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RESEARCH THERMAL CONDUCTIVITY OF POLYMER MATERIALS

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ABSTRACT

This article presents the thermal conductivity of various polymer materials. Thermoplastic polymers, especially high density polyethylene, polypropylene, and polymethyl methacrylate are described for their thermal conductivity under pressure. The change in thermal conductivity curves according to the type and amount of fillers added to thermoplastic polymers is explained by diagrams.

KEYWORDS: Polymer, thermal conductivity, thermoplastic, filler, temperature, pressure.

INTRODUCTION

In the current time of rapid development, polymer materials are being replaced to replace increasingly depleted metallic materials. Polymer materials are able to equate to metals in all respects. The thermal conductivity of polymer materials plays important role in this regard. Fillers added to polymers have a positive effect on their properties. At the same time it also improves the thermal conductivity.

METHODS AND OBJECTS OF RESEARCH

When analyzing thermal processes, thermal conductivity, k, is the most commonly used property that helps quantify the transport of heat through a material. By definition, energy is transported proportionally to the speed of sound. Accordingly, thermal conductivity follows the relation

$k \approx C_p pul$

where u is the speed of sound and l the molecular separation. Amorphous polymers show an increase in thermal conductivity with increasing temperature, up to their glass transition temperature, T_g. Above T_g, the thermal conductivity decreases with increasing temperature. Figure 1. presents the thermal conductivity, below the glass transition temperature, for various amorphous thermoplastics as a function of temperature.

Due to the increase in density upon solidification of semi-crystalline thermoplastics, the thermal conductivity is higher in the solid state than in the melt. In the melt state, however, the thermal conductivity of semi-crystalline polymers reduces to that of amorphous polymers, as can be seen in Fig. 2. Furthermore, it is not surprising that the thermal conductivity of melts increases with hydrostatic pressure. This effect is clearly shown in Fig. 3. As long as thermosets are unfilled, their thermal conductivity is very similar to that of amorphous thermoplastics. Anisotropy in thermoplastic polymers also significantly influences their thermal conductivity. Highly drawn semi-crystalline polymer specimens may have a much higher thermal conductivity as a result of the orientation of the polymer chains in the direction of the draw. For amorphous polymers, the thermal conductivity in the direction of the draw can increase by a factor of two. Figure 4. presents the thermal conductivity in the directions parallel and perpendicular to the draw direction for high density polyethylene, polypropylene, and polymethyl methacrylate.[1]

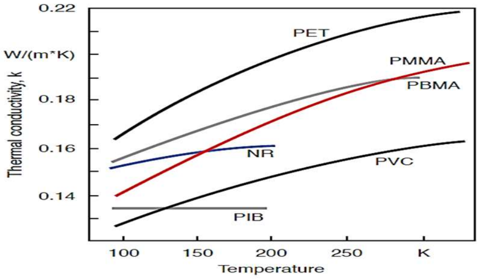

Figure 1. Thermal conductivity of various materials.

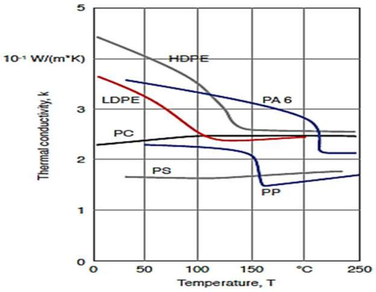

Figure 2. Thermal conductivity of various thermoplastics

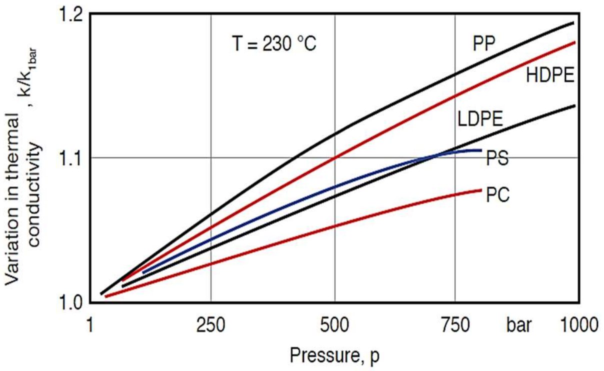

Figure 3. Influence of pressure on thermal conductivity of various thermoplastics

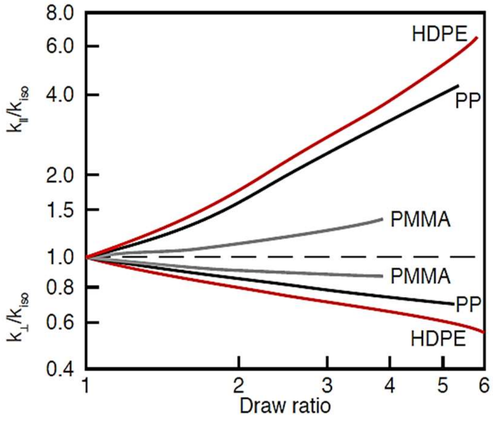

Figure 4. Thermal conductivity as a function of draw ratio in the directions perpendicular and parallel to the draw direction for various oriented thermoplastics

A simple relation exists between anisotropic and the isotropic thermal conductivity; it can written as

$$\frac{1}{k_1}+\frac{2}{k_1}=\frac{3}{k} \qquad (1)$$

where the subscripts ∥ and ⊥ represent the directions parallel and perpendicular to the draw direction, respectively.

The higher thermal conductivity of inorganic fillers increases the thermal conductivity of filled polymers. Nevertheless, a sharp decrease in thermal conductivity around the melting temperature of crystalline polymers can still be seen with filled materials. The effect of fillers on thermal conductivity of various thermoplastics is shown in Figs.5. to 8. Figure 5. shows the effect of fiber orientation as well as the effect of quartz powder on the thermal conductivity of low density polyethylene. Figures 6. to 8 show the effect of various volume fractions of glass fiber in polyamide 6, polycarbonate, and ABS, respectively. Figure 9. demonstrates the influence of gas content on thermal conductivity of expanded or foamed polymers, and the influence of mineral content on thermal conductivity of filled polymers. [2]

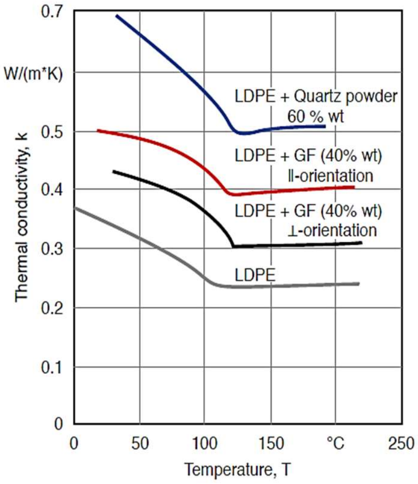

Figure 5. Influence of filler on the thermal conductivity of LDPE.

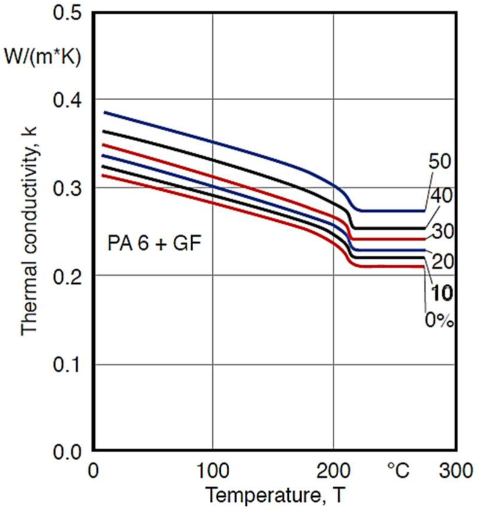

Figure 6. Influence of glass fiber on the thermal conductivity of polyamide 6.

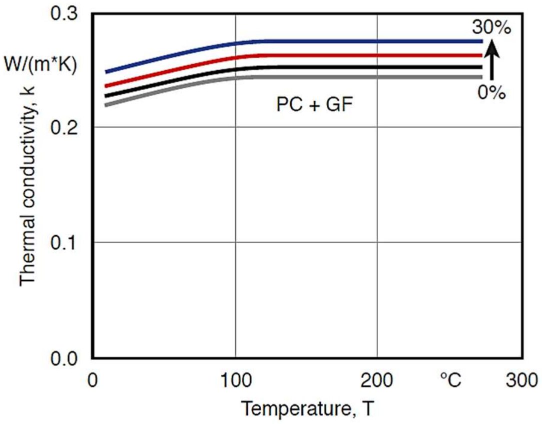

Figure 7. Influence of glass fiber on the thermal conductivity of polycarbonate.

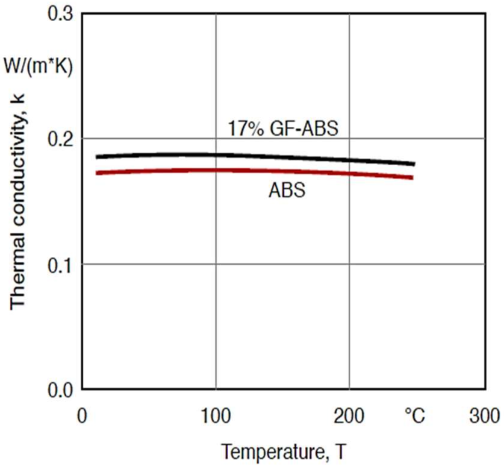

Figure 8. Influence of glass fiber on the thermal conductivity of ABS.

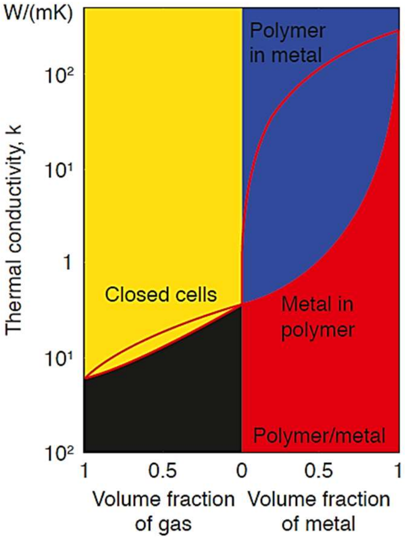

Figure 9. Thermal conductivity of plastics filled with glass or metal.

There are various models available to compute the thermal conductivity of foamed or filled plastics. A rule of mixtures, suggested by Knappe, commonly used to compute thermal conductivity of composite materials is written as

$$k_c = \frac{2k_m + k_f - 2\phi_f\left(k_m - k_f\right)}{2k_m + k_f + \phi_f\left(k_m - k_f\right)} k_m \qquad (2)$$

where, ϕ_f is the volume fraction of filler, and k_m, k_f and k_c are the thermal conductivity of the matrix, filler and composite, respectively. Figure 10. compares Eq. 2. with experimental data for an epoxy filled with copper particles of various diameters. The figure also compares the data to the classic model given by Maxwell, which is written as

$$k_c = \left(1 + 3\phi_f\left(\frac{k_f / k_m - 1}{k_f / k_m + 2}\right)\right) k_m \qquad (3)$$

In addition, a model derived by Meredith and Tobias applies to a cubic array of spheres inside a matrix. Consequently, it cannot be used for volumetric concentration above 52% because the spheres will touch at that point. However, their model predicts the thermal conductivity very well up to 40% by volume of particle concentration.

When mixing several materials the following variation of Knappe's model applies

$$k_c = \frac{1 - \sum_{i=1}^{n} 2\phi_i \frac{k_m - k_i}{2k_m + k_i}}{1 - \sum_{i=1}^{n} \phi_i \frac{k_m - k_i}{2k_m - k_i}} k_m \qquad (4)$$

where k_i is the thermal conductivity of the filler and ϕ_i its volume fraction. This relation is useful for glass fiber reinforced composites (FRC) with glass concentrations up to 50% by volume. This is also valid for FRC with unidirectional reinforcement. However, one must differentiate between the direction longitudinal to the fibers and that transverse to them. For high fiber content one can approximate the thermal conductivity of the composite by the thermal conductivity of the fiber. [3]

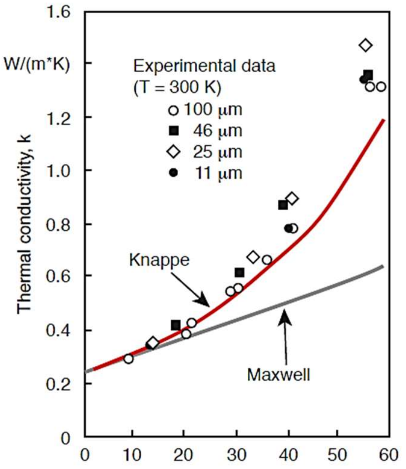

Figure 10. Thermal conductivity versus volume concentration of metallic particles of an epoxy resin. Solid lines represent predictions using Maxwell and Knappe models.

Thermal conductivity can be measured using the standard tests ASTM C177 and DIN 52612. A new method is currently being balloted, ASTM D20.30, which is preferred by most people today.

CONCLUSION

In conclusion, it should be noted that in order to improve the properties of polymer materials, in particular to increase the thermal conductivity, they were added the required amount and type of fillers. The results obtained show that the thermal conductivity of polymers used in machinery has been improved.

REFERENCES:

1) Tim A.Osswald and Georg Menes “Material Science of Polymers for Engineers” 3rd Edition. Carl Hanser Verlag, Munich 2012.
2) Soumya Mondal, Dipak Khastgir “Carbon-Containing Polymer composites”. Springer Singapore 2019.
3) 3. U. A. Ziyamukhamedova. “Promising composite materials based on local mineral and energy resources” Tashkent: Tashkent State Technical University. 2011