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Review Article

ANALYTICAL STUDY OF FACTORS AFFECTING AND APPLICATION OF FINITE ELEMENT ANALYSIS FOR HEAT TRANSFER THROUGH FIBER REINFORCED COMPOSITE MATERIALS

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As composites are made up of two different materials having different properties therefore their response to heat transfer will also be different. Due to different materials, a composite have different conductance, cooling rate, strength values for each material which effects rate of heat transfer in different environmental and operating conditions. Due to which heat transfer rate will be different in matrix and in fiber which effects overall heat transfer rate through the composite. In addition, by using FEM analysis it has been concluded that if the fibers are located at different positions in composite they can also affect the heat transfer rate. This paper deals with study of different parameters that affect the heat transfer through FRC.

Keywords: FRC (fiber reinforced composites), FEM analysis, Heat transfer, Microstructural topography.

INTRODUCTION

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. On the basis constituent materials composite materials are classified as:

1. Metal-Matrix Composites
2. Fiber-reinforced composites
3. Ceramic-Matrix Composites
4. Carbon-Carbon Composites

Based on size and shape of dispersed medium composite materials can be classified as

1. Particle-reinforced (large-particle and dispersion-strengthened)
2. Fiber-reinforced (continuous (aligned) and short fibers (aligned or random)
3. Structural (laminates and sandwich panels)

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Fiber-Reinforced Composites often aim to improve the strength to weight and stiffness to weight ratios (i.e. desire light-weight structures that are strong and stiff!). Glass or Metal Fibers are generally embedded in polymeric matrices.

Due to features like lightweight, specific strength, stiffness, dimensional stability, suitable properties like coefficient of thermal expansion, high thermal conductivity composite usage has increased enormously as engineering material these days. The environmental factors like biological attack, moisture penetration, temperature change etc. may pose threat to structure and must be considered during the design process of composite, otherwise failure will cause waste of time, energy and money. As composite are made up of two different materials so the degree of sensitivity of composites to individual environmental factors is quite different.

Also during curing of a composite material several residual stresses are generated at the interface of fiber and matrix. Which affects the overall strength of the composite material.

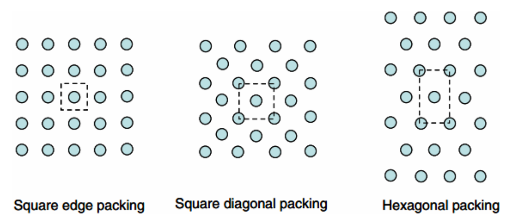
LITERATURE REVIEW

T J Vaughan *et al*., 2011 worked on effect of fibre-matrix debonding and thermal residual stress on the transverse damage behaviour of a unidirectional carbon fibre reinforced epoxy composite. It is found that for a weak fibre-matrix interface, the presence of thermal residual stress can induce damage prior to mechanical loading. However, for a strong fibre-matrix interface the presence of thermal residual stress is effective in suppressing fibre-matrix debonding and improving overall transverse strength by approximately 7%. Also the composite was employed to multiple loading conditions and role of weak and strong fiber-matrix bonding was noticed in generating macroscopic crack from microscopic one.

Hui Mei, 2008 calculated Thermal Residual Stresses (TRS) in fiber reinforced composite like SiC-ceramic matrix composites reinforced with carbon fiber (C/SiC) and silicon carbide fiber (SiC/SiC) by three different methods i.e. analytical method, experimental and theoretical predictions. And also relation between thermal stress and macroscopic mechanical properties was studied. It was concluded that if TRS of any composite is less, more strength it will have and its properties will be more stable.

Jia-Lin Tsai *et al*., 2008 worked to find effect of thermal residual stress on mechanical behavior of composite with three different fiber orientations i.e. irregular, square edge and square diagonal. Thermal residual stresses are generated in composite due to mismatch of coefficient of thermal expansion during cooling. It was found that composite with square edge packing fibers is more sensitive to the thermal stresses as comparative to others.

Figure 1: Different Micro Architectures Considered for the Study (a) Square edge Array (SEA) (b) Square Diagonal array (SDA) and (c) Hexagonal Packing



Z H Zhu, 2009 have worked on finding the interfacial thermal stresses of fiber reinforced composites under assumption of plane stress and plane strain. Under this approach the fiber and matrix was assumed to be isotropic. The matrix was composed of randomly spaced fibers and was subjected to thermo-mechanical loads. The whole study was done on single fibered composite and results were superimposed with multi-fiber arrangement which reduced the complicated problem into linear.

Jean-Louis *et al*.,1994 has studied the heat transfer on five different models at interfacial thermal barrier between fiber and matrix. Also influence of interfacial barrier on thermal conductivity and heat transfer rate in composites. It was concluded that the heat transfer from component with interfacial thermal barrier resistance depends strongly on the value of resistance of thermal barrier between interface and component. All the five models are having different barrier resistance. The five models can be regrouped into two classes. The first class comprises models I-III. The most powerful model is model II since it gives models I and III on increasing or decreasing thermal conductance, respectively. The second class contains models IV and V. Here the most powerful model is model IV which yields model V on decreasing thermal conductance.

Jinfeng Zhuge *et al*., 2012 studied post fire flexural modulus of E-glass fiber matrix and it was concluded that composites with more thickness have high flexural modulus than with higher fiber volume fraction.

M. Norouzi *et al*., 2013 studied steady state heat transfer for multi layered composite vessel in case of varying outside temperature and secondly in case of varying inside temperature. The temperature and heat flux continuity is applied between the laminas. In order to obtain the exact solution, the separation of variables method is used and the set of equations related to the coefficient of Fourier-Legendre series of temperature distribution is solved using the recursive Thomas algorithm. The solution is obtained under linear boundary conditions so that it can be applied to other conditions like conduction, convection and radiation from sphere surface inside and outside. These results are useful in controlling thermal fractures and controlling directional heat transfer through laminates.

J W Klett *et al*., 1999 studied A finite-element model has been developed to predict the thermal conductivities, parallel and transverse to the fiber axis, of unidirectional carbon/carbon composites. This versatile model incorporates fiber morphology, matrix morphology, fiber/matrix bonding, and random distribution of fibers, porosity, and cracks. The model first examines the effects of the preceding variables on the thermal conductivity at the microscopic level and then utilizes those results to determine the overall thermal conductivity. The model was able accurately to predict the average thermal conductivity of standard pitch-based carbon/carbon composites. The model was also used to study the effect of different composite architectures on the bulk thermal conductivity. The effects of fiber morphology, fiber/matrix interface, and the ratio of transverse fiber conductivity to matrix conductivity on the overall composite conductivity was examined.

S I Kundalwal, 2014 have estimated the thermal conductivity of FFRC by employing the effective medium approach in conjunction with the composite cylinder assemblage approach.

S Ramakrishna, 1997 have suggested that when properly designed, polymer composite materials absorb more energy per unit mass of material than the conventional metals and polymer composites can also be used for crashworthy structural applications. Energy absorption characteristics of polymer composite materials are influenced by the microstructural variables, such as types of fibers and resins used; the way fibers are arranged and the fiber matrix interface bond strength.

Siu N Leung *et al*., 2013 studied thermal and electrical conductivity of composite material filled with spherical particulate. Also the effect of particulates on the thermal conductivity was discussed. It was noted that the weak interfacial bonding is the main reason that hinders the promotion of thermal conductivity in filler particulates.

CONCLUSION

Based on the literature review presented here in, the following points have been noted:

1. Most of the work has been done on the thermal stress analysis along with interfacial studies but not much work was noticed on the transient heat transfer response of composites.
2. A number of fiber architectures have been reported but it is still not clear that which fiber arrangement is best suitable for the heat transfer response.

The objective of research would be to study the heat transfer response in fiber polymer regimes and to analyze the behavior of different fiber architectures subjected to similar boundary conditions.Effect of heat transfer and rate of heat transfer will be concluded from different fiber arrangements in reinforced fiber polymer composites. The behavior of different fiber architectures subjected to similar boundary conditions will be analyzed to come up with the optimum design for best heat transfer response. Heat transfer is greatly influenced by the microstructural topology with the objectives in hand, the heat transfer analysis will be performed for various microstructural topologies by creating different arrangements of fiber insertion within matrix and their heat transfer response using finite element software.

Various commercial personal computer programs are available for solving a wide array of problems by the finite element method. ABAQUS we will be applying FEM for heat transfer analysis on Fiber Reinforced Composite materials having different fiber orientations.

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