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Experimental Study on Effect of Area and Turbulence on Heat Transfer through Circular Pipe by Using Internal Threading in Drying System

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Abstract: **Present experimental study has been carried out to investigate effect of area and turbulence on heat transfer in forced convection through circular galvanized iron pipe without threading and by using internal threading with pitches 6mm and 4mm. The experiment is carried out for three heater inputs and with three different flow rates of air with Reynolds number 5000 to 9000. The effect on heat transfer rate and outlet temperature of air is calculated and observed respectively for threaded pipes and the results are compared with plain pipe. The variations are plotted for heat transfer rates Vs area and Reynolds number. In addition to that the moisture holding capacity of the air which is applicable in onion drying system is analyzed. Heat transfer rate for the threaded pipes is higher as compared to plain pipe for the given conditions and the highest performance is observed for the pipe with pitch= 4mm means with the highest internal surface area. Also with increase in Reynolds number heat transfer rate is increasing. Friction factor is calculated for all the pipes & found highest in case of threaded pipe with minimum pitch means with maximum area. Also decrease in friction factor is observed with increase in Reynolds number. Exit temperature of the air is increased with respect to the exit temperature of the plain pipe, which increases moisture holding capacity of the air.**

1. INTRODUCTION

Drying is mandatory processes for food preservation to avoid spoilage before use. Many food drying processes are using hot air. Electrical heaters are used to heat the air. The drying time is dependent on the temperature and flow rate of the air. In onion preserving unit the drying system controls the temperature range from 50^0 C to 85^0 C. To reduce the drying time, the temperature or flow rate of the air can be increased. In the above said ranges if system needs increase in the temperature for a given flow rate, it is required to increase the power input to the heater, which leads to increase in electric power consumption. Also, to increase the temperature if heater input is increased excessively, due to excess heating the system may not work efficiently or at the extreme it may fail. Therefore, the dissipation of the heat from the pipe surface to the flowing air through the pipe is very important for maintaining the efficient and reliable functioning of the plant. Also to increase the efficiency of the plant it would be beneficial to increase the temperature without increasing the heat input.

Hamidou Benzenine, Rachid Saim and Hamidou Benzenine, Rachid Saim and Said Abboudi, Omar Imine [1] found that the heat transfer can be enhanced by the use of transversal waved baffles. Soo Wban Abn and Kang Pil Son [2] found that the heat transfer can be enhanced in case of smooth ducts by using rough surfaces and it depends upon properties and size of the fluid molecules. Prashanta Dutta and Akram Hossain [3] studied the effect of local heat transfer and friction factor in a rectangular pipe with inclined and perforated baffles. The effect of baffle size, position, and orientation were studied for heat transfer enhancement. Kang-Hoon Ko and N. K. Anand [4] studied the effect of local heat transfer in a rectangular pipe with porous baffles. The conclusion of this study is that the heat transfer increases 2 to 4 times than the solid baffle. Rajendra Karwa and B. K. Maheshwari [5] studied the heat transfer and friction in an asymmetrical rectangular duct with some solid and perforated baffles with relative roughness. The friction factor for the solid baffle was found between 9.6-11.1 times than smooth duct which decreases in perforated baffle. TANG Xinyi and ZHU Dongsheng [6] studied the turbulent flow and heat transfer enhancement in ducts or channels with rib, groove or rib-groove tabulators.

The combination of crossed and discontinuous rib grooves array was used to enhance heat transfer with less pressure loss and better thermal performance is expected. Waleed Mohammed Abed and Mohammed Abed Ahmed [7] studied the effect of heat transfer and Pressure drop in a duct with corrugated surface. The heat transfer coefficients obtained from the channel with the corrugated surface are higher than those with the plain surface. The pressure drop also increased on corrugated surface. **S.** Naga Sarada, A.V. Sita S. Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha and L. Shyam Sunder [8] used coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. In order to enhance heat transfer in internal flow, tape is inserted in channel. They reported better performance of the helical twisted insert in comparison to the twisted tape insert. Modification of twisted tape was made by focusing in increase of heat transfer rate rather than the reduction of friction loss. Dr. Kenneth J. Hellevang [9], said that higher temperature, higher flow rates, higher moisture holding capacity and lower relative humidity increases drying speed means decrease in drying time. Hany S. EL.Mesry and Gikuru Mwithiga [10], concluded that increase in temperature or flow rate of air decreases the time for the drying.

This thesis studies and investigates experimental parameters of internal surface area, flow rates, heat inputs which plays roles on heat transfer rate in food preserving unit. In this experimental setup, air is used as working fluid and circular pipes of Galvanized Iron as a test specimen. To change the internal surface area of the test specimens, pipes are internally threaded with different pitches (p=6mm and 4mm). To examine the effect of turbulence, three different pressure heads (60mm, 90mm and 120mm) which are responsible for the turbulent flow range (Re=5000 to 9000) are taken. 27 experiments with different geometric and flow parameters have been performed and effect on heat transfer rate and friction factor in forced convection is examined for constant heater inputs (825W, 1105W and 1425W) through circular pipes by compound technique means by combining passive technique (threading) and active technique (increase in flow rate of air with blower). The effects are examined for the moisture holding capacity of air which is used in an onion drying system. For this, the internal surface area of the pipe is changed by threading and effects on heat transfer and friction factor have been investigated for different flow rate values and for different heater inputs.

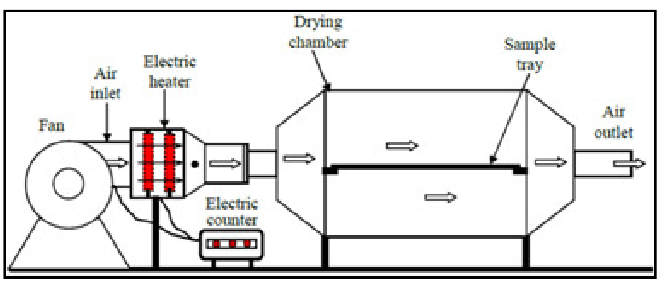


Figure 1: Forced convection in drying of onion

In Figure1, horizontally mounted dryer is shown to which hot air is supplied by using blower and electric heater. In this dryer the air is supplied directly to the drying chamber after heating through hot pipe. In above case, the electric heater is heating the pipe through which air is passed in the drying chamber. By changing the internal surface area of this pipe this investigation has been carried out for different flow rates and the effect on heat transfer and moisture holding capacity of air is studied.

2. EXPERIMENTAL WORK

2.1 Experimental Setup

The apparatus consists of a blower unit fitted with a pipe, which is connected to the test section located in horizontal orientation. Electrically powered heater encloses the test section. Six thermocouples are embedded on the walls of the pipe and two thermocouples are placed in the air stream, one at the entrance and the other at the exit of the test section to measure the temperature of flowing air as shown in Figure 1. The pipe system consists of a valve, which controls the airflow rate through it and an orifice meter to find the volume flow rate of air through the system. The two pressure tapings of the orifice meter are connected to a water U-tube manometer to indicate the pressure difference between them. Input to heater is given through dimmer stat. Display unit consists of digital voltmeter, ammeter and temperature indicator. Difference in the levels of manometer fluid represents the variations in the flow rate of air.

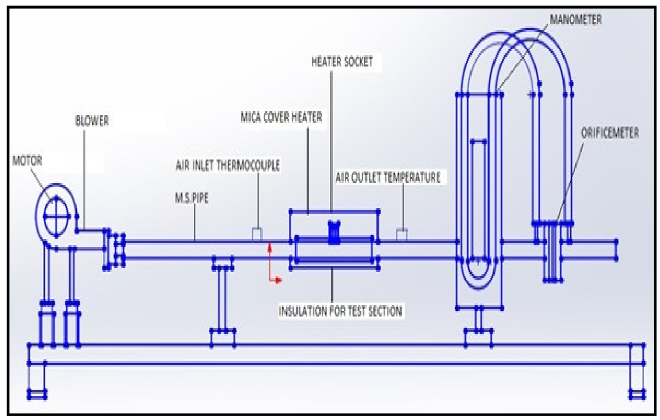


Figure 2: Schematic Arrangement

Figure 3: Actual Arrangement

2.2 Procedure

Start main switch of control panel. Switch On the blower.

Adjust the flow rate by means of gate valve to 60 mm in the manometer level. Increase slowly the input to heater by varying the dimmer stat and adjust the Input Voltage to 75 V. Read the current in ammeter. Wait till fairly steady state condition is reached. Take readings of all the eight thermocouples at an interval of 5mins until steady state are reached. Note down all the temperature readings in the observation table. Then adjust the manometer reading to 90 mm and at the end 120 mm, keep voltage constant at 75 V for both the readings. For the same pipe, set the voltage at 85 V and repeat the procedures. Again for the same pipe, set the voltage at 95 V and repeat the procedures.

Experiments are conducted on three different G.I. pipes

1. Plain internal surface area
2. Internally threaded surface of pitch 4mm.
3. Internally threaded surface of pitch 6mm.

2.3 Data Reduction

Power Input to the Heater (Q) watts

$$Q = V \times I \tag{1}$$

Bulk Mean Temperature of Air (T_{bm}) °C

$$T_{bm} = \frac{Ti + TO}{2} \tag{2}$$

Actual Discharge of Air (m^3/sec)

$$Q_a = \frac{Cd.a1.a2^2\sqrt{2.g.hw.\frac{\rho w}{\rho a}}}{\sqrt[2]{a1^2 - a2^2}} \tag{3}$$

Mass flow rate of air (kg/s)

$$\square = Qa \times \rho_a \tag{4}$$

Heat transfer rate of air (watts)

$$q = \square \times c_p \times (T_o - T_i) \tag{5}$$

Average temperature of the test section pipe (T_s)

$$T_s = \frac{T1 + T2 + T3 + T4 + T5 + T6}{6} \tag{6}$$

Heat transfer coefficient (W/m^2 K)

$$h = \frac{q}{As(Ts - Tbm)} \tag{7}$$

Velocity of flow (m/sec)

$$v = \frac{Qa}{A} \tag{8}$$

Reynolds Number

$$Re = \frac{\rho.v.D}{\mu} \tag{9}$$

Nusselt number

$$Nu = 0.023\, Re^{0.8} \times Pr^{1/3} \tag{10}$$

Heat transfer coefficient (W/m^2 k)

$$h_c = \frac{Nu.K}{D} \tag{11}$$

Friction Factor

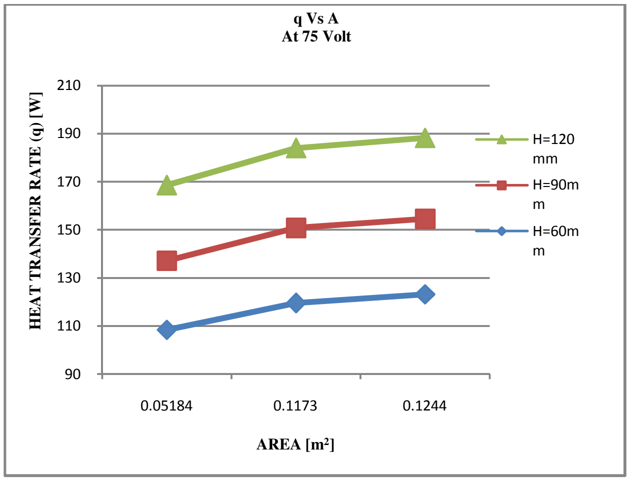
$$f = \frac{1.325}{[\ln(\frac{e}{3.7D} + \frac{5.74}{Re^{0.9}})]^2} \tag{12}$$

3. RESULTS AND DISCUSSIONS

3.1 Heat transfer rate Vs area at Constant heater input

The following graph is obtained for comparing performance of three pipes having different internal surface areas for different working conditions. Three curves on the same graph are representing the trend for three pipes at three different conditions.

The graph-1 is obtained at constant heat input i.e. at 75 Volts and 11 Amps (825W). From the graph it can be seen that the heat transfer rate increases with increase in surface area for the constant pressure head i.e. for constant mass flow rate or constant volume flow rate. This graph is a combination of the effect of area and mass flow rate on the heat transfer rate. For the first pipe, having plain surface area, heat transfer rate increases with increase in mass flow rate (pressure head). Due to increase in the pressure head value the volume flow rate also increases, which results into increase in value of mass flow rate. As the flow velocity is dependent on the volume flow rate, the flow velocity also increases with increase in volume flow rate. More flow velocity of air helps to draw more heat from the surface of the pipe. Also increased mass flow rate means more no. of molecules of air are passing per second over the internal surface of the pipe. Each molecule draws heat which is in contact with the surface and transfers it to others by the self movement, as per the principle of convection. Though at the surface of the pipe the heat is transferred to air by conduction, major portion is transferred through convection. If the value of heat transfer rate for pipe-II and pipe-III are compared with respect to the pipe-I (plain pipe), the highest value is for pipe-III, means that pipe with greater internal surface area gives higher performance for above mentioned conditions.

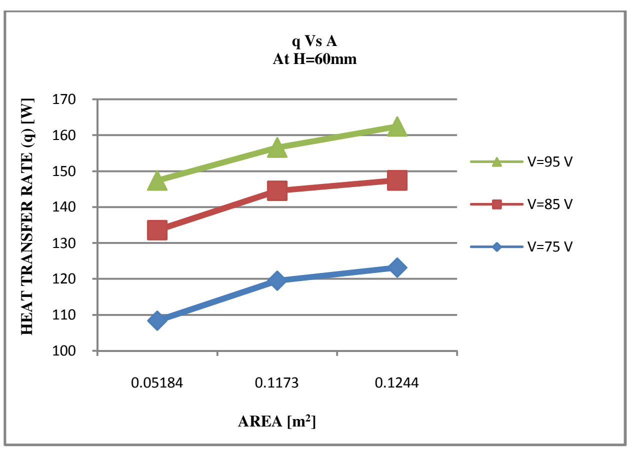


Graph-1

3.2. Heat transfer rate Vs area at Constant pressure head

The following graph is plotted for constant pressure heads i. e. for constant mass flow rate. In the graph-2, the first bottom curve represents variation in heat transfer rate with surface area at constant heat input (825W) to the heater. The heat transfer rate increases as surface area of the pipes increases.

The value of heat transfer rate is higher for pipe-III and pipe-II with respect to the pipe-I. So for the above stated geometric and thermal conditions larger area improves heat transfer rate largely.

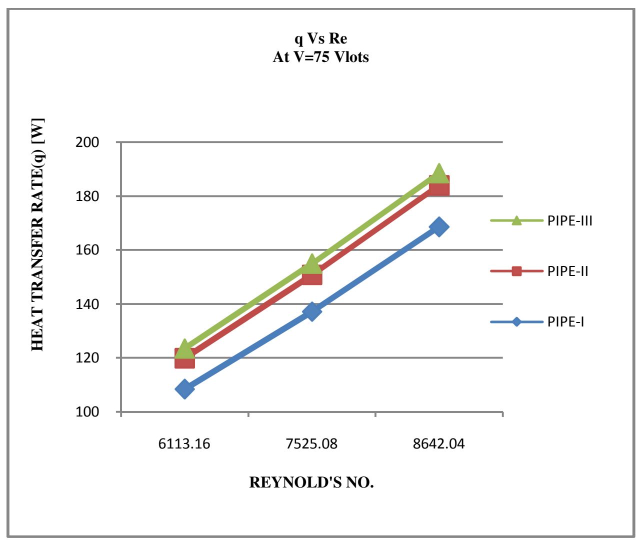


Graph-2

3.3. Heat transfer rate Vs Reynolds number at Constant heat input

In the following graph three pipes are compared on the basis of change in heat transfer rate with respect to Reynolds number. The graph is obtained at constant heat input from the heater i.e. at 75 Volts and 11A. From the graph-3 it is seen that as Reynolds number goes on increasing heat transfer rate also increases. The results of threaded pipes are compared with that of plain pipe. The same trend but with higher values is observed in case of Pipe-II & Pipe-III which are internally threaded with no. of pitch, p=6mm & p=4mm respectively. In case of p=4mm, the pipe have more no. of threads as compared to the pipe with p=6mm. Because of more no. of threads the swirl formation is more for p=4mm. More swirl formation insists more turbulence and more turbulence improves contact surface of air with the heated pipe, this phenomenon helps to improve heat transfer rate.

Though the main reason to increase the heat transfer rate is increased internal surface area of the pipes, due to threads, swirl formation is created, which helps to improve the heat transfer rate. More no. of molecules of air are coming in contact with the heated pipe, which leads to improved heat transfer. To observe, whether the results are consistent or not, the readings are also taken for the heat inputs at 85Volts & 95 Volts. Almost same trends but with higher values are observed in case of different heat inputs.

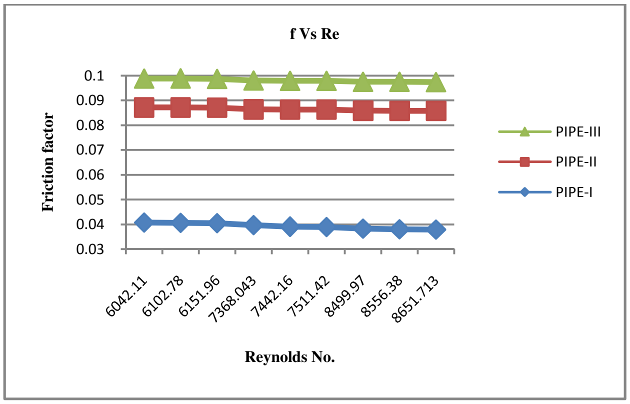


Graph-3

In the plotted graph, the abscissa is values of average Reynolds number which are taken for three pipes and the ordinate is heat transfer rate values. From the graph we can see that heat transfer increases with increase in Reynolds number.

3.4. Friction factor Vs Reynolds Number

Graph-4 is plotted for Friction factor Vs Reynolds number. On the same graph three pipes are compared. From the nature of the graph, it is observed that as the Reynolds number increases the friction factor is decreasing. The Reynolds number is dependent on flow velocity and the friction factor is dependent on velocity. The friction factor is inversely proportional to the square of the flow velocity. The minimum friction factor is observed for internally plain pipe and the maximum friction factor is observed for threaded pipe with minimum pitch. The increase in friction factor leads to increased pressure drop which increases pumping power.



Graph-4

4. CONCLUSION

To investigate the effect of area and turbulence on the heat transfer, experimental investigations have been carried out on the internally threaded pipes with Reynolds number 5000 to 9000 and the results are validated with the results of standard correlations and compared that with plain pipe. Heat transfer rates and friction factors are calculated for different geometric, thermal and flow conditions and graphs are obtained. From the experimental investigations following conclusions are made:

1) Heat transfer rate increases as internal surface area increases. Heat transfer rate for the threaded pipe with pitch=6mm is increased approximately by 8.92%, 7.45% and 5.32% and for the pipe with the pitch=4mm, it is increased by 11.34%, 10.23% and 8.43% for the constant heat inputs 825W, 1105W and 1425W respectively with respect to the results of plain pipe for the above mentioned conditions. With decrease in pitch value means with increase in internal surface area, friction factor increases which leads to increase in pressure drop.

2) For a given pipe, as Reynolds number increases heat transfer rate increases for constant heat inputs and friction factor decreases with increase in Reynolds number.

3) Increase in internal surface area of pipe and flow rate of the air, enhances the heat transfer between pipe and flowing air due to which exit temperature of the air is increased by 4^0C to 5^0C which increases moisture holding capacity of the air approximately by 27%, 35% and 40% with respect to plain pipe for constant heat inputs 825W, 1105W and 1425W respectively, which increases the drying speed, means decrease in the drying time, which leads to increase in drying rate of the drying system.

NOMENCLATURE

A_s	Heat Transfer Area, (m^2)
C_p	Specific heat of air, (J/Kg.K)
D	Hydraulic diameter, (m)
f	Frictional factor, (Dimensionless)
g	Acceleration due to gravity, (m/s^2)
h	Heat transfer coefficient, (W/m^2 K)
p	Pitch of threads, (m)
□	Mass flow rate, (kg/s)
Nu	Nusselt Number, (Dimensionless)
Re	Reynolds Number, (Dimensionless)
q	Heat transfer rate, (W)
V	Velocity of flow, (m/s)
μ	Viscosity of Air , (N.s/ m^2)
ρ	Density of air, (kg/m^3)
e	Average height of rough surface (m)

REFERENCES

[1] Hamidou Benzenine , Rachid Saim and Said Abboudi, Omar Imine, "Numerical analysis of a turbulent flow in a channel provided with transversal waved baffles".

[2] Soo Wban Abn and Kang Pil Son, "An Investigation on Friction Factors and Heat Transfer Coefficients in a Rectangular Duct with Surface Roughness" *KSME International Journal* Vol 16 No.4, pp. 549-556, (2002).

[3] Prashanta Dutta and Akram Hossain, "Internal cooling augmentation in rectangular channel using two inclined baffles" *International Journal of Heat and Fluid Flow* 26, pp. 223–232, (2005).

[4] Kang- Hoon Ko and N.K. Anand , "Use of porous baffles to enhance heat transfer in a rectangular channel" *International Journal of Heat and Mass Transfers* 46 pp. 4191– 4199, (2003).

[5] Rajendra Karwa and B.K. Maheshwari, "Heat transfer and friction in an asymmetrically heated rectangular duct with half and fully perforated baffles at different pitches" *International Communications in Heat and Mass Transfer* 36, pp. 264–268, (2009).

[6] Tang Xinyi and ZHU Dongsheng, "Experimental and Numerical Study on Heat Transfer Enhancement of a Rectangular Channel with Discontinuous Crossed Ribs and Grooves" *fliud dynamics and transport phenomena Chinese Journal of Chemiacal Engineering*, 20(2) 220 to 230, (2012)

[7] Waleed Mohammed Abed and Mohammed Abed Ahmed, "Numerical Study Of Laminar Forced Convection Heat Transfer And Fluid Flow Characteristics In A Corrugated Channel"

Journal of Engineering and Development, Vol. 14, No. 3, ISSN 1813-7822, September (2010).

[8] S. Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha and L. Shyam Sunder, "Enhancement of heat transfer using varying width twisted tape inserts", *International Journal of Engineering, Science and Technology* Vol. 2, No. 6, pp. 107-118, (2010).

[9] Dr. Kenneth J. Hellevang Grain Drying book, North Dakota State University, Fargo, North Dakota, October (2013).

[10] Hany S. EL-Mesery and Gikuru Mwithiga, University of KwaZulu-Natal, African Journal of Agricultural Research Vol. 7(31), pp. 4440-4452, Aug, (2012).

[11] Teerapat Chompookham, et al., "Heat transfer augmentation in a wedge-ribbed channel using winglet vortex generators" *International Communications in Heat and Mass Transfer*, vol.37, 163–169,(2010).

[12] Q. Liao and M.D. Xin, "Augmentation of convective heat transfer inside tubes with three-dimensional internal extended surfaces and twisted-tape inserts", *Chemical Engineering Journal,* Vol. 78, pp. 95-105,(2000).

[13] S.S Hsieh, M.H. Liu, H.H. Tsai, "Turbulent heat transfer and flow characteristic in a horizontal circular tube with strip-type inserts part-II (heat transfer)", *International Journal of Heat and Mass Transfer*, Vol. 46, pp.837-849, (2003).

[14] R.K. Rajput, a text book of Heat and Mass Transfer.

[15] Engineering toolbox-Effect of temperature on moisture holding capacity.

[16] Moody's chart for friction factor.