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Study The Thermal Conductivity of Polymethyl Methacrylate Reinforcing with Cotton, Hair, and Burlap

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Abstract

This study includes the manufacture of two sets of composite materials consisting of polymethyl methacrylate reinforced with natural fibers. The first (R) group included eight layers of cotton with one layer of hair in the middle, and the second (O) group included six layers of cotton with three layers of burlap in the middle. The thermal conductivity of the two groups was checked using a Lee disc to identify the thermal conductivity (K), of group R 0.0771 w/m.c, and of group O 0.0754 w/m.c. These values are considered good as the material has good thermal insulation due to its low thermal conductivity values and is therefore suitable for use in prosthetic limbs as it can preserve the body temperature from external influences.

Key words: Thermal Conductivity, Cotton, Hair, Burlap, PMMA.

1. Introduction

One of the essential thermal properties of composites is their capacity to transmit heat through a specific cross-sectional area of material samples over a specific time [1]. The term "thermal conductivity" refers to the rate at which heat moves through a single material per unit of time, per unit of area, and per unit of temperature gradient perpendicular to the area [2]. Because of their low thermal conductivities, polymers are frequently used as thermal insulators. These materials get energy from the rotating and vibrating of the chain molecules [3,4]. The movement of polymer molecular chains caused by heat energy in composite specimens is referred to as thermal conductivity, and it is directly correlated with the number of conductive components present [5]. Heat transmitted from a material's high-temperature portion to its low-temperature region is another definition of thermal conductivity. Enhancing the properties of poly (methyl methacrylate) by adding particles or fibers allows scientists to study the effect of reinforced materials on the mechanical and physical properties of the composite material.[6,7] In this study, natural fibers such as cotton, burlap, and hair were added because these materials provide multiple properties, including low cost, low density, relatively similar tensile qualities, no abrasiveness to tools, no skin irritation, less use of energy, a lower risk of health concerns, renewability, recyclability, and biodegradability [8]. In fact, a high fiber content is necessary for an installation to function well. The effect of fiber content on the properties of natural fiber-reinforced composites is so critical. It is frequently noted that increasing the fiber loading causes the tensile characteristics to rise [9]. The selection of appropriate processing methods and parameters is crucial for producing the best composite products, as they significantly influence the interfacial features and properties of composites.[10,11].

2. Experimental

2.1 Polymethyl methacrylate material

One of the most acrylic polymers the frequently used is polymethylmethacrylate (PMMA) resin, with its chemical formula ($C_5H_8O_2$) [12,13]. It is one of the strongest thermoplastic linear polymers. PMMA has outstanding stability in dimensions, a small elongation at break, low moisture absorption, excellent optical transparency, good mechanical and Young's modulus, and great outdoor weather resistance and water absorption [14, 15]. The fluid resin matrix used in this study was created by the German company Ottobock SE & Co. KGaA. Due to its height force, which makes it possible for a lamination to be thinner and lighter, and its thermoplastic characteristics, which, by warming the plastic and bending it, allow faster prosthesis acclimatization , PMMA resin is growing in popularity for prosthetic laminations [16,17]. Moreover, table 1 lists the properties of PMMA.

Table 1: The PMMA properties that were acquired from the business.

Tensile strength (MPa)	Young Modulus (GPa)	Density (g/cm^3)	Thermal Conductivity (W/m.k)	Percent Elongation (%)
48.3-72.4	2.24–3.24	1.19	0.17-0.25	2-5.5

2.2 Cotton Fiber material

The Malvaceae family of cotton plants produces balls, or protective shells, around their seeds, which contain the soft, fluffy staple fiber known as cotton. The fibers are virtually pure cellulose, nature's most prevalent polymer, with minor amounts of waxes, lipids, pectin, and water [18]. Cotton fibers are composed of 85–90 percent cellulose, 0.1% pectin, 5.7% hemicellulose, and 0.6% wax [19]. Chemical composition varies with variety, growth conditions (water, soil, pests, temperature, and so on), and maturation. Cotton fibers' substantial intra molecular, and intermolecular hydrogen bonding, fibrous and crystalline composition, and stiff cellulose chains all contribute to their strength [20]. The woven cotton used in this study and manufactured in the Kut Textile factory is shown in figure 1.

2.3 Hair fiber material

Protein strands that originate from follicles in the dermis are what make up hair. One of the things that distinguish mammals is their hair. The human body is covered in follicles that create fine, vellus hair with a thick tip, except for regions of shiny skin. The most frequently expressed worries about hair relate to its types, growth, and maintenance, but it's also an important biomaterial made primarily of proteins, especially alpha keratin. [21]. In this study, the prosthesis socket was made using woven goat hair as an intermediate reinforcement. [22]. The woven hair utilized in this study as shown in figure1.

2.4 Burlap Fiber material

Jute, burlap, or hessian. They are all the same product, manufactured from jute or sisal fibers. Burlap is a durable natural fiber that is used in a variety of sewing and crafting tasks. Clothing, for example, but it is rough and abrasive on the skin; bags, umbrella covers, sacks, curtains, and decorations; and it may be mixed with other plant fibers to form ropes, nets, and similar things. And many additional craft ideas that are "eco-friendly." [23-24]. The woven Burlap utilized in this study is shown in figure1.

Figure 1: Reinforcing materials utilized in this Study.

3. Lee's disc instrument.

Samples thermal conductance was recorded using a Lee's disc instrument at the University of Baghdad, Department of Materials Physics, College of Science, as shown in figure 2. This device, which composed of three brass discs measuring 40 mm in diameter and 12.250 mm in thickness, along with a heater, is clear in the image. In contrast to the heater, which is located between discs B and C, the total current flowing through the circuit was around 0.17 A. Where the value of (k) and by knowing the value of the disc (ds mm), the disc radius (r mm), the amount of current through the coil (I) of (0.17 A), and the potential difference over both ends of the coil (V) are equal to (6.17 V). The value of (e) can be calculated, which represents the quantity of heat energy passing through Via unit disc space per second (W/m^2. K). Thermal conductivity (K) (W/mm. K) measured utilize the equation that was derived from the equation1 [25].

$$K[(TB-T)/ds = e [TA+ 2/r (da+1/ 4ds) \quad TA+1/2 \, rds. \, Tg \ldots.. (1)$$

K: thermal conductivity coefficient.

e: It shows the quantity of heat energy passing out of a unit of disc space per second (W/m^2. K) is determine from the following equation:

$$IV= m^2 e (TA+TB) + 2 \Pi re [dA TA+ ds \quad 1/2(TA+ TB+ dB TB dC TC \ldots.. (2)$$

Where, TC, TB, TA refers to the temperature of the discs (C, B, A), respectively, and are measured in °C. Thickness of the heating coil and three discs: dH , dA, dB, dC, respectively (mm). dS: the thickness of the sample) (mm). r: the radius of the disc (mm). V: the potential difference at both ends of the coil (V).

Figure 2: Thermal Conductivity Test Instrument.

Moreover, samples were cut with a diameter of 30 mm and a thickness depending on the type of sample, as shown in figure 3.

Figure 3: All group samples for the thermal conductivity test.

4. Result and Discussion

A measurement of the thermal conductivity (k) was made at room temperature. Thermal conductivity values for various material groups were displayed in table 2, and figure 4. These polymers' suitability for use as insulators and their low thermal conductance are both due to the absence of extra electrons. It is therefore advantageous to use it in prosthetic sockets.

Table 2. Thermal Conductivity (k) W/M.C for the groups.

Groups	Thermal Conductivity (k) w/m.c̊
R	0.0771
O	0.0754

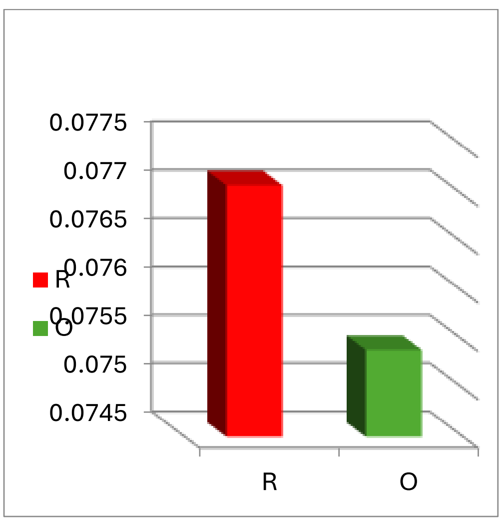

Figure 4: Thermal conductivity for all groups.

5. Conclusion

In conclusion the current study indicates a decrease in the thermal conductivity of Group R and Group O compared to polymethyl methacrylate. This means an improvement in the thermal conductivity properties when adding the natural fibers of cotton, burlap, and hair to the PMMA.

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