CONVECTIVE HEAT TRANSFER

Objective

To perform free/forced convection experiments with different fin configurations and to learn the basic techniques in designing the experimental procedures/matrix

Background

Heat transfer by simultaneous conduction and convection, whether forced or free, forms the basis of most industrial heat exchangers and related equipment. In this experiment, the student will conduct an experiment to study the effect of forced convection and adding extended surfaces. The specific procedures of this study will be determined by each group of students. In fact, part of the overall grades will reflect the rigor and thoroughness of the students in designing the experimental procedures. In this regard, the students are reminded that each group of students is expected to design their own experiments, and that copying between groups will result in the sharing of the overall grades by all the groups involved. That is, a grade of 100 will be split into two grades of 50 if two groups were involved together.

The goals are to quantify the effects of forced convection (total of 4 speed settings, with a speed of zero corresponding to natural convection), of extended surfaces (total of 3 surfaces), and of various input power (total of 2 power levels). Thus, in experimental terms, this experiment has a total of 3 degrees of freedom (or equivalently, it is a 3-D matrix). To illustrate this idea, supposed for example, that one wishes to perform an experiment to determine the dependence of burning rate on pressure and temperature. In that case, the experiment has 2 degrees of freedom, and thus one would construct a two dimensional chart with the rows corresponding to different pressure, the columns corresponding to different temperature, and with each entry being the actual burn rate.

In the above example, the primary variable of interest is the burn rate, thus that is the values recorded into the entries. However, in this experiment, the primary variable of interest has not been defined. The goal only states that we wish to quantify the effects of 3 parameters, but what would be an appropriate way of expressing this effect? In this experiment, the effects can be expressed in terms of the mean Nusselt number as given in equation (1). Also, the four speed settings to be used are: 0, 0.5, 1.0 and 1.5 m/s. The 3 surfaces to be used are: flat, finned and pinned. The 2 power levels to be used are: 50 and 25 Watts.

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\overline{Nu} = \frac{\bar{h}L}{k} \\
q = \bar{h} A (T_w - T_\infty)
$$

(1a)  
(1b)

Nu is the mean Nusselt number  
h is the mean heat transfer coefficient  
L is the length of the heat exchanger  
k is the thermal conductivity of air
\( q \) is the total input power  
\( A \) is the total area of the exchanger  
\( T_w \) is the temperature of the exchanger  
\( T_x \) is the ambient temperature

**Facility**

The measurements for the above study is achieved in the Armfield Thermal Convection apparatus by studying the temperature profiles and heat flux in an air duct with associated flat and extended transfer surfaces. The vertical duct is so constructed that the air temperature and velocity can be readily measured, and a variety of "plug-in" modules of heated solid surfaces of known dimensions can be presented to the air stream for detailed study. A fan situated at the top of the duct provides the air stream for forced convection experiments. An independent bench mounted console contains temperature measurements, power control, and fan speed control circuits with appropriate instrumentation. Temperature measurement, to a resolution of 0.1 °C, is effected using thermistor sensors with direct digital read-out in °C. Air velocity is measured with a portable anemometer mounted on the duct. The power control circuit provides a continuously variable, electrical output of 0-100 Watts with a direct read-out in Watts.

As shown in figure 1, the apparatus consists of a vertical rectangular duct supported by a bench-mounted stand (1). A flat plate (3), pinned (4) or finned (5) exchanger may be installed in the duct and secured by a quick-release catch (18) on each side. Each exchanger incorporates an electric heating element with thermostatic protection against overheating. The temperature at the base of each exchanger is monitored by a thermistor sensor (19) with connecting lead (7). While in use, the exchanger may be viewed through an acrylic window (14) in the wall of the duct. An upward flow of air may be generated in the duct with a variable speed fan (21) mounted at the top. Air velocity in the duct, whether natural or forced, is indicated on a portable anemometer (2) held in a bracket (15) on the duct wall. The anemometer sensor (16) is inserted through the wall of the duct. A thermistor probe (6) permits measurement of the in-going and out-going air temperatures together with surface temperatures of exchanger pins and fins. These temperatures are determined by inserting the probe through access holes (20) in the duct wall. An electric console (8) incorporates a variable auto-transformer with a digital readout to control and indicate power supplied to the exchanger on test. The exchanger is connected to the console via the supply lead (10). A variable low voltage DC supply is provided for the fan via the supply lead (17). A digital readout indicates the temperature using a thermistor probe connected to a flexible lead (6). Power is supplied to the equipment via a supply lead (9) connected to the rear of the console.

**Procedure**

The procedures are to be independently designed by each group of students. However, the following should be noted:

1. Make sure that steady state is reached before recording any data
2. Make sure that the ambient temperature is recorded each time the condition is changed.

References


Figure 1: Convection heat transfer apparatus