

Chapter 5

Transient Heat Conduction: Analytical Methods

1 Introduction

Many heat conduction problems encountered in engineering applications involve time as an independent variable. The goal of analysis is to determine the variation of the temperature as a function of time and position $T(\mathbf{x}, t)$ within the heat conducting body. In general, we deal with conducting bodies in a three dimensional Euclidean space in a suitable set of coordinates ($\mathbf{x} \in \mathbf{R}^3$) and the goal is to predict the evolution of the temperature field for future times ($t > 0$).

Here we investigate specifically solutions to selected special cases of the following form of the heat equation

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + g(\mathbf{r})$$

Solutions to the above equation must be obtained that also satisfy suitable initial and boundary conditions.

2 Fundamental Solutions

Transient problems resulting from the effect of instantaneous point, line and planar sources of heat lead to useful fundamental solutions of the heat equation. By considering media of infinite or semi-infinite extent one can conveniently ignore the effect of boundary conditions on the resulting solutions.

Let a fixed amount of energy H_0 (J) be instantaneously released (thermal explosion) at time $t = 0$ at the origin of a three dimensional system of coordinates inside a solid body of infinite extent initially at $T(\mathbf{x}, 0) = T(r, 0) = 0$ everywhere, where $\mathbf{x} = r = \sqrt{x^2 + y^2 + z^2}$. No other thermal energy input exists subsequent to the initial instantaneous release. Assuming constant thermal properties k , ρ and C_p , the heat equation is

$$\frac{\partial T}{\partial t} = \alpha \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial T}{\partial r} \right)$$

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