SYNOPSIS

During the past thirty years research on heat transfer by impinging jets led to a multitude of experimental data obtained by different methods. Experiments have been carried out with various nozzle geometries, namely, single round nozzles, arrays of round nozzles, single slot nozzles, and arrays of slot nozzles. The main aim have been to establish the nature of dependence of heat transfer on main variables, namely, the air flow rate, the diameter of the nozzle, the spacing of arrays and height of the nozzles above the impingement surface.

Heat transfer by impinging jets have wide application in various fields. Not only do they provide high heat transfer coefficients but they can be applied to spot cooling or heating. The industrial applications are cooling of glass and metal objects of various shapes, wall of glass tank furnaces, high energy density electronic components, gas turbine blades, ingots in continuous castings and steel strips etc. This work is an attempt to evolve some working engineering formulae for the use of plant designers for removal of heat by impinging jets. Heat transfer by impinging jets involves the computation of the following : (i) the air flow rate (ii) the diameter of the nozzle (iii) the nozzle-to-plate distance.

In this work a systematic attempt has been made of study the velocity distribution in the jet, the static pressure distribution and heat transfer by impingement upon a surface under (i) a single round nozzle (simple jet) and (ii) a swirl nozzle (swirl jet). The parameters considered here are (i) Reynolds number (ii) Nozzle-to-plate distance and (iii) Flow ratio (tangential-total flow for a swirl nozzle) which represents the intensity of swirl in case of a swirl jet.

A laminar flow model for impingement heat transfer of a single slot jet has been developed for prediction of skin friction and heat transfer in the impingement region. Theoretical results have been compared with the experimental results of other workers.

This thesis contains six chapters :-

In the chapter 1, the industrial applications of impinging jets have been outlined. The applications are cooling of glass and metal objects of various shapes, glass tank furnaces, high energy density electronic components and gas turbine blades. It is established that in order to achieve a suitable plant design both from economic and technical view points the computation of the parameters like the air flow rate, the diameter of the nozzle, the nozzle-to-plate distance are required to solve a given jet impinging heat transfer problem. The scope of the present work is also mentioned. A systematic attempt has been made to study the velocity distribution, the static pressure distribution and the heat transfer on the impingement surface both for simple jet and swirl jet.

In the chapter 2 a survey of literature relevant to the present problem has been grouped under the following two heads :

2.1 Simple jet

2.2 Swirl jet

The review of the literature has led to the conclusion that although quite a few works have been carried out in simple jet, there is hardly any work on swirl jet. Martin [1], Gauntner et al [2] and Hrycak et al [3] has published extensive literature surveys emphasizing the engineering applications. The pioneering work in this field has been done by Perry [4] and Thurlow [5], followed by Smirnov et al [7], Gordon and Cobonpue [8], Nevins and Ball [9] , Huang [10], Coleman du P. Donaldson et al [11] and Gordon and Akfirat [12].

Chapter 3 contains the theoretical formulation of the problem. The fluid flow and heat transfer for a two dimensional jet with flat velocity profiles at the nozzle exit has been analysed for different nozzle-to-plate spacings. The available potential flow solution has been used to solve the boundary layer and energy equations by using the Blasius - Frossling series solution method.

A dimensional analysis has also been made and the average Nusselt number has been obtained in the following form :

$$\overline{Nu} = \text{Const.}\ (Re)^{m}\ (Pr)^{n}\ (Z)^{r}\ (Dp)^{s}$$

Since Dp is constant and n is taken to be equal to 0.33,

$$\frac{\overline{Nu}}{Pr^{.33}} = \text{Const.}\ (Re)^{m}\ (Z)^{r}$$

Chapter 4 contains the experimental set-up and experimental procedure. A heat transfer plate with arrangement of electrical heating through a number of heaters is used, as the target plate for the impinging jet. Proper insulation has been provided and there is provision for measurement of temperatures at different points on the heat transfer plate with the help of a number of thermocouples. The supply to the individual heaters can be controlled with the help of autotransformers, so that at the steady state condition uniform temperature within the constraints of experimental facilities can be achieved. A compressed air system is used for producing the impinging jet and the rate of flow is controlled with the help of a by-pass valve. The rotameters are provided for measuring the flow-rate. The velocity distribution in the free jet is measured with the help of a pitot tube. The static pressure distribution on the impingement surface is measured with the help of static pressure tappings. The heat transfer is computed from the power supply to the heaters after the loss correction is made.

Chapter 5 contains the results and discussions. The results for both simple jet and swirl jet have been presented under three heads, namely, velocity distribution, static pressure distribution and heat transfer. The dimensionless plot of axial velocity distribution and static pressure distribution have been obtained. Correlation of average Nusselt number has been obtained as a function of Reynolds number and nozzle-to-plate distance. For the swirl jets the above results have been obtained for different flow-ratios.

In chapter 6 an overall conclusion for the present work has been drawn. The important facts regarding the correlation of the main parameters have been discussed in short. Finally the scope of further work in the present field have been outlined.