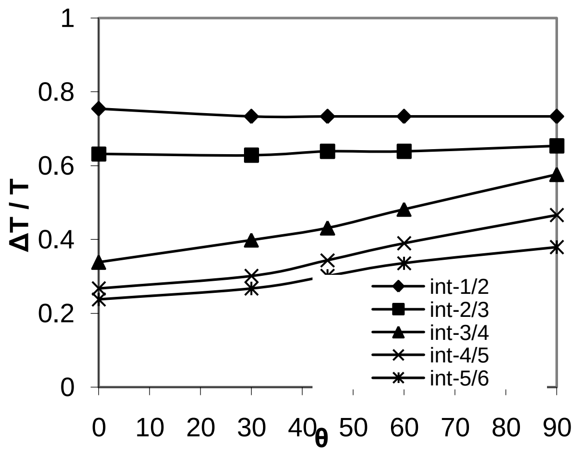

Fig.12. temperature discontinuities at different interfaces with debond a/h=1 in ($0^0/90^0/\theta^0$) laminate.The temperature discontinuities in a laminate varies with the

position of the debond and this effect is shown in figs 11,12.

The variation of temperature discontinuities in a laminate across the debond for different fiber angles and k_L/k_T values is shown in fig13 and for a particular value of k_L/k_T the variation of temperature discontinuities across the debond at different fiber angles with debond at different interfaces.

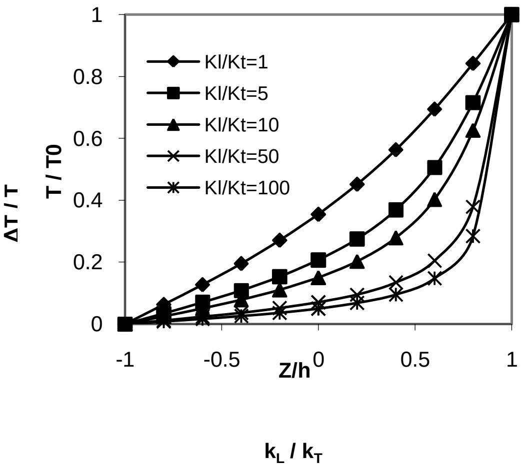

Fig.13. temperature discontinuities across the debond at different interfaces for different k_L/k_T values.

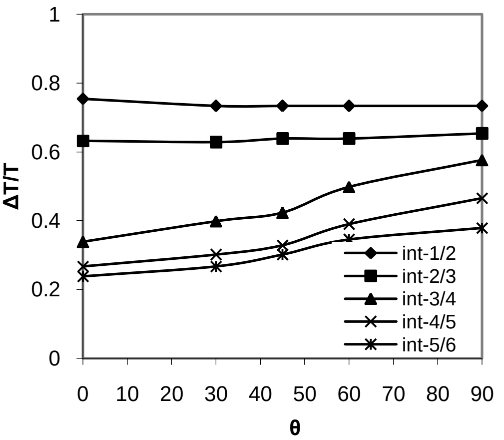

Fig.14. temperature discontinuities across debond at different interfaces with k_L/k_T =4

IV. CONCLUSIONS

The present work proved that the assumption of linear temperature distribution in composite laminates is no longer valid and an accurate temperature distribution must be obtained for finding the thermal stresses. The analysis can be extended to different boundary conditions and different laminate sequences.

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