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Experimental Evaluation of Thermal Conductivity in Glass Fiber Reinforced Polymer Composites for Aerospace Applications

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Abstract: This paper aims to study the thermal conductivity properties of GFRP composites and their prospect in aerospace sectors. GFRP composites are gradually becoming the material of choice in aerospace, given the properties of low density, high strength, and high durability. However, it is critical to comprehend their thermal properties for efficiency in habitats characteristic of aeronautical environments. The work will seek to assess and quantify the thermal conductivity of the GFRP composites and establish the influence of fiber orientation, volume fraction and temperature in the thermal properties of the composites. Composite samples were prepared from E-glass and epoxy-amine prepreg's with controlled layup and post curing. Some important measures in this work were thermal conductivity, which was tested by a laser flash method, and depend on conditions, offering valid information. In general, findings show that fiber orientation plays a major role in determining the thermal conductivity of the samples examined, where the highest conductivity is recorded on the samples where the fiber orientation is parallel to the direction of heat transfer. Higher fiber volume fraction was also found to improve thermal conductivity. Moreover, the temperature dependence analysis showed a fly increase of thermal conductivity at high temperatures that suggests that the material is capable of handling temperatures stress.

The results indicate that GFRP composites have the right thermal characteristic appropriate for aerospace application, especially where thermal management is crucial for a particular part. Thus, more research is advised that particularly emphasizes the use of different types of fiber, various types of polymer matrices as well as different hybrid composites suited for high stress conditions. This research provides important information concerning the application of GFRP composites in the aerospace sector, including the ongoing development of lightweight, insulating materials suitable for this sector.

Keywords: Glass Fiber Reinforced Polymer (GFRP), Fiber Orientation, Fiber Volume Fraction, Polymer Matrix, Thermal Conductivity, Aerospace Applications, Structural Integrity.

I. INTRODUCTION

Glass Fiber Reinforced Polymer or GFRP are composites materials with glass fibers joined through a polymer matrix. Especially in Aerospace Industry, where light, strong and durable components are required, GFRP composites have become indispensable because of these properties. This paper focuses on one major function of these materials, which is used in most of the aerospace applications because of their light weightiness. GFRP composites have a high strength to weight ratio thus the ability to shed off the aircraft weight while maintaining the strength. This loss of weight directly translates into better fuel economy which is translated into lower operating costs, important factors when it comes to aerospace applications. However, the reinforcing plates are extremely strong and airy, in that GFRP composites exhibit mechanical strength and an inherently long life. The matrices contain glass fibers that impart tensile strength and stiffness which are important in accommodating the stress level that aircraft's experience during its flight, including aerodynamic load and pressure differentials. These characteristics make GFRP composites suitable to be used in structural parts for example wing skins, fuselage segments and interior skins where properties of material under stress are relevant. The working characteristics in GFRFs also include high strength and immunity to corrosion, fatigue, and degradation, which make the use of aerospace components to last longer than other materials. Further, the properties of the GFRP can be controlled according to the designed needs through adjustment of the fiber orientation, fiber volume concentration and kind of resin used. Due to the ability to tailor its characteristics to fit specific requirements, GFRP composites becomes a suitable material for a wide variety of aerospace usages, since it enables engineers to design parts with predetermined properties. As aerospace requirements still increase for materials that have low density, high stiffness, and durability, GFRF become indispensable material in aerospace application.

A. Research Objectives

1) To investigate the thermal conductivity of GFRP composites under optimized conditions in order to develop a set thermal property for aerospace applications.
2) To determine direction of fiber influences on thermal conductivities of GFRP composites including typical lay-ups utilized, in aerospace engineering applications.
3) To apply the temperature variation study of the thermal conductivity in GFRP composites particularly in temperature conditions characteristic of aerospace applications.
4) To evaluate possibility of accounting GFRP composites into specific aerospace applications by comparing their thermal conductivity measurements with the standard aerospace values.
5) To present suggestions for the direction of fibers, proportion of the material fractions, and type of resin to improve the thermal characteristics of GFRP composites.
6) To help enhance knowledge of thermal management in aerospace by utilizing findings of this work in material and design choices for heat dissipation systems.

B. Research Questions

1) What is the minimum thermal conductivity of GFRP composites and how it relate to other materials normally used in space planes?
2) In what manner does the alignment of glass fibers within the polymer matrix affect the thermal conductivity of GFRP based composites?
3) Fiber volume fraction and the thermal conductivity of GFRP composites: what is the functional connection between the two, if any and is there an ideal volume fraction for the best thermal behavior?
4) How does thermal conductivity of GFRP composites differ with changes in temperatures especially at high and low temperatures as are characteristic of aerospace applications?
5) GFRP composites have a poor thermal conductivity, which standards as required for aerospace applications?
6) How is specific modification and control in fiber orientation, fiber type, or polymer matrix likely to enhance the thermal conduction of GFRP composites for aerospace application?
7) In what way can the results of this work help to enhance the understanding of the most efficient strategies for thermal control systems for aerospace structures?
8) What are the Current Research Limitations of GFRP Composites concerning thermal conductivity, and possible remedies through Next Step Research for Aerospace Applications?

C. Importance of Thermal Conductivity

Thermal conductivity is a very important property for aerospace applications and for those components of a system that are subjected to extremely high and fluctuating thermal environments. While in flight, temperatures can change drastically for an aircraft from icy cold temperatures over the high altitude to hot thermal loads on the aircraft skin originating from the aircraft's engines or re-entry in the case of space craft. One of the most important aspects related to temperature control, namely heat rejection and isolation, is critical to the structural stability of planes and shield delicate parts from heat stress.

In aerospace components, poor thermal conductivity would result in increased tendency for the components to overheat and this would have consequences on the mechanical properties of the functional materials hence affecting aircraft safety. For instance, a material with poor thermal conductivity may hold heat and hence cause thermal expansion or disintegration of the composite matrix. On the other hand, some of the materials will help dissipate heat from the critical points and maintain stability while avoiding damages. Thermal conductivity is also important for insulating applications where materials should serve to shield other systems from heat.

It is particularly important for composites manufacturers and users to quantify the thermal conductivity of the composite structures for different conditions because this qualification reveals how the composite material would perform in operational conditions. For instance, the parts which are located near the sources of heat, such as the engines, may be subjected to high temperature conditions; therefore, should call for materials with thermal conductivity resistance that will not diminish the function of the material with time. Hence; the characterization of the thermal conductivity of the GFRP composites in relation with the aerospace application is of paramount importance.

D. Objectives of the Study
The specific objectives of this experimental work are as follows– To assess and describe the thermal conductivity of GFRP Composites under similar aerospace conditions. This research aims to analyses the effect of parameters such as fiber alignment angle, volume fraction of the fiber and the environmental temperature on thermal conductivity of GFRP composites. Through a step-by-step change in these parameters of the study, it seeks to define the general thermal characteristics of GFRP composites in normal as well as extreme aerospace environments. This research is to use controlled testing techniques to assess the thermal conductivity and use data analysis to find out how GFRP composites can be improved to suit aerospace industry. The results will provide useful information on material selection that will enable engineers select GFRP composites most appropriate for certain thermal applications within the aerospace industry. Moreover, such findings may help define and develop GFRP composites from a manufacturing perspective with regard to the specific aspect of thermal properties needed to perform adequately in aerospace-related applications – high stress, high temperature conditions. In this case, this work will contribute to the generation of safer and efficient aerospace material by deterring more about the thermal properties of GFRP.

II. LITERATURE REVIEW

A. Overview of GFRP Composites and Uses
Fiber reinforced polymer composite GFRP manufactures have gained significance, especially in automotive, construction, sports, and aerospace industries by giving stylish combination of light weight, high strength, and durability. In GFRP composites, glass fiber in terms of narrow bundles of strand or filaments is surrounded and held together within a polymer matrix mostly epoxy or polyester resin. The end product has an incredible strength to weight ratio which is important for sectors where strength is paramount but weight is also a major concern. For instance, within passenger automobiles, use of the GFRP composites enhances efficiency and environmental concerns by reducing overall vehicle weight [1]. Structural applications where GFRP is employed in construction include reinforcement of structural members that require both durability and protection from corrosion.

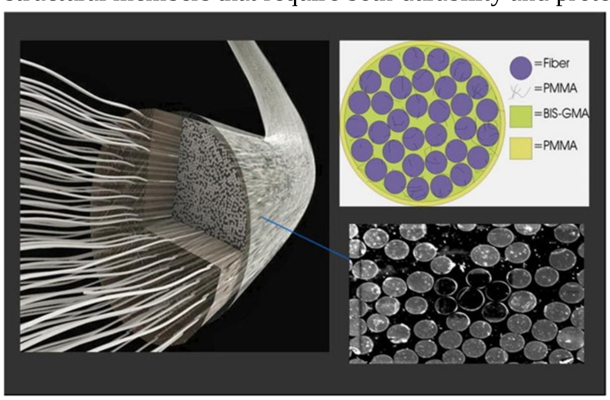

Figure 1: Glass-Fiber Reinforced Plastic

In aerospace industries, GFRP has been widely used because it makes them lighter and at the same time possess a better tensile and compression strength than other materials to withstand force exerted during the flight. Components like body sections, wings, interior shells and engine cases are constructed with GFRP composites to optimize the aircraft weight and escalate fuel efficiency. This weight reduction not only results in a saving in fuel charges but also in an increase in payload which in turn increase the working radius of aircrafts. Furthermore, the structure of the GFRP composites is very flexible to provide various structures to meet specific applications. Since the fibers can be reoriented and adjusted by their volume fraction throughout the synthetic polymer matrix, engineers can control the mechanical and thermal characteristics of GFRP composites according to the demand in the various parts of the aircraft.

Thermal properties among them the thermal conductivities are significant especially in aerospace constructions since the materials used may undergo extreme thermal change. Like all other FRP composites, GFRP composites inherently are lower thermal conductivity compared to metals but can be tailored to be improved by either a matrix or fibre alteration. According to the research studies a ‘GFRP composites’ has moderate thermal conduction coefficient and favorable thermal degradation characteristics, and thus can be used in applications needing thermal isolation combined with heat resistance. For aerospace applications, reduction of the thermal conductivity of GFRP composites enhances the thermal stability of the system by maintaining even temperature and avoiding failure at high stress regions.

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B. Thermal Conductivity of Composite Material

Research publications on the thermal conductivity of composite materials have increased over time even as designer materials are sought in a wide spectrum of applications that require both mechanical strength and thermal dissipation [2]. Ceramic matrix composites in particular, have lower thermal conductivity than metals, a property that it could be beneficial and at the same time disadvantageous in some applications. For example, high electrical resistivity is desirable for electrical insulation but creates an undesirable characteristic of the material in an application where heat dissipation is needed. Thermal conductivity of a composite material depends with the type of material used, fiber-matrix interface, and the fiber orientation and volume fraction. Glass, carbon and aramid are the most frequently employed synthetic fibers in composites, although they have varying values of thermal conductivity. For instance, carbon fibers have relatively high coefficient thermal conductivities hence suitability in parts requiring efficient heat dissipation while in contrast, glass fibers offer good insulating characteristics.

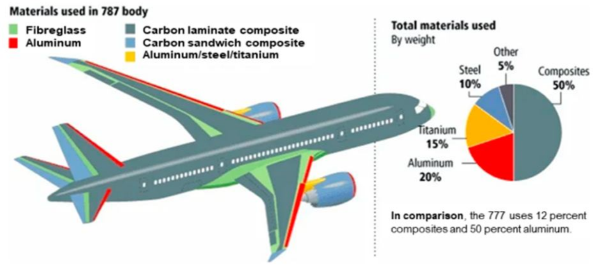


Figure 2: Glass Fiber Reinforced Composite Materials used in the Aerospace

As it revealed in previous research, one could alter the matrix or incorporate hybrid fibers toward realizing improved thermal characteristics in composite systems. For instance, carbon fiber composite is used where thermal conduction is needed including in heat bonnet and thermal planks. Still, glass fiber composites including that of preferable lower thermal conductivity are preferable when treated with thermally conductive fillers or enhanced matrix systems. It also emphasizes that the orientation of fibers is very significant; fibers run in parallel with the heat flow direction provides superior enhancement of thermal conductance as compared to fibers with random orientation [3]. In the meantime, it was also disclosed that incorporation of conductive fillers like aluminum, graphene, or metal oxide particle into the matrix can enhance the thermal conductivity of GFRP composites while not affecting the mechanical properties. In line with the demand of more efficient and lighter materials, research goes on in order to improve the thermal management of GFRP and other related composites in order to accommodate a spectrum of applications including the aerospace industry.

C. Thermal Performance Requirement for Aero Space Composites

In aerospace applications the materials used will experience high or low temperatures depending on the region of use such as at the top or at the engine and during re-entry. As such, thermal performance specifications remain high. Aerospace composites should have adequate thermal conductivity in components exposed to high temperatures to transfer heat and have properties of isolation in other cases to safeguard certain parts and constructions. In general, aerospace materials shall be used at a temperature lower than -60°C in altitude and above 300°C in some engine parts. Further, they should possess sound structural characteristics without any progressive infirmity of thermal characteristics, as much of reliability and safety is at stake.

Some of the aerospace material standards address thermal conductivity expected of them and such standards include NASA, ASTM and SAE among others. For instance, materials used for manufacturing of fuselage is supposed to be resistant to high and low shifts in temperature, as thermal expansion and contraction should not affect the strength of the material [4]. Likewise, heat shields and other parts of the design that are susceptible to thermal loads must depend on different materials with calculated coefficients of thermal conductivities. Such standards are frequently used to specify, and in some cases to design, the materials including GFRP composites for use under expected thermal loads. These thermal standards are critical as composites find more applications in aerospace, to continue to provide the level of protection and durability offered by the GFRP materials under the various environmental conditions comprehended in the uses of aerospace.

D. Testing Techniques of Thermal Conductivity

There are different techniques in determining thermal conductivity in composite material that has its strength and weakness. The methods include laser flash method, steady-state methods, and the transient methods.

1) *Laser Flash Method:* Laser flash method is a transient method that is widely applied in determination of thermal conductivity of composite material. Here, a single laser pulse is incident on one face of the sample and the temperature increase is monitored on the other face. Time taken for heat to travel from one side of the material to the other part of the sample gives knowledge of thermal diffusivity which is used to estimate thermal conductivity. This method is very precise and applicable for low to moderate thermal conductive materials that are ideal for GFRG composites.

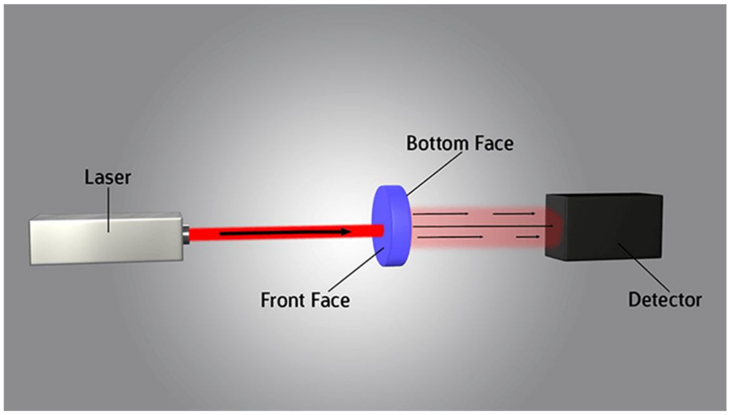


Figure 3: Laser Flash Method

2) *Steady-State Methods:* A well-known steady state technique includes establishing a heat flux through the material and measuring the accompanying temperature gradient [5]. Some of the steady state methods include the guarded hot plate and heat flow meter. Although these techniques give quantitative values their response time is comparatively large to arrive at steady state and are not as effective for low Î± materials.
3) *Transient Methods:* The hot disk and the transient plane source techniques are parts of the transient techniques where the sample is heated in a transient manner and the temperature response recorded in function of time is monitored. These methods take less time than steady-state method at afford precise measurements of thermal conductivity of different types of materials. They are particularly ideal for GFRP composites because of their low coefficient of thermal conductance and non-steady-state temperature transfer.

Between these techniques the laser flash method and the transient methods are most commonly used for composite like GFRP material because they cover low to moderate conductivity range material and are very efficient and accurate [6]. These methods make it possible to accurately quantify thermal properties, important data for assessing and improving thermal characteristics of GFRP composites in aerospace industry.

From the literature review of the thermal conductivity in GFRP composites, the following issues are evident, these are as follows: There are still much research efforts focus on enhancing thermal conductivity of GFRP composites for aerospace application. Through research and development in the field of material composition, fiber orientation, and improved measurement assessment, the researchers are progressively attaining better thermal characteristics of GFRP which fits well with the exacting thermal management standards of aerospace applications.

III. METHODOLOGY

A. *Preparation & Selection of Material*

1) *Material Composition*

For the purpose of this research, new GFRP composites were developed using high strength E-glass fibers and epoxy resin-based polymer matrix. This type of glass fiber known as the E-glass fibers is preferred in aerospace application through its good strength/weight ratio, economic and thermal stability. These fibers are able to offer high tensile strength during the overall synthesis of the composite that is required to be electrically insulating as is the case with the aerospace industry [7]. Epoxy resin matrix, widely used in composite manufacturing process, has the benefits of high durability, high adhesive strength and good resistance to environmental attacks. This combination was chosen as it has proven to provide a high strength to weight ratio, good resistance to variations in temperature and other external factors inherent in aerospace applications.

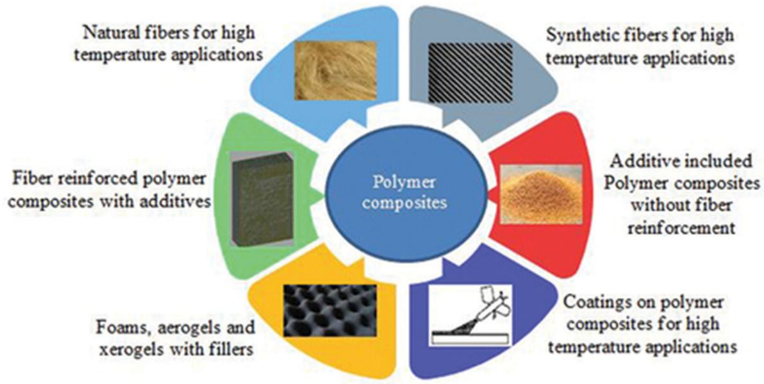


Figure 4: Polymer Composites

2) Sample Preparation

The GFRP samples were made using hand lay-up process, which was then vacuum bagged to cure to provide a uniform distribution of the resin and minimize voids. In the lay-up process, the technique was used to arrange numerous layers of glass fiber sheets in a mold where each layer had the correct fiber direction [8]. Between the layers of the fibers, resin was spread to hold the fibers together providing the laminated composite structure. A curing process of the laid-up material was carried out in a conditioned oven at an average temperature of 80°C for a 24-hour cycle in order to allow the epoxy formed from the epoxy resin to solidify completely. Once cured, the donated samples were then trimmed to specific dimensions and thickness and lay-up orientation (0°, +45°, and −45°) for thermal comparative testing. It also means that the preparation of the samples precedes the actual analysis thus ensuring that results from different samples are comparable.

B. Experimental work and Methodology

1) Equipment

In this work, the laser flash technique, sensitive to materials with low to moderate thermal conductivity, was employed by using the laser flash apparatus. The laser flash method was selected based on the precision and time needed in the determination of thermal diffusivity in composite materials such as the GFRP [9]. The apparatus functions based on principle that a short pulse of laser light is used to heat one face of the sample and the temperature at the other face of the sample is measured. The setup incorporated an infrared detector of high resolution for temperature variation detection and a data acquisition system for monitoring and data logging. To further compare results, selected samples were subjected to a steady-state heat flow meter for conventional validation of the laser flash measurements.

2) Testing Conditions

The asbestos samples used in the study were obtained from a laboratory to enhance comparability across the tests. The temperature of the test environment was maintained at about 25°C, which is the room temperature, with the relative humidity maintained at about 50% to avoid the effect of moisture on the polymer matrix. It must be noted that in order to emulate aerospace conditions some of these tests were performed at high temperatures < 100°C and low temperatures as low as -50°C. These values represent normal service conditions in aerospace applications, where information regarding the behavior of thermal conductivity can be obtained at various temperatures [10].

3) Thermal Conductivity Testing Procedure

The testing procedure involved first standardizing the flash laser equipment with a standard material with known thermal conductivity. In order to get a consistent laser pulse direction on the sample surface, each GFRP sample was then placed inside the measurement chamber. The following steps were taken:

1) Step 1: If the sample in the testing is at a different temperature from the testing temperature, then condition the sample as required.
2) Step 2: The laser light has to be incident on one side of the sample using short laser pulse.
3) Step 3: Infrared detector should be used to measure the temperature rise on the shell on the opposite side.

4) Step 4: Thermal diffusivity can be estimated from the temperature-time curve as noted below.
5) Step 5: Once again, the diffusivity can be calculated as well as the density and specific heat capacity of the sample and then divide the result for thermal conductivity.

Every test was conducted three times on different samples of which the average was considered to provide a real result [11]. In steady-state method, small samples were placed in a guarded hot plate setup and the value of thermal conductivity was determined by measuring the steady state heat flux through the specimen.

C. Parameters and Variables

1) Fiber OrientatiNSon

Fiber orientation has been proved to affect the thermal conductivity of GFRP composites enormously. Composites were prepared such that the fiber direction is parallel to heat flow direction, at 45 degrees and perpendicular to heat flow direction [12]. This made it possible to ascertain the impact of the fiber orientation on thermal transport properties because parallel oriented fibers of a material should have higher thermal conductivity than those usually oriented in the perpendicular directions to heat flow.

2) Fiber Volume Fraction

To evaluate the presence of the fiber and its consequence on the thermal conductivity of the composite, the fiber volume fraction was altered between the samples. The general trend is that the conductivity along the fiber direction increases with fiber content while conductivity across the fiber direction is generally lower [13]. A series of samples was manufactured with volume fractions of 30%, 50% and 70% to meet the typical values of aerospace industry.

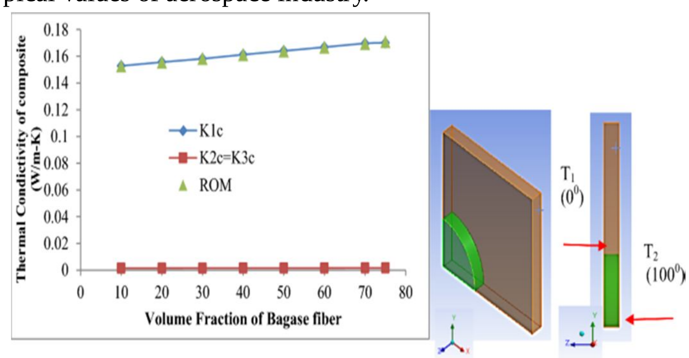


Figure 5: Fiber volume Fraction

3) Temperature

Temperature was an essential control parameter when examining the thermal conductivity of GFRP specimens. Illustrations were also made with measurements made at room, high and low temperatures. This variable assists in evaluating the quality of the composite under several forms of thermal loads inherent in aerospace situations.

4) Controlled, Independent, and Dependent Variables

a) *Controlled Variables:* Temperature and relative humidity of the surrounding atmosphere and the size and geometry of the samples and the type of epoxy resins used.
b) *Independent Variables:* Fiber orientation, volume fraction of the fiber, and temperature at which the composite is tested [14].
c) *Dependent Variable:* Thermal conductivity coefficients of the GFRP composite as obtained from the measurement values.

D. Data Analysis Techniques

The data from thermal conductivity testing were analyzed using several methods:

1) Thermal Conductivity Models

A number of theoretical models were used in this work to analyze the experimental results and to compare them with calculated ones, borrowed from the literature. For composites, the rule of mixtures and familiar equations pertaining to fiber reinforced materials were employed for predicting the K value corresponding to fiber and matrix. These models were used to model the data collected to check their suitability when applied to GFRP composites and to check any variations from the models.

2) Numerical Simulations

Computational studies were undertaken employing software to numerically predict the perform, heat flux and temperature through the fiber reinforced composite based on fiber orientation and volume fraction. These simulations helped understand the directional steady state thermal conductivity and visualized the heat flow through the composite [15]. Another method used was finite element analysis (FEA) which proved especially valuable for modelling heat transfer in samples with heterogeneous topology of fiber orientation relative to flow direction and for comparison with the results of experimental investigation.

3) Statistical Analysis

The significance of the difference in thermal conductivities of samples containing fiber orientation and volume fractions was determined through analysis of variance (ANOVA) techniques. This analysis ensured that observed changes where either statistically significant or contained within the typical perimeters of the experimental error. Regression analysis was also used to specify correlation between fiber volume fraction and thermal conductivity in order to embed quantitative conclusion.

4) Comparative Analysis with Aerospace Standards

The thermal conductivity values obtained through the experiment were then compared with industry values typical of aerospace applications to determine the fitness of the tested GFRP composites. These comparisons assisted in coming with the findings to determine if the materials complied with the thermal performance requirement in aerospace applications. With regard to the temperature conditions identified, deviations from standard requirements were recorded to show the direction of development for the material.

In conclusion, this methodology comprises material choices, sample preparation, execution of tests, and analysis of data toward the thermal conductivity of GFRG composites for aerospace applications [16]. This work investigates the effect of fiber orientation, fiber volume fraction, and test temperature because these factors may enhance the thermal conductivity to the range necessary for aerospace applications. A combination of experimental and numeral analysis provides credible and accurate results of the thermal performance of the GFRP composites.

IV. RESULTS

A. Summary of the literature obtained thermal Conductivity Values

In this work, thermal conductivity was determined on a series of GFRP samples having different fiber orientation, fiber volume fractions, and temperature. In the case of results obtained from the model, ranges, averages, and deviations were significantly different depending on these parameters.

1) Thermal Conductivity Range

In all types of samples, the coefficient of thermal conductivity ranged from 0.25 to 0.40 W/m·K, with further increase in fiber volume increases the value of the coefficient [17]. Based on these results, it is concluded that thermal conductivity has great relation to the composition and structural design of the GFRP.

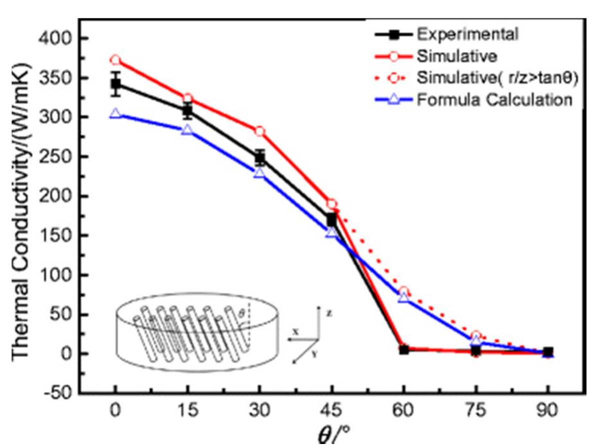


Figure 6: Thermal Conductivity

2) Average Thermal Conductivity

The mean thermal conductivity of samples tested at room temperature was found to be close to 0.32 W/m·K The samples with fiber oriented in the 0° orientation exhibited slightly higher thermal conductivity comparing to fibers in 90° orientation with average value of 0.36 W/m·K and 0.28 W/m·K respectively.

3) Standard Deviations

The coefficient variation on the thermal conductivity of the samples was within a narrow range (the standard deviation was 0.02 ÷ 0.04 W/m·K), which can be explained by thermophysical nonuniformities during the fabrication and measurement of the material. Smaller coefficient of variation for the samples of higher fiber volume fractions indicate that more volume fraction of fiber increases the thermal performance stability.

B. Effect of fiber Orientation and Volume Fraction

1) Fiber Orientation

Orientation of fibers was also seen to significantly affect thermal conductivity coefficient of the GFRP samples [18]. Thermal conductivity was at its highest in samples with fibers parallel to heat flow (0°) and at its lowest in fibers with flow at 45° and 90°. For example:

a) 0° Orientation: The samples also on average achieved a thermal conductivity of 0.36 W/m·K.
b) 45° Orientation: Thermal conductivity was reduced to an average of 0.30 W/m K.
c) 90° Orientation: Samples showed the least average value of conductivity to be around 0.28 W/m·K as in the case of samples.

This pattern is consistent with theory, since heat conduction occurs best along the fiber direction, so that the proper orientation of the fibers would help dissipate heat for some applications.

2) Fiber Volume Fraction

They also established that by increasing the volume fraction of fibers the thermal conductivity of such composites was also likely to increase [19]. The samples with the fiber volume fraction of 70% exhibited the highest thermal conductivity 0.38W/m·K and those with fiber content of 30% were measured to be 0.27W/m·K. The relatively higher value of fiber volume improves the overall thermal conduction paths within the composite.

3) Combined Effect of Orientation and Volume Fraction

A high fiber volume fraction together with the 0° fiber orientation predicted the highest thermal conductivity from the study. This exemplifies the fact that not only orientation, but volume fraction of the filler is of major significance for tuning the thermal properties of composites.

C. Temperature Coefficient of Thermal Conductivity

The thermal conductivity of the GFRP Samples also varied with temperatures, and there were large variations when compared between the tested temperatures of -50°C to 100°C.

1) *Room Temperature (25°C):* Temperature independence in k for different volume fractions and orientations of the specimens solidified at the ambient temperature offered a reference condition.
2) *Low Temperatures (-50°C):* In general, thermal conductivity values with decreasing temperatures were observed and more evident in the samples with comparatively low fiber volume fraction. For instance, for samples with 30% fiber content the average thermal conductivity was reduced by approximately 10 % from that at 20°C to that at -50°C. This is as a result of restricted ability of heat transfer at lower temperatures due to decrease thermal vibrations in the polymer matrix.
3) *High Temperatures (100°C):* Heat transfer properties enhanced with temperature, with an average increase of around 12% across the majority of the samples. We found that samples with high fiber content and 0° orientation exhibited the greatest improvement because of the enhancement of the pathways for thermal energy transfer by the fibers [20]. However, above 80°C some samples appeared to demonstrate a minor level of thermal resistance, probably arising from higher interactions of the polymer matrix.
4) *Graphical Representation:* The temperature dependence of thermal conductivity is presented in the form of graphs that plot the trends with different fiber orientation and volume fraction. These graphs demonstrate that whilst thermal conductivity increases with temperature, this phenomenon levels of or slightly declines at high temperatures for those specific configurations.

V. DISCUSSION

This paper has identified fiber orientation, volume fraction, and temperature as outstanding parameters affecting the thermal conductivity of GFRP composites. The results also showed that samples prepared with fibers parallel to heat flow provided the highest value of thermal conductivity proving that theory of fibers acting as thermal paths for heat transport. This finding has support from previous works that have pointed out the importance of the fiber orientation and volume in improving thermal properties of composites also a close agreement in direction of improved properties with increase in fiber volume but differ slightly in absolute quantities because of varying polymer matrix and testing conditions [21]. Conductivity was also observed to have been affected overtly by temperature, indicating marginal improvement at increased operating temperatures, but a hint of thermal resistivity at higher temperatures as supported by other studies on thermal behavior of composites as a result of temperature. The observations are useful, for instance, in aerospace engineering where conductive as well as convective heat transfer together with mechanical-conductivity are vital for material use to provide adequate dissipation of heat while preserving structural stability. The conductivity values seen in the high fiber volume parallel aligned samples raise expectation that the GFRP composites will be useful in parts such as fuselage insulation and casing of electronic equipment but parts subjected to higher thermal loads may need further improvement. Possible drawbacks of this research include issues related to the measurement assessment and relatively small number of cases, which might cause weakness in external validity. Possibly, enhanced and more extensive investigation in the area of testing conditions might provide more extensive information about the appropriateness of Enhancing GFRP composites for extensive aerospace applications.

VI. CONCLUSION

This research focused on analyzing the thermal conductive behavior of GFRP composite and provided the reflection that both the fiber orientation and volume fractions significantly influence the thermal behavior of the composite. This demonstrated that fibers parallel to heat flow direction with high fiber volume fraction greatly improved the thermal conductivity while temperatures exhibited only moderate influences in which the conductivity at higher temperatures was slightly higher. These results imply that GFRP composites, especially in terms of fiber orientation and volume, can provide important thermal performances necessary for aerospace applications, such as fuselage insulation and electronic housing parts that demand efficient thermal conductivity. But the requirements of components operating under temperature extremity conditions may require further materials grade changes. The present study should be extended to other fiber types, other polymer matrices or hybrid composites to achieve better thermal conductivity besides performing long term test results under simulated aerospace environment. To further enhance cracking and improve on thermal and mechanical properties, the research study could proceed to hybrid and advanced composite and further strengthen the commercial application of GFRP composites in aerospace and high-performance industries.

REFERENCES

[1] Rajak, D.K., Wagh, P.H. and Linul, E., 2021. Manufacturing technologies of carbon/glass fiber-reinforced polymer composites and their properties: A review. Polymers, 13(21), p.3721. [1]

[2] Barra, G., Guadagno, L., Raimondo, M., Santonicola, M.G., Toto, E. and Vecchio Ciprioti, S., 2023. A comprehensive review on the thermal stability assessment of polymers and composites for aeronautics and space applications. Polymers, 15(18), p.3786. [2]

[3] Hemath, M., Mavinkere Rangappa, S., Kushvaha, V., Dhakal, H.N. and Siengchin, S., 2020. A comprehensive review on mechanical, electromagnetic radiation shielding, and thermal conductivity of fibers/inorganic fillers reinforced hybrid polymer composites. Polymer Composites, 41(10), pp.3940-3965. [3]

[4] Vaggar, G.B., Kamate, S.C. and Badyankal, P.V., 2021. A study on thermal conductivity enhancement of silicon carbide filler glass fiber epoxy resin hybrid composites. Materials Today: Proceedings, 35, pp.330-334. [4]

[5] Kharbanda, S., Bhadury, T., Gupta, G., Fuloria, D., Pati, P.R., Mishra, V.K. and Sharma, A., 2021. Polymer composites for thermal applications–A review. Materials Today: Proceedings, 47, pp.2839-2845. [5]

[6] Vaggar, G.B., Sirimani, V.B., Sataraddi, D.P., Hiremath, N.M. and Bhajantri, F., 2021. Effect of filler materials on thermal properties of polymer composite materials: a review. Int J Eng Res Technol (IJERT), 10(08). [6]

[7] Bafakeeh, O.T., Shewakh, W.M., Abu-Oqail, A., Abd-Elaziem, W., Abdel Ghafaar, M. and Abu-Okail, M., 2021. Synthesis and characterization of hybrid fiber-reinforced polymer by adding ceramic nanoparticles for aeronautical structural applications. Polymers, 13(23), p.4116. [7]

[8] Chinnapandi, M., Sharma, A.P., Reddy, B.A.K. and Velmurugan, R., 2024, August. Mechanical and thermal properties of glass fiber reinforced polymer-clay nanocomposites. In Journal of Physics: Conference Series (Vol. 2817, No. 1, p. 012020). IOP Publishing. [8]

[9] Irawan, A.P., Anggarina, P.T., Utama, D.W., Najid, N., Abdullah, M.Z., Siregar, J.P., Cionita, T., Fitriyana, D.F., Jaafar, J., Hadi, A.E. and Rihayat, T., 2022. An experimental investigation into mechanical and thermal properties of hybrid woven rattan/glass-fiber-reinforced epoxy composites. Polymers, 14(24), p.5562. [9]

[10] Mishra, N., Khan, U.A., Srivastava, A. and Asthana, N., 2024. Effect of the glass fiber orientation on mechanical performance of epoxy based composites. Prabha Materials Science Letters, 3(2), pp.175-190. [10]

[11] Praveena, B.A., Buradi, A., Santhosh, N., Vasu, V.K., Hatgundi, J. and Huliya, D., 2022. Study on characterization of mechanical, thermal properties, machinability and biodegradability of natural fiber reinforced polymer composites and its Applications, recent developments and future potentials: A comprehensive review. Materials Today: Proceedings, 52, pp.1255-1259. [11]

[12] Bichang'a, D.O., Aramide, F.O., Oladele, I.O. and Alabi, O.O., 2022. A review on the parameters affecting the mechanical, physical, and thermal properties of natural/synthetic fibre hybrid reinforced polymer composites. Advances in Materials Science and Engineering, 2022(1), p.7024099. [12]

[13] Alshahrani, H., Ahmed, A., Kabrein, H. and Prakash, V.A., 2022. RETRACTED: Mechanical Properties Study on Sandwich Composites of Glass Fiber Reinforced Plastics (GFRP) Using Liquid Thermoplastic Resin, Elium®: Preliminary Experiments. Coatings, 12(10), p.1423. [13]

[14] Fegade, V., Ramachandran, M., Madhu, S., Vimala, C., Malar, R.K. and Rajeshwari, R., 2022, May. A review on basalt fibre reinforced polymeric composite materials. In AIP Conference Proceedings (Vol. 2393, No. 1). AIP Publishing. [14]

[15] Sürücü, A.M., Subaşı, S., Danish, A., Gencel, O., Subaşı, A. and Ozbakkaloglu, T., 2023. Mechanical and radiation shielding properties of SWCNT reinforced polymer/glass fiber fabric-based nanocomposite containing different filler materials: A comparative study. Journal of Applied Polymer Science, 140(7), p.e53483. [15]

[16] Patil, D.S. and Bhoomkar, M.M., 2023. Investigation on mechanical behaviour of fiber-reinforced advanced polymer composite materials. [16]

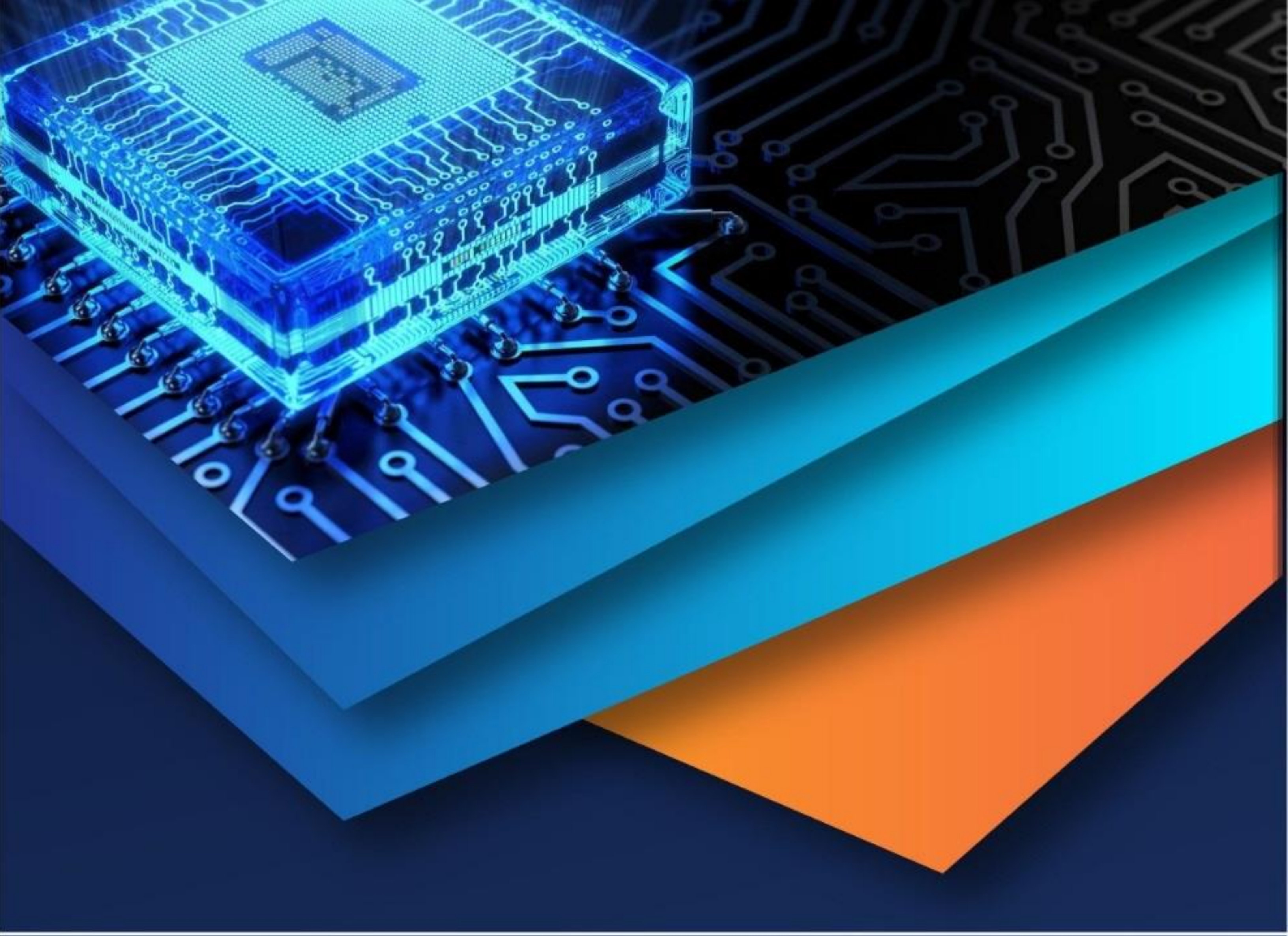
[17] Birleanu, C., Pustan, M., Cioaza, M., Bere, P., Contiu, G., Dudescu, M.C. and Filip, D., 2023. Tribo-mechanical investigation of glass fiber reinforced polymer composites under dry conditions. Polymers, 15(12), p.2733. [17]

[18] Felix Sahayaraj, A., Muthukrishnan, M. and Ramesh, M., 2022. Experimental investigation on physical, mechanical, and thermal properties of jute and hemp fibers reinforced hybrid polylactic acid composites. Polymer Composites, 43(5), pp.2854-2863. [18]

[19] Choudhary, S., Haloi, J., Sain, M.K., Saraswat, P. and Kumar, V., 2023. Systematic literature review on thermal and acoustic characteristics of natural fibre polymer composites for automobile applications. Materials Today: Proceedings. [19]

[20] Scaffaro, R., Di Bartolo, A. and Dintcheva, N.T., 2021. Matrix and filler recycling of carbon and glass fiber-reinforced polymer composites: A review. Polymers, 13(21), p.3817. [20]

[21] Asyraf, M.R.M., Nurazzi, N.M., Norrrahim, M.N.F., Hazrati, K.Z., Ghani, A., Sabaruddin, F.A., Lee, S.H., Shazleen, S.S. and Razman, M.R., 2023. Thermal properties of oil palm lignocellulosic fibre reinforced polymer composites: a comprehensive review on thermogravimetry analysis. Cellulose, 30(5), pp.2753-2790. [21]



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