# ME 331 Extended Surface "Pin Fin" Laboratory

The purpose of this experiment is to determine the effectiveness of various pin fins with cross-flow forced convection, and to compare the measured and predicted temperature distributions along the length of the fins. Heat transfer coefficients (both forced and natural convection) for each of the pin fin configurations will be obtained experimentally, and also by using one or more appropriate empirical (forced convection) correlations from Chapter 7 of the textbook.

## Introduction

Heat transfer theory provides a direct means of developing engineering estimates of the rate of heat transfer in various practical situations. For forced or natural convective heat transfer, empirical correlations are developed with a theoretical basis, but with experimentally determined parameters. Such empirical correlations can represent idealizations that are not typically realized, even in the laboratory. It is often not appreciated that convection correlations are seldom better than 20% accurate, and can frequently be even worse. Thus, although the correlations can be used for engineering estimates, more exact information is obtained by the construction and testing of a prototype. In this experiment, the temperature distributions for three different pin fins are measured first with natural convection, then with forced convection: a copper fin, a stainless steel fin, and an aluminum fin.

## Apparatus

The apparatus consists of three different fin configurations. At the base of each fin is a threaded section, which is used to attach the fin base to a heater. The heater and base of the fin are surrounded by insulation to reduce heat loss. Five to seven type K thermocouples (chromel/alumel) are embedded at the base and along the length of each fin. The heater is powered from a reduced line source by a VARIAC. Fluke multi-meters are used to measure the voltage and current drawn by the heater. *Note:* the current is actually measured as a voltage drop across a 1-Ohm resistor. A data acquisition system (DAQ) is used to acquire the temperature data.

## Experimental Procedure

With the fin securely installed and the VARIAC set to the proper voltage, the fin temperature measurements are monitored until a steady state condition has been reached. Steady state temperatures are then recorded along with the measured power for the natural convection case. The procedure is then repeated with the fan blowing on the pin fin cylinder in cross flow (forced convection case).

1. Turn on the power supply to the electric heater (if it is not already on). Do not change the setting on the power supply. Use the multi-meters to obtain the voltage and current. (The current is determined indirectly by measuring the voltage across a 1-ohm resistor.)
2. Determine whether the fin is made of copper, aluminum, or stainless steel.
3. Measure the room air temperature.
4. Use the DAQ system to monitor the temperatures along the length of the fin. When the system has reached steady-state under natural convection conditions, record the temperatures. (If allowed by the TA, you may use the handheld anemometer in attempts to measure natural convection air velocities, slightly above the fin and at several positions along its length.)
5. Turn on the fan, monitor the temperatures and then record steady state readings for the forced convection boundary condition. Use the handheld anemometer to measure the air velocity at a distance approximately 1/3rd of the fin length L measured from the fin tip (or 2/3rd of L measured from the fin base). Turn OFF the fan, but leave the power supply to the electric heater ON.

6. Carefully measure the dimensions of the fin including its length and diameter. With ***extraordinary*** care, measure the distance of each thermocouple from the base of the fin. (The thin thermocouple wires and sensor potting are very fragile and should absolutely not be touched.)

**Pin Fin Analysis**

1. Estimate the fin heat transfer rate $q_f$ assuming negligible heat loss from the insulated heater / base.
2. Estimate h values (two) using an overall heat balance on the fin and an "average" fin surface temperature for both the natural and forced convection cases.
3. Calculate the predicted temperature profile T(x) along the length of the fin, based on an appropriate boundary condition at the fin tip and the measured fin heat transfer rate $q_f$. Note that these "predictions" will rely on the measured fin geometry, the material thermal conductivity, the measured base temperature, and the estimated values of h.
4. How does the predicted T(x) compare with the measured values? On the same graph, plot and compare the predicted and measured temperature profiles T(x) along the length of the fin, first for the natural convection case, then for the forced convection case.
5. Obtain another estimate of the heat transfer coefficient by using measured air velocity and an appropriate forced convection correlation from Chapter 7 of your textbook. Using this estimate of h from an empirical correlation, how does the predicted T(x) compare with measured values?
6. Plot and compare the predicted (Chapter 7 correlation) and measured temperature profiles T(x) along the length of each pin fin, making sure to obtain a new estimate of h for each pin fin configuration, based on measured air velocity and at least one correlation from Chapter 7.
7. Calculate the fin effectiveness for all three pin fins, both natural and forced convection cases.

**Discussion**

In your report discuss the following:

1. The accuracy of your estimates of convection coefficients h. What are potential sources of error?
2. Discuss the uncertainty of forced convection air velocities. Estimate velocity measurement error.
3. Estimate the heat dissipated from the electric heater through the backing insulation. How does this compare with the fin heat transfer rate?
4. What is the effect of neglecting radiation? Are the errors greater or lesser for natural convection compared to forced convection cases?
5. Compare predicted and measured temperature profiles T(x) along the length of each pin fin. Estimate an error range for measured location of the thermocouples and include (horizontal) error bars on all plots of T(x) versus x. What is the typical accuracy of type K (un-calibrated) thermocouples? Include vertical error bars to illustrate uncertainty in the temperature measurements for all plots of T(x) versus x.
6. Could any of the fins be modeled as infinite? If so, explain. If not, what fin length would be needed for an infinite fin model to be valid?
7. Compare the calculated values of fin effectiveness for natural and forced convection and for each of the three different pin fins. Compare and discuss each of the fin effectiveness values.