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The Effect of Thickness on the Thermal Conductivity Coefficient and Some Mechanical Properties of Acrylic Material Used in the Manufacture of Dentures

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Abstract

Different thickness samples of acrylic used in the manufacture of dentures were prepared, and the thermal conductivity was studied using the Lees disk experiment for all samples that were cast in the form of discs. We found that the thermal conductivity decreases with increasing thickness of the sample. The bending was also studied by calculating the values of the elastic modulus of the samples, and we found that the elastic modulus decreases with increasing thickness. Finally, the X-ray spectrum showed a group of peaks that correspond to pure acrylic material.

Keywords: Acrylic, Lee Disk, Thermal Conductivity and Elasticity Modulus.

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Introduction

Polymers are important materials in the field of industry due to their characteristics that make them superior to traditional solid materials such as (copper, iron, aluminum, etc.). One of the most important characteristics that distinguish them is the low cost of their preparation and their resistance to rust and corrosion (Ates, 2016; Chen et al., 2005; Singh & Singh, 2012). Modern technology seeks to study the properties of polymeric materials and improve their qualities and make them more suitable for industrial production purposes and various applications (Rajak et al., 2019; Rajak et al., 2019). Therefore, the topic of polymers has received the attention of researchers in scientific and industrial circles, and various research and studies have emerged from the physical and chemical properties and applied engineering of polymers (Kumar & Gupta, 2018; Rudin & Choi, 2012; Jancar et al., 2010). Polymers are materials made of long, repeating chains of molecules. These materials have unique properties, depending on the type and how they are bonded together (Brazel & Rosen, 2012; Gedde et al., 2019).

The term polymer is often used to describe plastic products, which are originally synthetic polymers, some of these polymers are bend and stretch, such as rubber and polyester, while Others are tough and strong, such as glass, acrylic and epoxy (Stokes, 2020; Crawford & Martin, 2020; Mastro, 2016). Acrylic is a transparent plastic material that is characterized by strength, hardness and clarity. It is easy to manufacture acrylic sheets and make many products with it. It is characterized by its good adhesion with adhesives, it is easy to shape and has strong properties compared to many other transparent plastic materials (Mosley, 2017; Babo et al., 2020; Metwally, 2023). Acrylic properties are similar to glass in terms of clarity, brilliance and transparency - but it is Lighter than glass, as it has half the weight. Plastic materials made of Acrylic provide superior versatility, durability and aesthetic properties (Kaltenbach, 2004; Tauchid, 2015; Ward, 2008). There are two types of acrylics, Extruded Acrylic and Cast Acrylic, Extruded acrylic is made through a process in which liquid plastic is forced through rollers, which compress it as it cools (Xanthos & Todd, 2000; Newton, 2013; Rosato, 2013).

It is a relatively inexpensive process, but the resulting sheets are lighter than cast acrylic and can be easily damaged, and they also contain impurities , while Cast acrylic has high quality cells, but it is more expensive than Extruded acrylic, where the cell is cast and individual sheets are made by pressing liquid plastic Between pieces of mold, which is often made of glass, and then gradually heating, these produce strong sheets, which are often used for aquariums, and other products that require Shaping the final product (Throne, 2024; Xanthos & Todd, 2000). One of the most important physical properties is the heat conductivity of acrylic, this property is measured (Ellakwa et al., 2008). Heat transfer coefficient describes the efficiency of a gas or liquid to transfer energy across its surface and thus dissipate energy from its surface (Ali et al., 2022; Siddique et al., 2010). This depends on the specific heat, density and thermal conductivity of the medium to which the heat is transferred as well as the body giving off the heat (Janna, 2018; Sultan et al., 2023). Heat transfer coefficients are calculated by determining the temperature difference between the two contacting bodies. heat transfer coefficient of acrylic can be calculated through the following equation (Przyłucka-Bednarska et al., 2022; Bai et al., 2012):

$$Q=\alpha.A.(T_1-T_2).\Delta t$$

Where Q: amount of heat transferred, α: Heat transfer coefficient, A: Contact area T_1 and T_2 mediums temperatures and Δt Time period.

In this study, the effect of thickness on the thermal conductivity decreases with increasing thickness of the samples and the elastic modulus decreases with increasing thickness.

Experimental Part

Lees discs experiment was constantly used to measure heat conductivity, two brass disks with same diameter were separated by samples as shown in fig. (1). Thermometer is installed on each of them, the steam flow from the top vent A and then release through point B. The upper thermometer should be checked at the same time as the lower one, once the lower one has stabilized at T_2, for example, after 75 minutes of steam circulation.

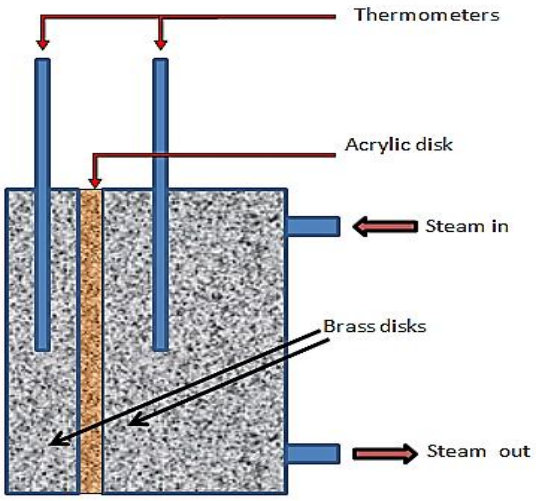


Fig. 1: Show Lees Disk

The equation for thermal conductivity is:

$$\emptyset = \lambda \frac{1}{4} \pi D^2 \left(\frac{\theta_1 - \theta_2}{d}\right)$$

Where λ is heat conductivity coefficient of the body; θ_1-θ_2 Temperature gradient in °C

When the steady state is obtained, the rate of heat flow through the poor conductor of heat is equal to the rate of heat radiated by the lower metal disc, and the latter rate can be obtained from the cooling curve as shown in fig. (2). The rate of heat loss from the lower disc is:

$$\emptyset = \lambda \frac{1}{4} \pi D^2 \left(\frac{\theta_1 - \theta_2}{d}\right) = mass\ of\ disc\ .Cc.\frac{PN}{QN}.\frac{1}{60}$$

Where Cc is specific heat capacity

Heat capacity of brass C = 0.094 cal/gm.C.

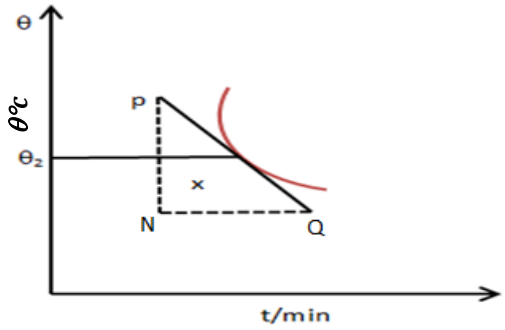


Fig. 2: Show Cooling Curve

Results and Discussion

The value of the thermal conductivity coefficient of the samples showed that the thickness is inversely proportional to the thermal conductivity value, i.e. the greater the thickness, the lower the thermal conductivity coefficient. We note from Fig. (3) that the highest thermal conductivity value was 4.1 W/m.°C for the models with the thinnest thickness, while the thermal conductivity was around 2 W/m.°C for the models with the thickest thickness. The readings came in sequence according to the thickness fig. (4), because increasing the thickness leads to impeding the transfer of heat table (1).

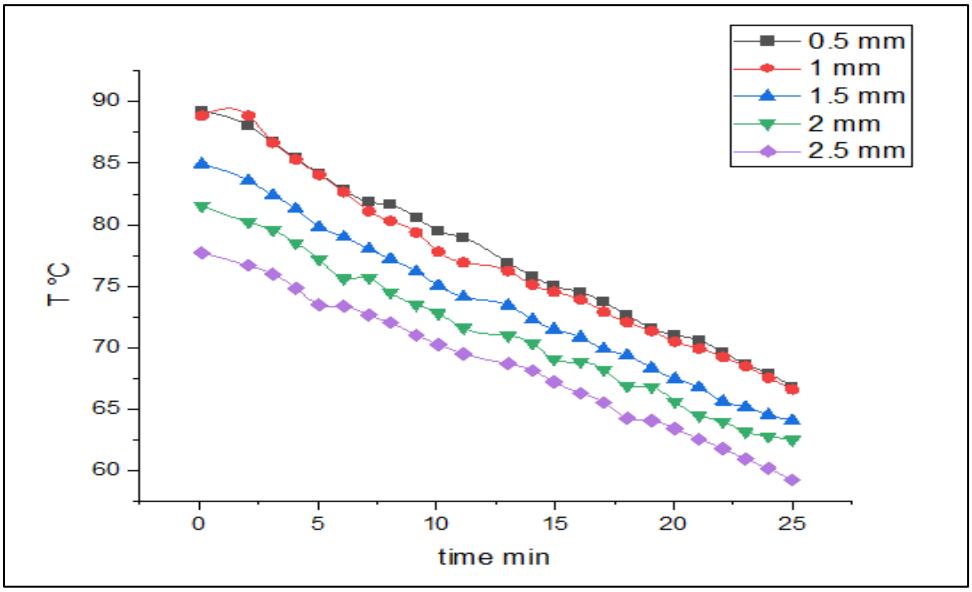


Fig. 3: Samples Temperture as a Function of Time

Table 1: Thermal Conductivity Versus Samples Thickness

Sample thickness (mm)	Thermal conductivity (W/m.°C)
0.5	4.1
1	3.1
1.5	2.7
2	2.6
2.5	2

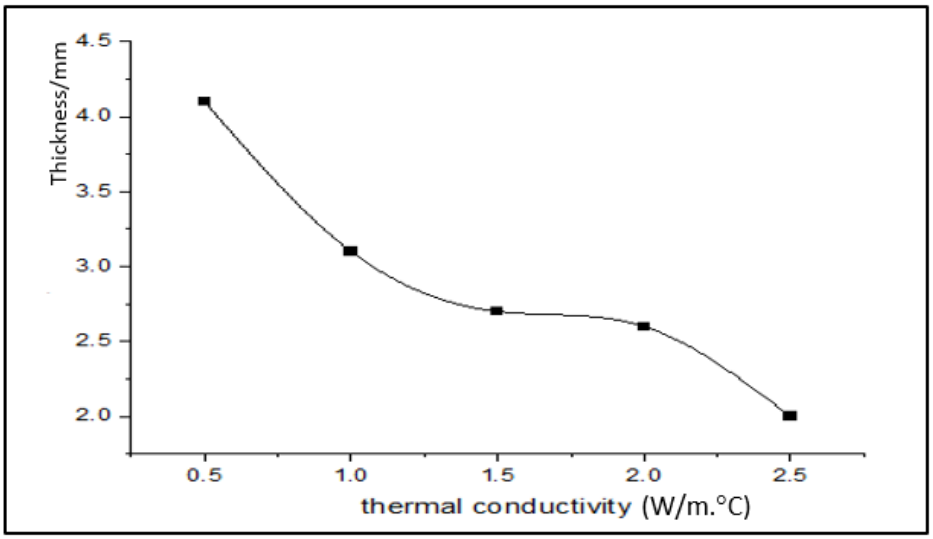


Fig. 4: Thermal Conductivity Versus Samples Thickness

The purpose of the bending test is to know the linear behavior of materials under the influence of loads applied perpendicular to the surface of the sample and to measure the elastic modulus (E) of the samples under normal conditions. Fig. (5) shows that the deflection is directly proportional to the load applied to it within the elastic limit, when the applied load is removed, the material returns to its original state. The slope of the ratio between mass and deflection is constant. We note from Fig. (5) that the value of this constant decrease as the sample thickness increase are shown in Table (2).

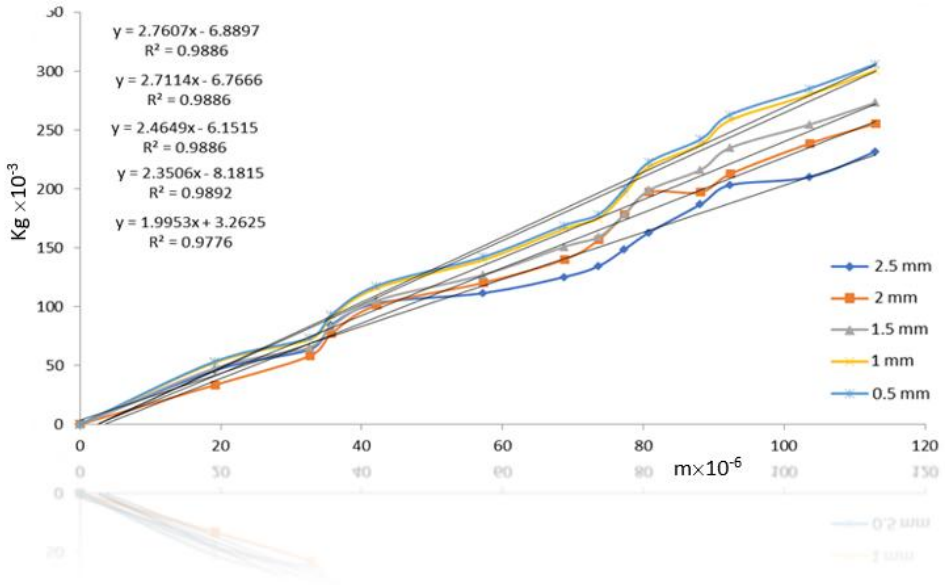


Fig. 5: The Relationship Between Mass and Deflection for all Samples at Room Temperature

Table 2: Modulus of Elasticity for all Samples at Room Temperature

Samples thickness mm	Young's modulus (GPa)
0.5	2.76
1	2.71
1.5	2.46
2	2.35
2.5	1.99

The x ray spectrum of the samples shows several peaks in the spectrums, these peaks were belonged to the acrylic material. The spectrum show also that films include crystalline and amorphous phases, fig. (6).

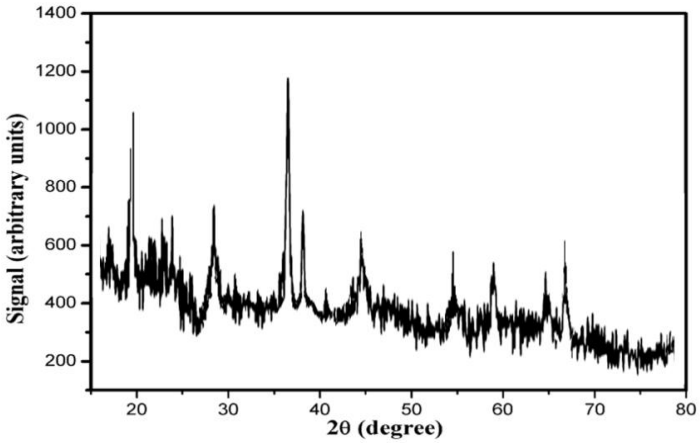


Fig. 6: X-Ray Spectrum of Acrylic Material

Conclusions

Different thickness samples were prepared from acrylic material used in the manufacture of dentures. The thermal conductivity of all samples was studied and we found that the thermal conductivity decreases with increasing thickness of the sample. The bending was also studied by calculating the values of the elastic modulus of the samples and we found that the elastic modulus decreases with increasing thickness. Finally, the X-ray spectrum showed a range of peaks that correspond to pure acrylic material.

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