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THERMAL CONDUCTIVITY ENHANCEMENT OF SILICON INSERTED HYBRID COMPOSITE MATERIALS

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ABSTRACT

In this investigation thermal conductivity test was carried out to the prepared specimen of silicon inserted hybrid composite material (on silicon inserted glass – fiber chop strand and other silicon inserted glass – fiber 90^0 woven). The specimens were prepared by hand layup followed by compression molding method. The apparatus consist of two copper plates and one specimen together clamped on both sides using bolts and nuts. On one side of the copper plate a heater is fitted. End losses from the plates are minimized by providing thick insulation all around to ensure unidirectional heat flow. A dimmer stat is provided for varying the input to the heater and measurements of input is carried out by Voltmeter. Thermocouples are bounded in mica are embedded between the interface of the copper materials and the specimen of silicon inserted hybrid composite material, to read the temperature at the surface.
The experiment can be conducted various values of input to find thermal conductivity of each material. By the experimental values we found by the results that the thermal conductivity of glass-fiber 90^0 woven is less in comparison with thermal conductivity of glass-fiber chop strand for all the cases and the thermal conductivity of glass-fiber 90^0 woven increases as the % of silicon increases for the different trails, and also for taking average of all trails the result is same the K value increases.

KEYWORDS: Thermal conductivity, Glass fiber, Silicon

INTRODUCTION

The science of thermodynamics deals with amount of heat transfer as a system under goes a process from one equilibrium state to another and makes no reference to how long the process will take. We are often interested in rate of heat transfer, which is the topic of science of heat transfer. Heat transfer deals with the rate of heat transfer between different bodies. While thermodynamics deals with the magnitude of heat exchanged in a process. Heat transfer is necessary to determine time required for a process or alternatively the size of a surface necessary to achieve a certain total rate of heat transfer.
Heat transfer analysis permits a calculation of the heat loss from a building surface to the surroundings for a given building size, window area and wail design, e.g. the level of insulation in the wall cavity. The comfort conditions for occupants in a room determined by a balance of heat transfer from the person to the air surrounding him or her as well as the heat transfer to the walls of the interior. The size and cost of a heat exchanger is also determined by considering the heat transfer between the fluid steams in the exchanger.
In other fields, heat transfer plays a key role as well. The design of integrated microprocessors which contain very closely spaced elements, each with a finite amount of heat generation, is limited by the requirement for an adequate cooling so that the operating temperature of the electronic components are not exceeded. Re-entry of the space shuttle in the earth's atmosphere must be carefully programmed so that a temperature extreme due to air friction is confined to the insulating tiles on the shuttles surface.
Heat: heat (denoted by the symbol Q) may be defined in an analogous to work as follows.
Heat is something, which appears at the boundary when a system changes its state due to a difference in temperature between system and its surroundings. Heat like work is a transient quantity, which only appears at the boundary while a change is taking place within the system.

MATERIAL AND METHODS

Increasing use of composites for various applications emphasizes its importance/significance in the thermal property analysis of an engineering system. Thermal conductivity of a composite (combination of two or more constituents) can be measured by experimental methods. Analytical equations are essential to predict thermal conductivities of a composite material. In advanced engineering applications, polymers and their composite are emerging as variable alternative to metal and their alloys. Due to the mechanical loading situation in engineering applications, the composite materials are needed to be tested intensively.
A glass-fiber/epoxy resin composite has been chosen for its good combination of high stiffness and low thermal conductivity over the 2-293 K temperature range. Plies of long glass-fibers are stacked optimally yielding the best mechanical behavior. However, heat leaks from the supports are influenced by the thermal characteristics of the composite, which in turn depend on the orientation of the fibers. To study the dependence of the thermal conductivity on fiber's orientation, we performed high precision thermal conductivity measurements of various samples of glass-fiber/epoxy resin composite.

2.1 METHOD TO PREPARE COMPOSITES

Hand lay-up is the oldest and simplest method of manufacturing composites. The tools required for the process are a mold to accommodate dry manufacturing according to the desired shape and a roller to facilitate uniform distribution of resin. Virtually any sized composites can be manufactured using this method. This method is the cheapest method of manufacturing but it has some disadvantages such as long curing time, low production rate, and further the quality of the composite depends on the skill of the worker.

2.2 MATERIALS

The compositions of the E – glass fiber used are in the table given below.

Table – 1 Compositions of the E – glass fiber.

Material	Quantity in grams (0% Carbon)	Quantity in grams (10% Carbon)	Quantity in grams (20% Carbon)	Quantity in grams (30% Carbon)
	Chop Strand	Chop Strand	Chop Strand	Chop Strand
Silicon	0	24.32	46	78.18
E-glass fiber	116.4	121.6	115	130.2
Epoxy resin	291	218.88	184	182.42
Hardener	29.1	21.88	18.4	18.242

Table – 2 Compositions of the E – glass fiber.

Material	Quantity in grams (0% Carbon)	Quantity in grams (10% Carbon)	Quantity in grams (20% Carbon)	Quantity in grams (30% Carbon)
	90^0 Woven	90^0 Woven	90^0 Woven	90^0 Woven
Silicon	0	19.5	45.12	73.62
E-glass fiber	125	97.5	112.5	122.7
Epoxy resin	250	175.5	180.48	171.78
Hardener	25	17.55	18.048	17.18

2.3 THEORY

The theory of thermal conductivity was proposed by Fourier in 1822. According to Fourier, the fundamental heat conduction equation can be stated as "For a homogeneous solid, the local heat flux is proportional to the negative local temperature gradient". For one dimensional steady state heat transfer, this statement can be represented by

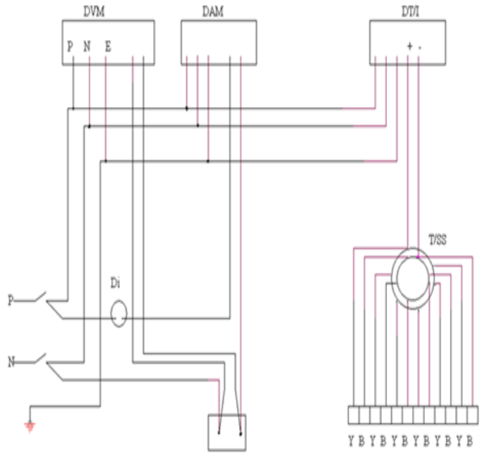
$$q'' = -K \frac{dT}{dX}$$

Where q is the heat flux, K is the thermal conductivity of the material, which is a positive 2^{nd} order tensor quantity, $\frac{dT}{dX}$ represents change in temperature across the thickness and negative sign indicates the temperature reduction from hotter surface to cooler surface. According to Equation 2.1, conductivity can be given as (under the assumption, that heat is not lost in its plane)

$$K = (Q/A)/\ (\Delta T/\Delta L)$$

Where K is the thermal conductivity (W /m-K), Q is the Heat Flux (W), A is the cross sectional area of the specimen (m^2), ΔT is the Temperature difference (K), ΔL is the overall distance (m). Thus, the thermal conductivity of a material can be defined as a rate at which heat is transferred by conduction through a given unit area of a given material, when the temperature gradient is normal to the cross sectional area. The thermal conductivity of a composite material depends on the fiber, resin materials, fiber volume fraction, orientation of the fiber, direction of heat flow and operating temperature.

EXPERIMENTAL DETAILS



DVM→ Digital voltmeter,
DAM→ Digital ammeter,
DT/I→ Digital temperature indicator
T/SS→ Temperature selector switch,
DI→ Electronic dimmer stat.

Fig.1 Schematic circuit diagram of experimental set-up for measuring thermal conductivity.

Fig.2 Schematic diagram of experimental set-up

The apparatus consist of two copper plates and one specimen together clamped on both sides using bolts and nuts. On one side of the copper plate a heater is fitted. End losses from the plates are minimized by providing thick insulation all around to ensure unidirectional heat flow. A dimmer stat is provided for varying the input to the heater and measurements of input is carried out by Voltmeter. Thermocouples are fitted at the interface of the copper plates at different points as to obtain average temperature of each surface. The specimen is insulated with glass wool to minimize the radiation and convection loss from the surface of the specimen and thus ensure the constant temperature gradient throughout the length of the specimen. The temperature of the specimen is measured at four different locations. The heater is provided with a dimmer stat for controlling the heat input. Heat conducted through the wall is taken away by circulating water on the outside of the wall whose rate of flow and temperature can be recorded.

RESULTS AND DISCUSSION

The Experimental set up has been calibrated using MS specimen and found satisfactory results. Then Experiments conducted for glass-fiber chop strand and glass-fiber 90^0 woven to find the thermal conductivity by using the equation $K = (Q/A)/ (\Delta T/\Delta L)$. The experiment is conducted under atmospheric temperature for different percentage of silicon for both glass-fiber chop strand and glass-fiber 90^0 woven material and we found by the results that the thermal conductivity of glass-fiber 90^0 woven is less in comparison with thermal conductivity of glass-fiber chop strand for all the cases. The thermal conductivity of glass-fiber chop strand increases as the % of silicon increases for the different trails, and also for taking average of all trails the result is same the K value increases as shown in figure 1. And the thermal conductivity of glass-fiber 90^0 woven increases as the % of silicon increases for the different trails, and also for taking average of all trails the result is same the K value increases as shown in figure 2.

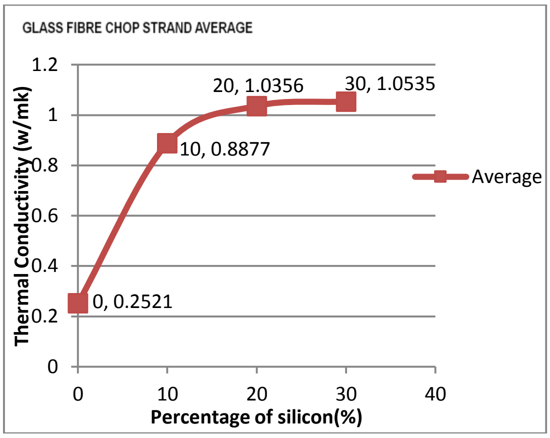


Figure 1 Variation of Thermal Conductivity with percentage of silicon for glass fiber chop strand.

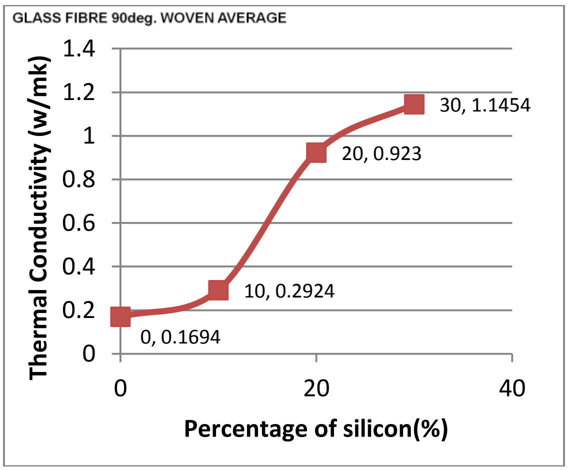


Figure 2 Variation of Thermal Conductivity with percentage of silicon for glass fiber 90 degree woven.

CONCLUSION

It was observed that the thermal conductivity of silicon inserted hybrid composite material **vary with temperature**. Thermal conductivity of the silicon inserted hybrid composite material **increases** with increase in percentage of silicon. Thermal conductivity of glass fiber chop strand is **more** when compared with glass fiber 90 deg woven. Silicon can be successfully used as filler materials for fabrication of Epoxy /Glass fiber based hybrid composites.

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