Chapter 10

Convection Heat Transfer

Abstract

Convection heat transfer is defined by the interplay of heat attached to a moving fluid (advection) and diffusion (conduction), specifically near the surface of a solid bathed in that fluid. To characterize the fluid-solid interaction, a heat transfer coefficient is defined proportional to the surface temperature gradient in the fluid; the Nusselt number is the nondimensional temperature gradient. External forced convection occurs at a surface with unbounded flow, which is driven by an imposed force. The scaling analysis near a flat plate defines a thermal boundary layer (the region where temperature ranges from the surface to the freestream values), which is useful to describe fluid-solid interactions in more complicated geometries. Internal forced convection is where a fluid at some inlet temperature interacts with the walls of a conduits at a different temperature. In both types of forced convection, modeling is done and experimental correlations are shown in terms of the dimensionless parameters, Nu = f(Re,Pr). Natural convection is not driven by forces independent of the temperature field, but is induced by the effect of spatial variations in temperature (or composition) on the local density. Scaling analysis on boundary layers on a vertical flat plate in a gravity field produces a new vigor parameter similar to the Reynolds number in forced flow. The Rayleigh number, Ra, includes the effect of buoyancy due to temperature differences. The heat transfer correlations in the form of Nu = f(Ra, Pr) are given from the scaling analysis and experimentation. Boiling heat transfer is presented, with descriptions of the nucleate, transition, and film boiling regimes, and their relationship to the temperature-heat flux plot of the boiling curve. Quenching is also discussed in terms of the temperature path on the boiling curve.