Chapter 2

Steady State Conduction Heat Transfer

Abstract

Steady heat conduction is introduced, first with coarse thermal resistance network, then by a detailed derivation of an energy balance in terms of the temperature field. Quantitative treatment of heat flow is facilitated by the electric circuit analogy; thermal resistance is defined as the ratio of potential (temperature difference) to current (heat flux). Resistances are derived for one-dimensional heat flow from rate equations for conduction, convection, and radiation, and the nature of thermal resistance at the interface between materials is discussed. Steady heat flow is approximated by resistance networks following thermal versions of Ohm's and Kirchhoff's laws. Heat flow through complicated geometries can be approximated by shape factors, reducing multidimensional paths to one-dimensional in the network. A transient, three-dimensional partial differential equation for temperature is derived, with heat conduction, thermal storage, and volumetric heat generation, based on the First Law of Thermodynamics and Fourier's Law of Conduction.. Idealized boundary conditions for temperature and their connection to real systems are discussed. Exact solutions and scaling analyses in steady state are presented to approximate the thermal behavior of real systems. The scaling introduced the Biot number, a useful ratio of conduction and convection resistances in a body, which quickly shows the coarse thermal behavior in a body.