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Transient Thermal Radiation Analysis of a polymer Fiber

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Abstract:

When a solid or stationary fluid is translucent, energy can be transferred internally by radiation in addition to heat conduction. Since radiant propagation is very rapid, it can provide energy within the material more quickly than diffusion by heat conduction. This is important for evaluating the thermal performance of translucent materials that are at high elevated temperatures, are in high temperature surroundings, or are subjected to large incident radiation. Convective heating or cooling can also be applied at the boundaries. Radiant effects are accentuated as temperatures rise; it can be the temperature of material, the temperature of the surroundings, or both. Examples are heating a window by radiation emitted at high temperature from the sun, cooling a white hot ceramic by radiation loss to lower temperature surroundings, heating an insulating shield during atmospheric reentry, and heating translucent plastic with infrared lamps to soften it for manufacturing processes.

Interests in polymer fibers derived from synthetic organic polymers, has grown substantially over the past 25 years. Underlying this growth is the remarkable range of mechanical properties exhibited by polymer fibers. They are widely used in the chemical, metallurgical and food and construction material industries as well as in the other branches of industry for the filtration of gaseous, aggressive liquid and high –temperature substances. Their application in the electrical and electronic industries is especially important, because it has enabled a real increase in the reliability of electrical machines and the development of materials for IC's and microelectronics.

In this paper, transient radiative and conductive heat transfer in a translucent medium (polymer) with isotropic optical properties is investigated. The radiative two-flux equation is coupled with the transient energy equation and both equations are solved simultaneously. Transient solutions are obtained for a plane layer with refractive index

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equal or larger than one, and with external convection and radiation at each boundary. First, it is placed in a hot radiative environment while being cooled by convection at both boundaries. The transient temperature distributions can have rapidly varying shapes when the optical thickness is large, so the absorption of incident energy is concentrated near the boundaries. An important effect of refractive index is that internal reflections promote the distribution of radiative energy within the layer; this makes the transient temperature distribution more uniform. When the boundary conditions are changed and the layer is heated by radiation on one side and is cooled by convection and radiation on the other, the result shows that, if the optical thickness is less than about 10, internal reflections provided by refractive index of two have a substantial effect in equalizing the temperature distributions.

Illustrative results obtained with the two –flux method show the effects of changing parameters such as optical thicknesses, refractive index, conduction-radiation parameter and scattering on the transient temperature distribution within the layer. Results are given at different instances during the transient and the distribution for the largest time is at or very close to steady state.