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Short Communication

Study on thermal and mechanical characteristics of different composite materials for thermal insulating applications

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ABSTRACT

Composite materials play a vital role in present industrial applications due to their positive properties when compared with the existing or conventional materials used for the same applications such as weight, strength, and flexibility in design. In this work, a laminate was prepared by considering three different fibers including, basalt, carbon, and glass fiber. The order of orientation is three different forms 40°, 60°, and 90°. The stacking of the fibers is of the same degrees and it is subjected to two different sets of tests such as failure analysis and thermal analysis. The results revealed that, increasing basalt fiber content (up to 50% wt.) reduced the thermal conductivity of the composite while reducing the glass fiber content increased the thermal conductivity. In addition, the orientation of 90° showed the best tensile strength and elongation over 40° and 60°.

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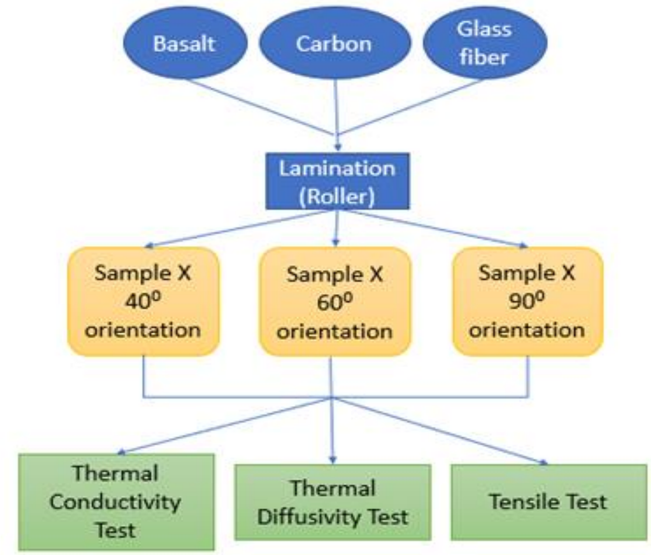
Graphical Abstract



Process of the work

Introduction

Composite materials play a key role in thermal insulation of the vital parts of automotive and aerospace applications. These composite materials have many advantages over the traditional materials due to their lightweight, flexibility of formation, and strength. Materials selected for composite laminate such as basalt, carbon, glass. Among these materials, basalt is free from toxic or any other carcinogenic effects and it has the property to withstand temperature around 1500 °C. Glass fiber-reinforced plastic (GFRP) composite and carbon fiber reinforced polyester (CFRP) composite has been investigated for its mechanical properties with a different proportionate composition such as GF 10%, 15% and 20% with CF 5%, 10%. It was found that, increasing the proportion of fiber in polyester resin improved the mechanical properties.

Sriram *et al.* [1] noted that a shaft made up of unidirectional epoxy glass (UD epoxy glass) composite is compared with the steel material for the same application that shows the better improvement in high specific stiffness and strength. Fiore et al. discussed about the fiber with different forms of composition and concentration in raw material produces the difference in chemical and thermal stability of the material. The basalt fiber is non-combustible with high chemical stability [2]. Also, as Tamburini et al. observed, the fiber reinforced geopolymer has a good adhesive property by using the fiber reinforcements such as carbon, basalt, alkali-resistant glass, and steel, furthermore, the durability and degree of strengthening are also considerably increased [3]. While Lapenaa and Marinuccib noted that the tensile strength of the fiber composite was increased when compared with the E-glass fiber composite when tested with a split disk method; the adhesion between the interfaces is also considered good for basalt fiber over the glass fiber [4]. Also, Sun and co-workers pointed out the flexural modulus of the material is increased by the stacking sequence; the stacking sequence also has the advantage of distributing the bending stress towards the thickness of the material [5]. Jang et al. reported that, the tensile and flexural strength of the material was increased with the increase in the concentration of the basalt fiber with the polycarbonate composites [6]. Hambach and Volkmer observed that the flexural strength of the composites increased with the use of basalt or carbon fibers, and also the material structure efficiency is also improved [7]. The lamination of basalt fiber reinforced polymer with the carbon nano-fibers when applied with the tensile load showed improvement in the self-sensing technology [8]. Composite materials need some more developments in testing methods for examining the integrity of the material [9].

Experimental

Materials and methods

Basalt, carbon, and glass fiber were selected based on the application process. All the materials used in this study were provided by El-kammash Company, Egypt. Basalt is the most promising material among these three substances which is naturally available from the volcanic rocks and suitable for operation at elevated temperatures, the basalt grain size was 3-5 mm. The second material was carbon with various superior properties such as high corrosion resistance, chemical resistance, and great electrical conductivity that makes it suitable for the high strength applications. The last one was the glass fiber, which is durable, good chemical resistant, and has very good dimensional stability. Hand layup is the process by which the resins are affixed with the fibers that may be in the form of bonds. This process requires a roller for forcing the resin over the fabric and the laminates are exposed to the ambient condition for curing. Figure 1**a–c** shows the 40°, 60°, and 90° of the orientation of composite laminates. Table 1 represents the four samples compositions that were tested in this study. The proportion of the three substance were selected based on the literature [2], [4], [8].

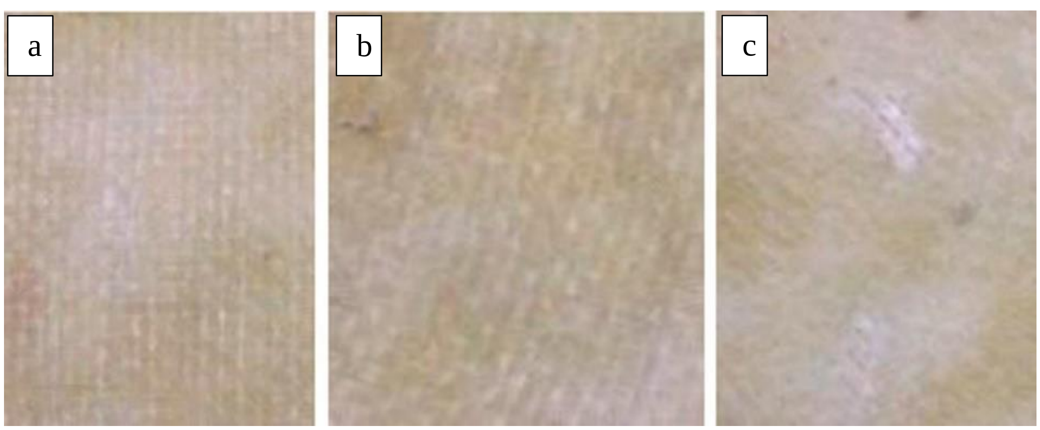


Figure 1. Laminated epoxy with a) 40° b) 60° c) 90° of stacking sequence

Table 1. Composition of the samples

sample	1 35/25/40	2 40/30/30	3 45/35/20	4 50/40/10
Basalt (wt.%)	35	40	45	50
Carbon (wt.%)	25	30	35	40
Glass fiber (wt.%)	40	30	20	10

Figure 2 reveals the experimental setup for measuring the ability of the substance to conduct the heat of the sample by taking the ratio between the rate of heat flow normally through an area to the difference between the area and component of temperature gradient in the direction of flow.

Figure 2. Experimental setup

Results and Discussion

Thermal conductivity of the material is the ability of a material to successfully conduct heat through it. As seen in Figure 3, it is clear that the material composition affects the ability of the material to conduct the heat. As shown in Figure 3, it is clear that among the different proportions of combination in the hybrid laminate, the thermal conductivity of the material was minimum when the proportion of the glass fiber was increased (35/25/40) with the minimum carbon composition in it.

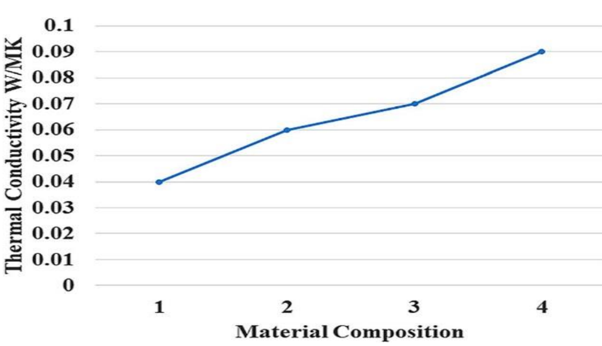


Figure 3. Thermal conductivity variation for composite laminate at 40 °C

Thermal conductivity for the composite hybrid laminate was tested for the thermal conductivity again by altering the temperature of the working medium. The results revealed that, the elevated temperatures could improve the thermal conductivity of the composite material and when compared among themselves the difference in the value for thermal conductivity is minimum for the composition of sample 3 (45/35/20), as shown in Figure 4.

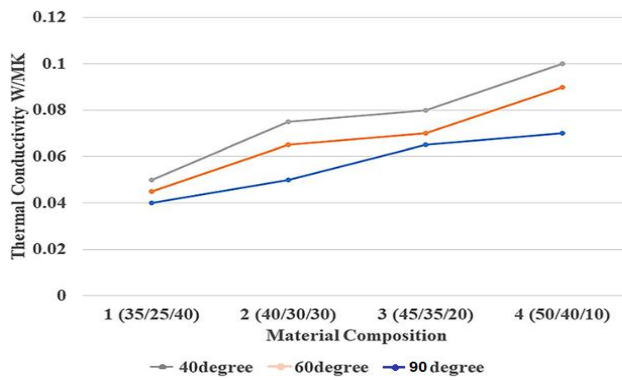


Figure 4. Variation in thermal conductivity for different material compositions at various temperatures

The ability of the material to transfer the heat from higher temperature to lower temperature was assessed for the sample no.4 (Figure 5). It was found that heat transfer of the laminate has reduced due to the increase in operating temperature which makes it suitable for the higher temperature applications. These results were found to be in good agreement with the literature [10]. The samples were prepared with tension under the controlled condition for identifying the tensile property. Three different degrees of orientation was applied to the hybrid laminate with load and the elongation was monitored. The point at which the specimen subjected to permanent damage is called the failure point. From Figure 6, it is noted that sample 1 (35/25/40) with 40° of orientation undergone failure at the load of 4.7 KN for the elongation of around 4.2 mm.

The composite laminate of the same proportion of combination sample 1 (35/25/40) with 60° of orientation was applied to the same tensile load testing machine for checking its load bearable capacity. As seen in Figure 7, due to an increase in the angle it showed an improvement in its tensile strength 7.8 KN, and the displacement was also increased to 6.8 mm.

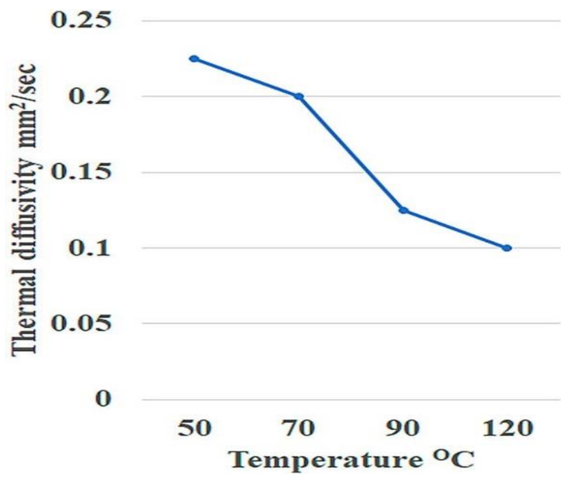


Figure 5. Variation in thermal diffusivity for the corresponding increase in temperature for sample no.4

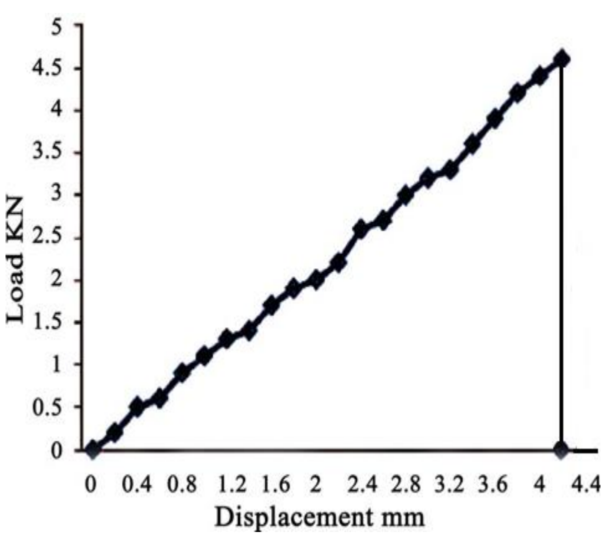


Figure 6. Load *vs*. displacement comparison for 40° laminates

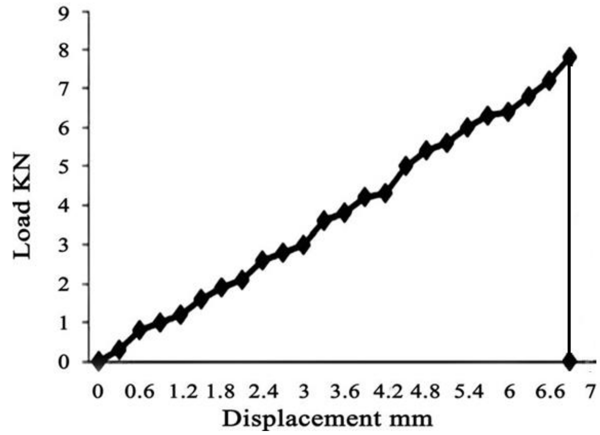


Figure 7. Load vs. displacement for 60° laminates

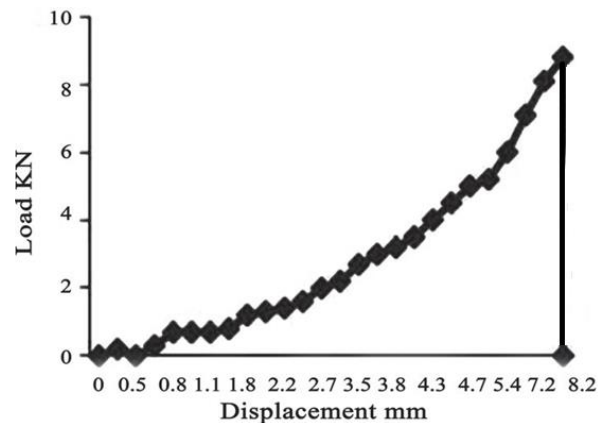


Figure 8. Load *vs*. displacement comparison for 90° epoxy laminate

Sample with a degree of orientation 90° in Figure 8 revealed a tensile 8.8 KN and the displacement is 8 mm.

Conclusions

From the graphs drawn for the different tests conducted on the composite laminate, we identified that the ability of the material to withstand load was increased with making difference in stacking of the laminate, and by making the proportionality alter, we can make it useful for a wide range of applications. While considering the thermal examination, the composite having the maximum proportion of basalt and minimum glass content revealed good heat-conducting property and maximum glass and minimum carbon proportion have opted for heat withstanding applications.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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