4th International Conference on Mechanical Engineering, December 26-28, 2001, Dhaka, Bangladesh/pp. III 159-163

HEAT TRANSFER AUGMENTATION IN A TUBE HAVING INTERNAL LONGITUDINAL INLINE FINS INTERRUPTED IN STREAM WISE DIRECTION

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Abstract The present work examines the heat transfer and pressure drop characteristics for turbulent flow in tubes having internal longitudinal inline fins interrupted in stream wise direction. Experiments were also performed in a smooth tube. The tube and the fins were cast together to avoid any thermal contact resistance, heat was supplied from an electrical heating system, air was used as the working fluid in all experiments. Reynolds number calculated based on the inlet diameter and varied in the range of 1.8×10^4 to $3.94\text{X}10^4$. Results indicate that for comparable Reynolds, friction factor for inline segmented finned tube is 1.72 to 2.5 times higher than the smooth tube. Pumping power for in-line segmented finned tube is 2.21 to 2.34 times higher than that of the smooth tube. Heat transfer coefficient for in-line segmented finned tube is around 2.30 to 2.37 times higher than that of the smooth tube for comparable Reynolds number. Results when compared with the performance of inline finned tube show that both inline finned tube and in-line segmented finned tube produces heat transfer enhancement but in-line segmented finned tube gives same enhancement of heat transfer with less pressure drop.

NOMENCLATURE

A	Total heat transfer area of a tube (m^2)
A_h	Perimeter of the finned tube (m)
A_{xf}	Cross-sectional area of the finned tube (m^2), $\pi D^2/4$-NWH
C_p	Specific heat at constant pressure (J/kg.K)
D	Inside diameter of the tube (m)
D_h	Hydraulic diameter (m)
F_h	Friction factor based on hydraulic diameter
F_i	Friction factor based on inside diameter of the tube
h	Fully-developed heat transfer coefficient (W/m^2K)
H	height of the fin (m)
k	Thermal conductivity (W/m·K)
M	mass flow rate (kg/s)
N	Number of fins
p	Static pressure (Pa)
P*	Dimensionless pressure
Q’	Heat transfer rate per unit length of the tube (W/m)
R_{ei}	Reynolds number based on inside diameter fo the tube
T	Temperature (K)
V	Mean velocity (m/s)
W	Width of the fin (m)

Creek Symbols

μ	Dynamic viscosity (kg/m.s)
ρ	Density (kg/m^3)

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Subscripts

i	Condition at inlet
w	Condition at wall
b	Bulk condition
o	Condition at outlet

INTRODUCTION

Among seve ral available techniques for the augmentation of heat transfer in heat exchanger tubes, the use of internal fins appears to be a very promising method as is evident from the results of several past investigators, For both laminar and turbulent flow regimes, the finned tubes exhibited higher heat transfer coefficients when compared with corresponding smooth (unfinned) tubes.

Hu and Chang (1973) showed that an enhancement as high as 20 times that of unfinned tube could be realized. Experimental data were reported by Bergles et al. (1971) Rustum and Soliman (1988) Mafizul Huq (1996)

The present study was undertaken to develop experimental data on pressure drop and heat transfer during turbulent flow of air in internally segmented fin tube and also for the smooth tubes in the same set-up.

EXPERIMENTAL SET-UP AND MEASUREMENTS

An experimental set up was designed, fabricated, and installed to study the friction factor and heat transfer performance of circular tube having segmented internal fins and smooth tube. The set up is schematically shown

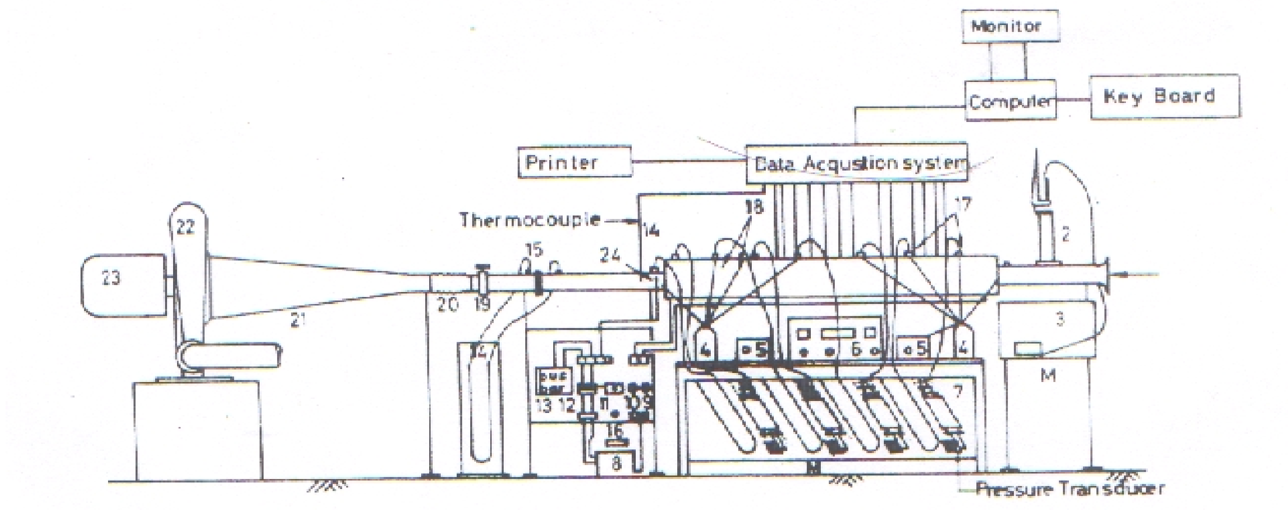

Fig. 1. Schematic diagram of experimantal set up

1. Shaped Inlet	9. Ammeter	17.Pressure tappings
2. Traversing pito	10. Voltmeter	18. Thermocouples
3. Inclied tube manometer	11. Temperature controller	19. Flow control valve
4. Ice bath	12. Magnetic contactor	20. Flexible pipe
5. Selector switch	13. Bus bar	21. Diffuser
6. Microvoltmeer	14. U-tube manometer	22. Fan
7. U-tube manometer	15. Orifice meter	23. Motor
8. Variable voltage transformer	16. Heater on-off lamp	

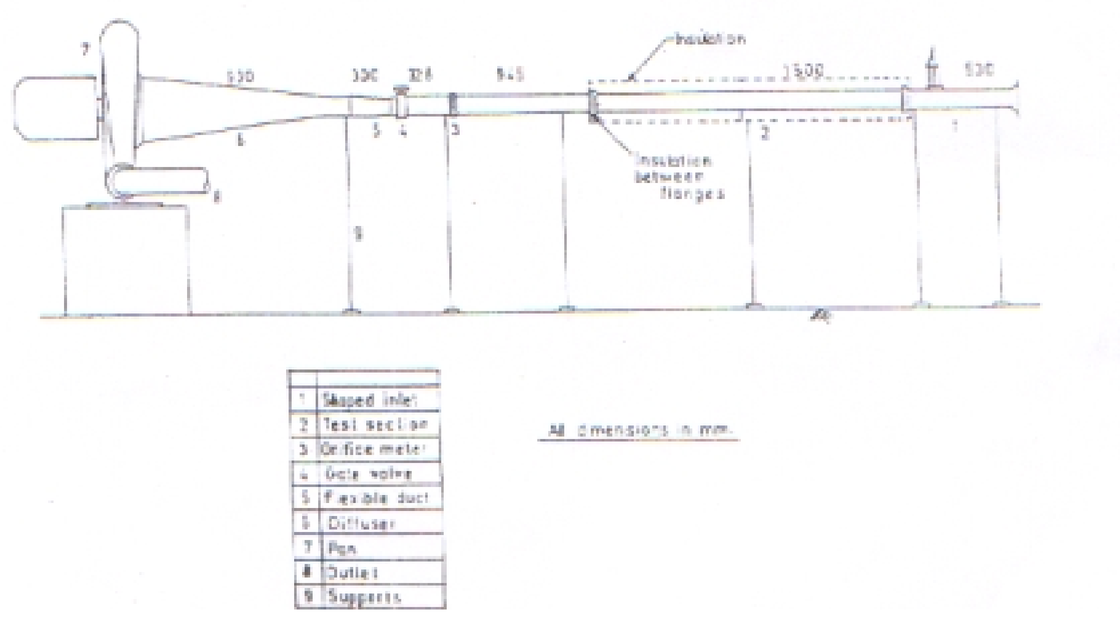

Fig 2: Schematic diagram of experimental set up with dimensions

in Figure 1. Air was used as the working fluid in all experimental measurements. It was supplied by a centrifugal fan installed at the end of the set up. The set up consisted of three major components: (1) inlet and flow, measuring section, (2) heat transfer section and (3) fan assembly.

The unheated inlet section (shaped inlet) and heat transfer section of same diameter (70 mm inside diameter) were cast from aluminum. The pipe and the shaped inlet (530 mm long) were made integral to avoid any flow disturbances at the upstream of the section during flow measurement. The contour of the shaped inlet section was designed to provide streamlined flow at the pipe entrance. The fin and the tube assembly were cast from brass to avoid any contact resistance at the fin-tube interface. Figure 2 shows the tube configuration and dimensions. The nichrome wire was covered with mica sheet and insulation tape to make it electrically insulated.

The electric power to the test section was supplied by a 5 kVA variable voltage transformer connected to 220 V a.c. supply via a magnetic contactor and a temperature controller. The flow of air through the experimental set up was measured at the inlet section with the help of a traversing pitot tube connected to an inclined tube manometer. The shaped inlet provided an easy entry and symmetrical flow. The measurement station was located at 4 pipe diameters downstream from the entrance. The static pressure tappings were made at the inlet and outlet of the test section as well as equally spaced 7 axial locations of the test section.

The temperatures were measured with the help of thermocouples at the following locations: (1) fluid bulk temperature at the inlet and outlet of the test section, (2) wall temperature and (3) fin-tip temperature. The bulk temperature of the air entering the test section was measured using a thermocouple situated in the air steam just upstream of the test section inlet.

The bulk temperature of the air at the outlet of the test section was measured using thermocouples situated at three locations. Data acquisition system was used to record the temperature dataFig.3 shows the tube configuration and dimension, Fig.4 shows the segmented tube, Fig.5 shows method for the temperature measurement at outlet, Fig.6 shows method for the velocity measurement at inlet and Fig.7 shows experimental & theoretical heat transfer results of smooth tube.

The following procedure was used for each experimental run. The fan was first switched on and allowed to run for a few minutes so that the transient characteristics died out. The air flow rate was established by adjusting the flow control valve. Then the electrical heating circuit was switched on. The electrical current was adjusted with the help of regulating transformer until a steady-state condition for a particular Reynolds number could be arrived. The steady state was determined. All the readings were taken at steady state condition. A series of runs with different Reynolds number for a constant power input were taken by adjusting the flow rate and letting the system to settle for a steady-state condition. The experimental measurements were also checked for consistency and found to be reproducible.

CALCULATION OF DIMENSIONLESS PARAMETERS

$$D_h = \frac{4x(\text{Cross sectional area of the flow})}{\text{Wetted perimeter}}$$

$$\mathrm{Re}_i = \frac{\rho V D_i}{\mu}$$

$$Q' = MC_p\,(T_i - T_o)\,/A_s\,L \quad \mathrm{W/m^2}$$

$$T_h(x) = T_i + \frac{Q' A_s x}{MC_p} \;{}^\circ C$$

$$\bar{h} = \frac{Q'}{A(T_{wav} - T_{bav})_x} W/m^2 \;{}^\circ C$$

$$Q' = MC_p\,(T_i - T_o)\,/\,A_h\,L \quad \mathrm{W/m^2}$$

$$T_h(x) = T_i + \frac{Q' A_h x}{MC_p} \;{}^\circ C$$

$$Q' = MC_p\,(T_i - T_o)\,/\,A_h\,L \quad \mathrm{W/m^2}$$

$$T_h(x) = T_i + \frac{Q' A_h x}{MC_p} \;{}^\circ C$$

$$\bar{h} = \frac{Q}{A(T_{wav} - T_{bav})} \qquad W/m^2 \;{}^\circ C$$

$$T_b(x) = T_i + \frac{Q' A_h x}{MC_p} \;{}^\circ C \text{ when } x < L_1$$

$$T_b(x)_1 = (T_i)_{1-1} + \frac{Q' A_s (0.2)}{MC_p} \;{}^\circ C \text{ when } L_1 < x < 2L_1$$

$$T_b(x)_1 = (T_i)_{1-1} + \frac{Q' A_h (0.2)}{MC_p} \;{}^\circ C \text{ when } 2L_1 < x < 3L_1$$

$$Pm = (-\Delta P/\rho)M = \frac{4F_i L}{D_i}\frac{V^2}{2} A_s V \rho \quad W$$

RESULTS AND DISCUSSION

Fluid flow and heat transfer results were calculated and comparative performance analysis is presented here.

Fig. 8, shows the variation of friction factor F_i with Reynolds number for all the three tubs. Friction for the in line fin tube is highest followed by in line segmented fined tube, F_i for smooth tube is lowest.

Fig. 9, shows the variation of pumping power with Reynolds number. It may be noted from the figure that pumping power of in line segmented fin tube is lower than that of the in line finned tube but higher than that of the smooth tube.

Fig. 10, shows the variation of average heat transfer coefficients with Reynolds number for all the three tubes. For all the tubes average heat transfer coefficient increases with Reynolds number.

It can be noted that average heat transfer coefficient for in line fin tube is higher than that of the smooth tube, average heat transfer coefficient for in line segmented finned tube is higher than that of a smooth tube but similar to that of in line finned tube for comparable Reynolds number.

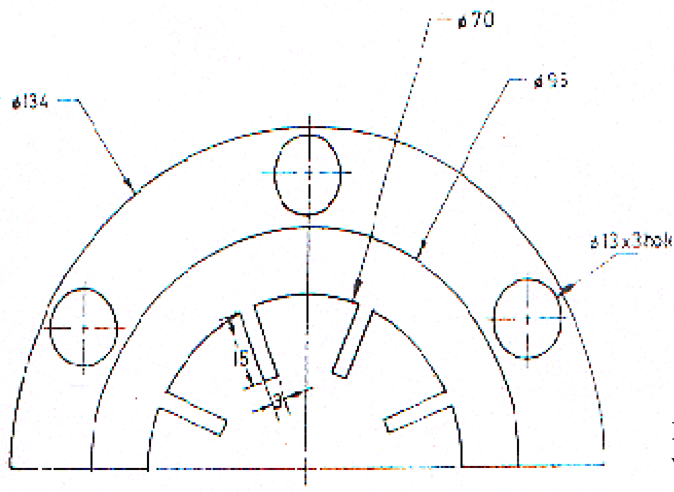

Fig. 3Half of the circular tube with fins

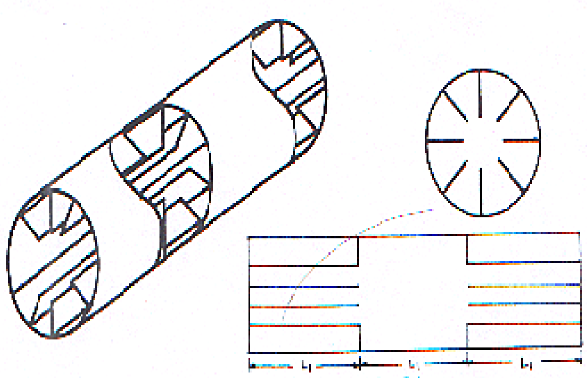

Fig .4 Schematic diagram of in line segmented fin tube

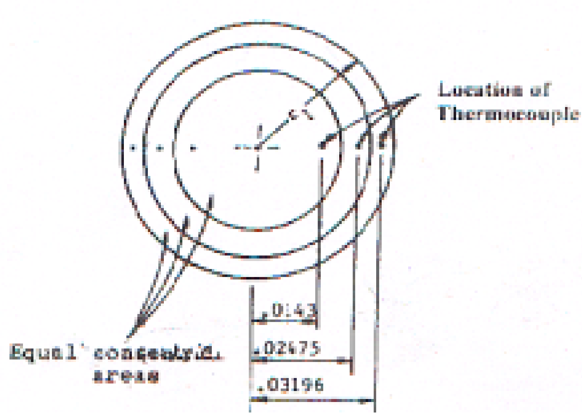

Fig 5: Location of thermocouple for meassurement of outlet temperature

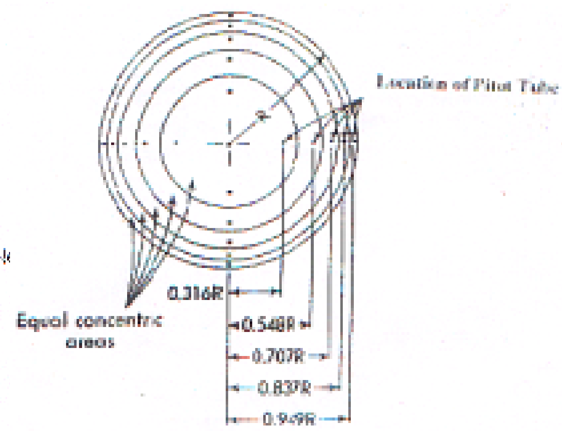

Fig. 6Location of pitot tube for meassurement of velocity

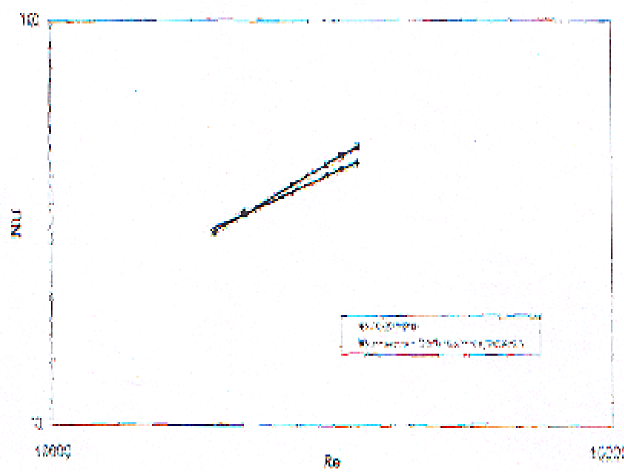

Fig. 7Heat transfer results of smooth tube

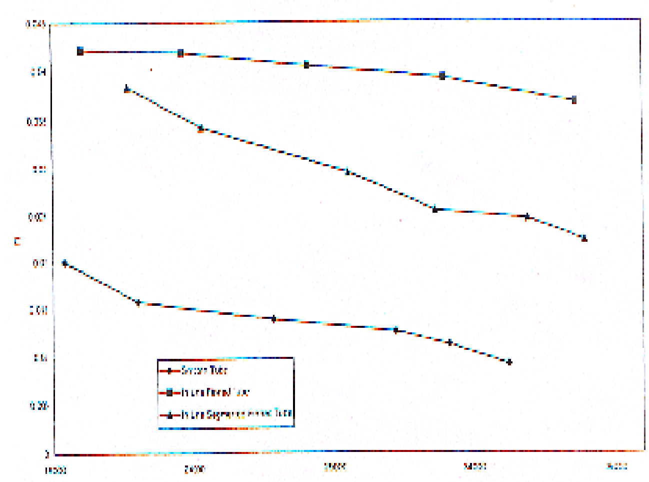

Fig 8: Friction factor at different Reynolds number of smooth tube, in line finned and in line segmented finned tube

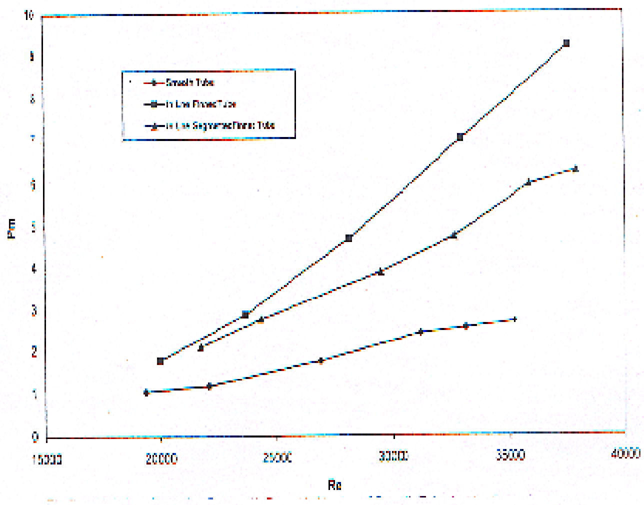

Fig 9: Variation of pumping power with Reynolds number of smooth tube, in line finned and in line segmented finned tube

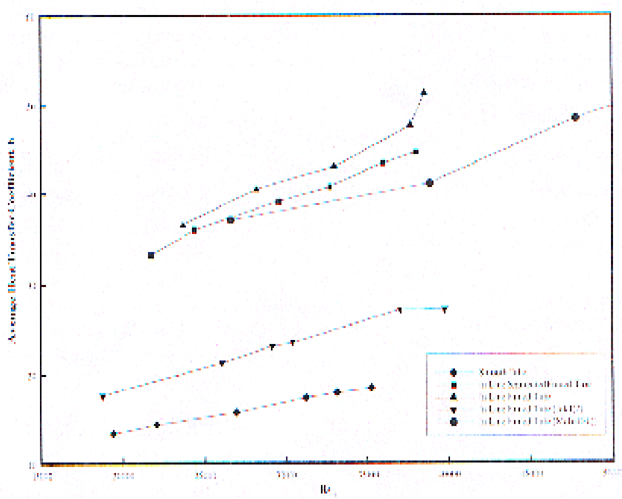

Fig 10: Variation average heat transfer coefficient with Reynolds number of different tubies

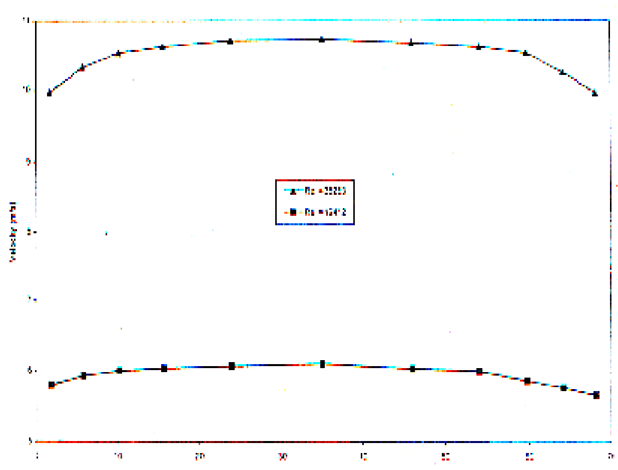

Fig 11: Velocity distribution along the diameter of smooth tube

CONCLUSIONS

Findings of the present study may be summarized below:

(a) Friction factor of in line finned tube is around 1.93 to 3.5 higher than the smooth tube and of in line segmented tube 1.72 to 2.5 times higher than the smooth tube.

(b) Pumping power for in line finned tube is higher than that of the smooth tube and also higher than that of the in line finned tube.

(c) Heat transfer coefficients of in line fin tube and in line segmented fin tube are almost similar and higher than that of the smooth tube. (Heat transfer coefficient for in-line fin tube is 2.40 to 2.47 times higher and for in-line segmented finned tube is 2.30 to 2.37 times higher than that of the smooth tube for comparable Reynolds number)

(d) Both in line fin tube and segmented finned tube produces enhancement of heat transfer, in line segmented fin tube produces almost similar enhancement with less pumping power.

REFERENCES

1. Bergles, A.E. Brown, J.S. and Snider, W.D., 1971, "Heat Transfer Performance of Internally Finned Tubes", ASME Paper No. 71, HT-31, American Society of Mechanical Engineers, New York.
2. Carnavos, T.C., Aug, 1977 "Cooling Air in Turbulent Flow ith Internally Finned Tubes", AI ChE Paper no. 4, 17th National Heat Transfer Conference.
3. Carnavos, T.C., Apr-June, 1980 "Heat Transfer Performance of Internally Finned Tubes in Turbulent Flow", Heat Transfer Engineering Journal Vol. 1, No. 4, pp. 32-37.
4. Hu, M.H. and Chang, Y.P., 1973, "Optimization of Finned Tubes for Heat Transfer in Laminar Flow", Journal of Heat Transfer, Vol. 95, pp. 332-338.
5. Mafiz, Huq and Rahman, An Experimental Study of Heat Transfer in an Internally Finned Tube", Proceedings ASME Heat Transfer Division, Volume 2, pp. 211-217, 1996.
6. Mafiz, Huq and Rahman, Experimental Measurements of Heat Transfer in an Internally Finned Tube", Accepted for publication in the journal of International Communication in Heat and Mass Transfer, CJ97/1890, 1998.
7. Jalal Uddin, Md. "Study of Pressure Drop Characteristics and Heat Transfer Performance in an Internally Finned Tube", Thesis submitted to the Dept. of Mechanical Engineering, BUET, 1998.