Chapter 3

Transient Conduction Heat Transfer

Abstract

Thermal energy in a body increases or decreases due to an imbalance of conduction across the system boundary and heat generation within it, causing transient temperature. The Biot number (the ratio of conduction and conduction resistances) is applied to transient conduction problems and is the basis for simplifications of the thermal energy conservation equation. For cases with Bi $<< 1$, there is a uniform internal temperature while the body is heated or cooled; all of the thermal resistance is at the boundary with its environment. This situation is the "lumped capacitance" problem. For the other extreme, Bi $>> 1$, the internal resistance dominates, and the convection resistance is so small that the boundary takes on the environmental temperature instantly. All of the temperature gradient is internal to the body. In the middle case, Bi $\sim O(1)$, the internal conduction resistance and the external convection resistance are the same order of magnitude, so there are temperature differences in each region and the surface temperature changes slowly. In the two latter cases, there is a finite time before the effect of changed boundary condition spreads throughout the entire body. Solutions have been developed in one-dimensional slabs and cylinders, using scaling, exact solutions, and integral analysis. Many examples of practical applications based on these solutions are studied. Transient conduction is also shown to control the one-dimensional solidification behavior for pure substances, with derivations of models to predict solidification times and transient temperature fields.