An Analytical Study of Heat Transfer on Different Materials: Thermal Engineering Perspective

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Abstract

The goal of this investigation is to utilize principles to analyze an improved lumped-parameter model for studying transient heat diffusion in a slab with temperature-sensitive thermal conductivity. Transient temperature changes are contingent on a variety of model parameters, specifically the Biot number, heat source coefficient, and time. Utilizing the Polynomial Approximation Method (PAM), a comprehensive connection has been established to portray the transient thermal dynamics of solid materials (slab and tube) with both internal heat generation and boundary heat flow. In all scenarios, a closed-form solution has been formulated that links temperature, Biot number, heat source parameter, and time. An enhanced lumped-parameter approach has been implemented, incorporating two-point Hermite approximations for integrals. When dealing with linear temperature-dependent thermal conductivity, a comparison with the numerical solution of the original distributed parameter model highlights the superior accuracy of the higher-order lumped model (H1,1/H0,0 Approximations) in predicting average temperatures compared to the conventional lumped model. A unified Biot number threshold, contingent on a single dimensionless parameter, is provided for both cooling and heating processes. The results of this analysis are contrasted with prior numerical and analytical findings, demonstrating a robust consistency between the current predictions and earlier results.

Keywords: Hermite approximations, PAM, Temperature-dependent thermal conductivity, Lumped model, Nonlinear heat Conduction, Transient heat conduction, Biot number.