

## CHAPTER 1

### INTRODUCTION

#### 1.1 Literature Survey

One dimensional transient conduction solutions inside plates, infinite circular cylinders and spheres are presented in all heat transfer texts. The governing equations for the three classical geometries are given in cartesian, circular cylinder and spherical coordinates. The initial and boundary conditions are specified. The dimensionless temperature distribution which is a function of three dimensionless parameters: position ( $\bar{x}$  or  $\bar{r}$ ), time ( $\tau$ ) and Biot number is presented in symbolic form for the three geometries. All texts present the respective solutions in graphical form, frequently called the Heisler [1] cooling charts (for the temperature at the centreline (plate) or the origin (cylinder and sphere) as a function of  $\tau$  and Bi. Auxiliary charts are available for all off-centre or off-origin points.

Grober et al [2] introduced the charts for the total heat loss fraction for the three geometries. These charts are presented in great detail in Liukov [3] and Grigull [4] all heat transfer texts.

Heisler [1], Liukov [3] and Grigull [4] discuss the fact that the temperature and heat loss fraction charts can be computed with acceptable accuracy using the leading term in the respective series solutions. The leading term can be used for all values of Bi provided  $\tau \geq \tau_0$ .

According to Heisler [1], the critical Fourier number ( $\tau$ ) is approximately equal to  $\tau_0 = 0.24; 0.21; 0.18$  for the infinite plate, infinite circular cylinder and sphere respectively. For  $\tau < \tau_0$  more terms in the series solutions are required to give acceptable accuracy.

Heisler [1] also noted that more than 80% of the total cooling time is accounted for with the single term solution.

Chen and Kuo [5] applied the heat balance integral method to obtain approximate solutions for the infinite plate and the infinite circular cylinder. These equations which are reported in Chapman can be evaluated by means of programmable calculators and they are said to be accurate provided  $\tau > \tau_0$ . Since these equations are lengthy and involved.

Some of the recently published heat transfer texts: Chapman [6], Bejan [7], Holman [8], Incropera and DeWitt [9] and White [10] recognize that the series solutions converge to the leading term for long times,  $\tau > 0.2$  with errors of about 1%. They present tables for the roots of the corresponding characteristic equations and the Fourier coefficients.  $A_1$  and  $B_1$  that appear in the dimensionless temperature and heat loss fraction expressions. For values of Bi not given in the tables, it is necessary to employ interpolation methods to use the tabulated values.

Once the roots are known, the evaluation of the Bessel functions  $J_0$  and  $J_1$  that appear in the characteristic equation for the circular cylinder and the Fourier Bessel coefficients that appear in the temperature and heat loss expressions must be considered. These calculations are tedious and prone to errors and unnecessary with the availability of programmable calculators and computers.

And also D.R. Buttsworth and T.V. Jones [11] presented some studies in May 1997. Results from the radial heat conduction analysis are compared with exact solutions in order to verify the accuracy of the approximate analytical relationships. A cylinder and a sphere were the geometries considered. Approximations to each of these geometries can arise in transient heat transfer testing. They present analytical solutions for the transient surface temperature of the above geometries under conditions. Temperature distribution has been determined using these exact results for a range of Biot numbers (0.1, 1 and 10) which might be encountered in heat transfer testing. Approximate values of the convective heat transfer coefficient are constant. They have shown these results in their study.

## **1.2 The Aim of the Study**

The temperature of a body, in general, varies with time as well as position. In rectangular coordinates, for one dimensional problems, this variation has been expressed as  $T(x, t)$ , where  $(x)$  indicates variation in the  $x$  direction, and  $t$  indicates variation with time. In this study, heat conduction unsteady conditions have been considered for which the temperature of a body at any point changes with time.

The variation of temperature has been considered with time as well as position for one dimensional heat conduction problems such as those associated with a large plane wall, a long cylinder and a solid sphere using analytical solutions. Transient heat conduction in one dimensional system has been solved by utilizing the product solution.

Then correction factor between exact solution and one term approximation has been investigated. And errors have been investigated in both of the approximation solutions.