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Research Paper**THERMAL ANALYSIS ON FIBER REINFORCED PLASTIC MATRIX COMPOSITE MATERIALS USING ANSYS**¹B. Ravi¹Assistant Professor,

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bravi1234@gmail.com**Abstract**

Thermal analysis is crucial for understanding how composite materials behave under different temperature conditions. It helps in predicting the thermal expansion, conductivity, and potential failure points of the materials. This analysis ensures that the composite materials can withstand operational environments without degrading or losing their structural integrity. Analysis has been carried out with simulation in ANSYS, first, import the geometry of the fiber-reinforced plastic matrix composite material. Next, assign the appropriate material properties, such as thermal conductivity and specific heat, to the different components of the model. Finally, apply boundary conditions, such as temperature or heat flux, and run the simulation to analyze the thermal response of the composite material. FRP composites have low intensity at higher temperatures with the addition of polymers.

Keywords: Fiber Reinforced Plastic, Composite Materials, ANSYS, Thermal Analysis.

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1.Introduction

Composite materials have been used for industrial products for nearly forty years, and they have developed significantly at duration of that period. Especially [1,2],. Furthermore, continuously developed new material systems are giving us infinite possibilities for structural design. Fiber reinforced composite materials are increasingly being used for joining composites to different composites or to metal. Fiber-reinforced composites are commonly differentiating by a high degree of specific strength and specific stiffness parameters (i.e., weight to strength ratios) and are commonly used in low-weight component applications [3]. All practical reinforced plastics composites are likely to contain defects of various kinds arising from the processes of manufacture. The micro structural in homogeneity and anisotropy of fiber composites are together responsible for the fact that the fracture of these materials is rarely a simple process. Although the complex

combination of micro-failure events that leads to deterioration of load-bearing ability, can often give rise to surprisingly high levels of toughness, the same complexity makes it difficult or impossible to use procedures based on fracture mechanics for design purposes. The fracturing of a composite therefore involves not only the breaking of the Load-bearing fibers and the weak matrix, but a complex combination of crack deviations along these weak interfaces [4,5]. The high strength and damage resistance of the composites are very important for several practical applications. Many kinds of mathematical models of deformation, damage, and failure of fiber reinforced composites have been designed in order to predict the strength and other characteristics of these composites [5]. The micro mechanisms of damage in fiber reinforced composites (FRC) can be described as follows [6]. When a fiber reinforced composite with a ductile matrix is subjected to longitudinal tensile loading, the fibers bear

most of the load and fail first. As the weakest fibers fail, the remaining intact fibers experience increased loading, potentially leading to the failure of neighboring fibers. Cracks in the fibers can cause stress concentration in the matrix, which may result in matrix cracking. However, if the interface between the fiber and matrix is weak, the crack can propagate along the interface. In ceramic and other brittle matrix composites, cracks initially form in the matrix. However, if there are intact fibers behind the crack and they connect the crack faces, a crack bridging mechanism occurs. This mechanism allows the load to be shared by the bridging fibers and the crack tip, resulting in a reduction of the stress intensity factor at the crack tip [7]. When there are more bridging fibers present, the stress intensity factor at the crack tip decreases, resulting in increased resistance to crack growth. As the crack extends and is bridged by intact fibers, the fibers may debond and pull out, which enhances the fracture toughness of the material. This phenomenon contributes to the overall strength and durability of fiber reinforced composites.

2. Methodology

Fiber Reinforced Plastic (FRP) matrix composites are known for their high strength-to-weight ratio, making them ideal for many advanced applications. However, these materials are susceptible to thermal stresses, which can lead to issues like warping, delamination, or degradation if not properly understood. Thermal analysis helps engineers simulate the material's behavior under thermal loads, providing insights into how temperature fluctuations affect the composite structure. This analysis ensures that the composite materials can operate safely without compromising their mechanical integrity or performance under extreme conditions.

The Plane Fiber Approach The way of modeling the woven fiber reinforced material is developed using the FEA software, ANSYS. A detailed steps on the composite modeling. A plane fiber approach was chosen to keep the model at a low level of geometric complexity.

In this approach, a thermal mass ANSYS SHELL131 element was used to stimulate the fibers and the matrix. Only ANSYS SHELL131 can be used to model the layered composites. The matrix is modeled in two SHELL131 layers with the fiber in between. The fiber layer and the matrix layers are considered to be in connection since they share the same node in each degree of freedom (DOF) as shown in Figure

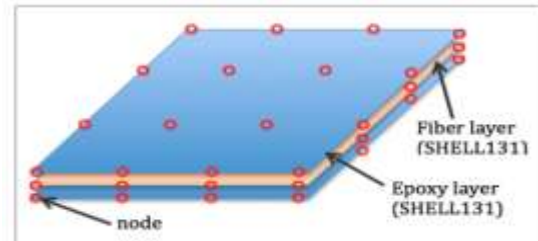


Figure 3.1: The Plane Fiber Approach

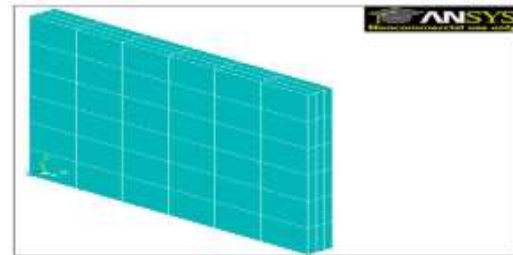


Figure 3.2: The meshed model of FRP composite

Steady State Thermal Analysis

A steady-state thermal analysis calculates the effects of steady thermal loads on a system or component. Steady state thermal analysis is often performed before performing transient thermal analysis to help establish initial conditions.

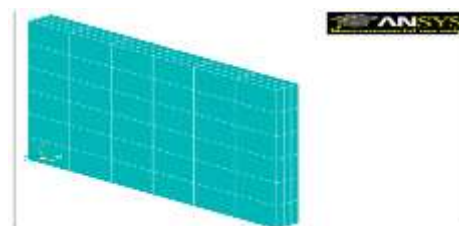


Figure 3.3: The Layered Model of FRP Composite

Figure 3.3 above shows the layered model of the composite that has been developed using ANSYS. The model consists of 3 layers, where the fiber layer in the middle is sandwiched by two layers of epoxy. The orientation of fiber is manipulated in lay-up properties of the model.

The angles chosen for the study are +40/-45 degrees, 0 degree and 90 degrees. These are the commonly used orientation of the composites

4. Results and discussion

The temperature distribution of the steady state analysis of the FRP composite is observed and evaluated for its thermal behavior. Each fiber orientation yielded a slightly different temperature distribution. First, the thermal analysis is done on the carbon fiber and epoxy resin alone. The temperature distribution of carbon fiber is shown in Figure

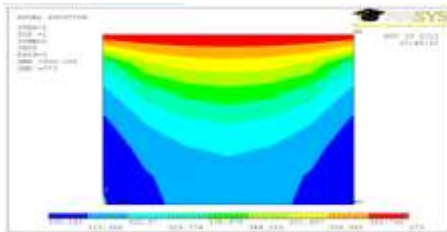


Figure 4.1: The temperature Distribution of FRP

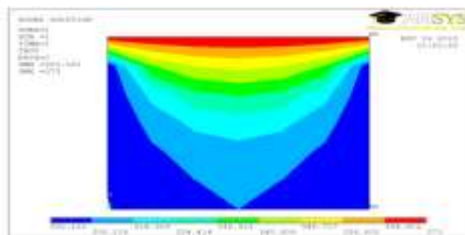


Figure 4.2: The temperature Distribution of Epoxy

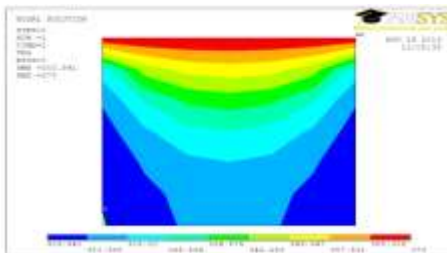


Figure 4.3: Temperature Distribution for 0° Fiber Orientation

The temperature distribution for the 0 degree fiber orientation of the carbon fiber composite is shown in Figure. The maximum temperature will always be the source of heat, which is 100 °C or 373 K. The temperature propagated from the maximum applied temperature on the top part through the composite to the insulated bottom part. The minimum temperature of the composite is recorded to be 303.8 K or 30.8

°C, 3.8 °C higher than the applied surrounding temperature (27 °C).

45° Fiber Orientation

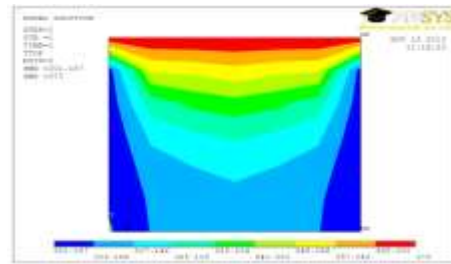


Figure 4.4: Temperature Distribution for 45° Fiber Orientation (top and bottom layer)

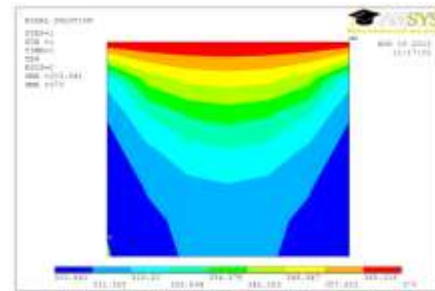


Figure 4.5: Temperature Distribution for 45° Fiber Orientation (middle layer)

For 45° fiber orientation, the analysis yielded two different temperature distribution of the composite. Figure 4.4 shows the temperature distribution for the 45° fiber orientation at the top and bottom layer of the carbon fiber composites and Figure shows the temperature distribution for the 45° fiber orientation at the middle layer. In structural point of view, at 45° orientation, the composite is said to be more flexible and has high torsional strength. However, the structural properties cannot be implemented in thermal analysis. The top and bottom layer temperature distribution in Figure 4.5 demonstrates a pattern that is almost similar to the temperature distribution of epoxy but with a better heat dispersion. The minimum temperature is 301.2 K or 28.2 °C which is 1.2 °C higher than minimum temperature of epoxy. The middle layer temperature distribution in Figure has a quite similar pattern to the temperature distribution of carbon fiber. The minimum temperature is 303.8 K or 30.8 °C.

Conclusions:

The main purpose of this project is to develop a 3D thermal analysis of carbon fiber composite using Finite Element Analysis to estimate its thermal behavior from the temperature distribution and thermal gradient. The 3D thermal analysis has been successfully developed by using ANSYS. Consecutively, the analysis on the temperature distribution and thermal gradient is done to estimate the thermal behavior of the composite. All the objectives are relevant and achievable throughout this project. The thermal conductivity of the composite in perpendicular direction is lower compared than that in parallel direction because its property is dominated by the epoxy resin. The composite can be designed to exhibit higher thermal conductivity by setting the fiber orientation in parallel direction (0°).

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