Experimental Investigation of Forced Convection Heat Transfer Co-Efficient Through Horizontal And Inclined Circular Tube with Pin Fins

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Abstract *- The innovation of cooling gas turbine parts through inside convective streams of single-stage gasses has created throughout the years from basic smooth cooling entries to exceptionally complex geometries including many varying surfaces. To accomplish high warmth move rate in a current roundabout tube it is vital to dealing with the expanded pumping power, a few systems have been proposed as of late.*

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. Convection is the mechanism of heat transfer through a fluid in the presence of bulk fluid motion. Convection is classified as natural (or free) and forced convection depending on how the fluid motion is initiated. In natural convection, any fluid motion is caused by natural means such as the buoyancy effect, i.e. the rise of warmer fluid and fall the cooler fluid. Whereas in forced convection, the fluid is forced to flow over a surface or in a tube by external means such as a pump or fan. In the present experiment forced convection is used to find the heat transfer coefficient.

Keywords *-* Heat transfer co-efficient,Reynolds number and Nusselt number.

I. INTRODUCTION

Mechanism of Forced Convection

Convection warm exchange is entangled since it includes smooth movement and additionally warm conduction, the smooth movement upgrades warm exchange (higher the speed higher the warmth exchange rate). The rate of convection warmth exchange is communicated by Newton's law of cooling.

The convective warmth exchange coefficient firmly relies on upon the liquid properties and unpleasantness of the strong surface, and the sort of the liquid stream (laminar or turbulent).

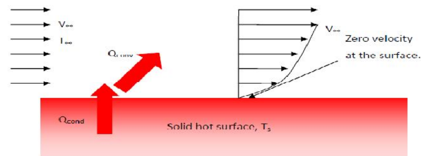


Fig 1. Showing the velocity profile

Convection warm exchange happens by the real development of particles starting with one locale then onto the next area. On the off chance that the movement of the atoms is brought about by some outside office, for example, pump, or a blower, then such sort of warmth exchange is known as constrained convection warm exchange.

Constrained convection technique is utilized in warmth exchangers, counterfeit draft in boilers, cooling of IC motors and so on. Newton's law of cooling is the basic condition used to discover warm exchange coefficient.

II. EXPERIMENTAL

The Circular Tube and the Heating Coil

In the present work plain round tube and roundabout tube with stick blade component have been examined. It ought to be noticed that the tubes utilized in the present examinations are symmetric in geometry. What's more, the tube is comprised of steel and three modern mica band radiators are utilized to warm the test segment whose arrangement subtle elements are appeared.

Circular Tube with Pin Fin Element

The trial examine on detached warmth exchange enlargement utilizing pin blade component in a round tube and plain tube were completed by warmth exchange increase system, in this method alteration of the geometry of the example is to be finished.

The rounds about tubes with 36 stick blades have been made with 4.7cm of equivalent dispersing between the balances. The outline is made to discharge the warmth from the test example with brief term, the design of the test example subtle elements are given beneath.

Length of the tube (L)	400mm
Outer dia of the tube (OD)	40mm
Inner dia of the tube (ID)	38mm
Number of pin fin used	36
Dia of the pin fin	4mm
Length of the pin fin	10mm

2.2 Fabricated Test Model

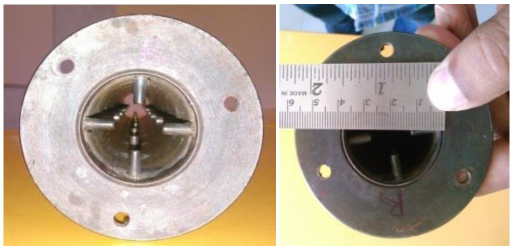


Fig 2.1Test specimen with the pin fins inside the tube and Dia of test specimen

In this photo finish created test demonstrate having pin balances inside in the orthogonally inverse request are plainly appeared.

Fig 2.3 Test section with thermocouple

Above figure demonstrating the test example appended by the five K-sort thermocouples, every thermocouple are having 95mm crevice between them.

Fig.2.4 Test specimen having three band heaters

Three band radiators are utilized to warm the tube consistently which are fitted on the tube, every warmer having ability to warm up to 350watt.

- Total number of band radiators utilized are 3*350=1050 watt

2.2.1 Insulating Material used for Test Specimen

- Glass-wool
- Asbestos rope
- Plaster of paries
- Asbestos powder

2.3 Instrumentation and the Experimental Setup

A list of the important instruments employed during the conduction of the experiments in the present study is given below. They are

- Thermocouples,
- Digital Ammeter,
- Digital Voltmeter,
- Blower
- Temperature Indicator

Voltme: Digital voltmeter is a device which is used for measuring the voltage in the range of 440V. In this experimental setup it is used for measuring the input power of heater.

Ammeter: Digital ammeter is a device which is used for measuring the current in the range of 1200A. In this experimental setup it is used for measuring the input power of heater.

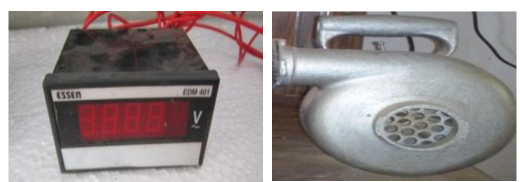


Fig 2.5 Typical digital voltmeter & Blower

U-Tube manometer

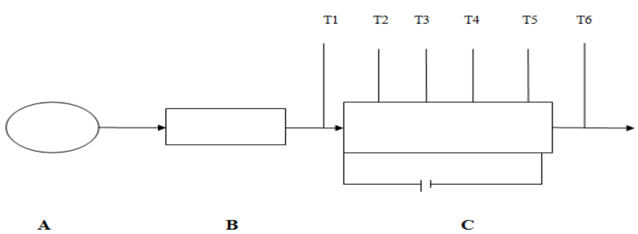
Systems have been developed for the estimation of weight and vacuum. Instruments which are used to measure weight are called weight gages or vacuum gages. A manometer could likewise be alluding to a weight measuring device, typically restricted to measure weights close to environmental. Manometer is generally used to allude particularly to fluid segment hydrostatic device.

Fig 2.6 Image showing the U-tube manometer

Centrifugal blower

A radial blower is one of the mechanical gadget used for moving the air or different gasses. They have fan with blades made out of various fan sharp edges, mounted around its periphery. As appeared in above, the center rotates on a driving shaft. That goes through the fan lodging. The gas passes through the sides of the fan blades, rotates around 90 degrees and quickens because of outward constrain as it streams over the fan cutting edges and leaves the fan lodging.

2.4 Experimental setup



A=Blower. B=Bellow.

C= Test section with heating coil.

T1=Thermo couple to read inlet temperature.

T2,T3,T4,T5=thermo couples to read surface temperature of test specimen

T6=Thermo couple to read outlet temperature.

Fig 2.8 Experimental setup arrangement

Fig.2.9 Experimental setup inclined to 60^O

Fig.2.10 Experimental setup inclined to 90^0

The examinations were done in an open-circle trial office as appeared in Fig. The circle comprised of a 7.5 kW blower, hole meter to quantify the stream rate, and the warmth exchange test segment. The steel test tube has a length of L = 400 mm, with 38 mm inward breadth (D), 40 mm external width (Do). The tube was warmed by electrical radiators a uniform warmth flux limit condition. The external surface of the test tube was all around protected to limit convective warmth misfortune to environment, and fundamental insurances were taken to keep spillages from the framework. The internal and external temperatures of the mass air were measured at specific focuses with the Chromel-consistent thermocouples. Five thermocouples were tapped on the surface of the tube and the thermocouples were put along the tube to gauge the temperature variety, which was observed to be immaterial. Also, another thermocouple is set at the exit of the tube to gauge the outlet temperature of the air which is brought out by the icy air through the blades inside.

2.5 Calibration of thermocouple

Keeping in mind the end goal to align the thermocouples, water in a recepticle is warmed and afterward temperature of a thermocouple is perused from a computerized temperature marker and RTD esteem is likewise noted and adjusted against the temperature of the water measured utilizing a mercury-in-glass thermometer.

The temperature measured by the thermocouples is perused utilizing a computerized temperature pointer. In any case, the exactness of the computerized temperature marker is restricted by the precision of the interior gadget, which might be a thermistor, gave by the producer to measuring the surrounding temperature. In any case, the temperature contrast ΔTtc as characterized underneath mirrors the exactness of the thermocouple which is not reliant or restricted by the precision of the inside thermistor gadget. Thus just the temperature distinction ΔTtc of the thermocouple is aligned against ΔTtm measured by the mercury thermometer as characterized beneath which is utilized as the reference for adjustment.

$\Delta T_{tc} = T_{tc} - T_{amb,\ indicator}$
$\Delta T_{tm} = T_{tm} - T_{amb,\ mercury}$
T_{tc} = Temperature of water in the water bath measured by the thermocouple.
$T_{amb,\ indicator}$ = Ambient temperature indicated by the digital temperature indicator.
T_{tm} = Temperature of water in the water bath measured by the mercury thermometer.
$T_{amb,\ mercury}$ = Ambient temperature measured by the mercury thermometer.
The rate blunder in thermocouple temperature estimation is presently characterized as

$$\% \text{ Error} = \frac{(\Delta Ttc - \Delta Ttm)}{\Delta Ttm} \times 100$$

Table 2.2. Thermocouple Calibration Results

Thermocouple T_1			Thermocouple T_2			Thermocouple T_3			Thermocouple T_4		
RTD	ΔT_{tc} (°C)	% Error	RTD	ΔT_{tc} (°C)	% Error	RTD	ΔT_{tc} (°C)	% Error	RTD	ΔT_{tc} (°C)	% Error
28.2	29.3	0.0390	28.2	29.2	0.036	28.2	29.3	0.390	28.2	29.4	0.043
30	31.1	0.0366	30	31.3	0.043	30	31.2	0.04	30	31.5	0.05

The strategy utilized for deciding the warmth exchange coefficient is to supply a known warmth contribution to the warming curl and measure the temperature achieved by the test show. Before undertaking the investigations an instability examination was performed to decide the impact of each of the parameters required on the vulnerability in the warmth exchange co-proficient qualities. The accompanying system is followed in directing trials.

Experimental procedure

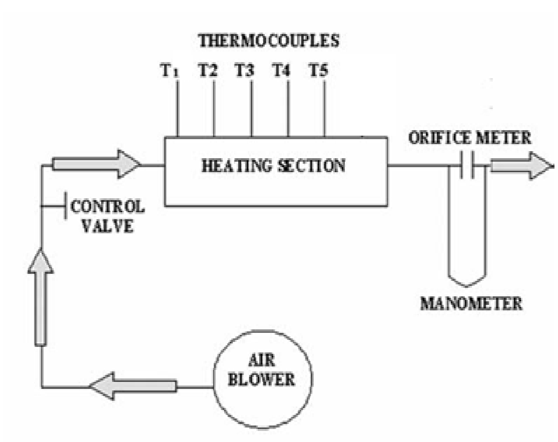


Fig.2.9 Schematic Representation of Experimental Setup

The trials comprise of an air blower to blow air through a tube. An esteem is given to control the wind current rate. A test area has been given in the straight bit extensively far from the twist so that at test segment the stream is completely created. A stream fixed is given. The test area has an electrical warmer which is protected to lessen the warmth misfortunes to the air. The test segment is given 4 thermocouples at various hub areas (T1, T2, T3, T4, and T5) to quantify the variety of the tube surface temperature along the test segment. Gulf and outlet air temperature is measured by giving two more thermocouples at the bay and the exit of the test area. Voltmeter and ammeter is given to gauge the rate of warmth info. Wind stream rate through the test area is measured by method for opening meter.

- Place the test area to a legitimate position
- Start the blower and switch on the warmer
- For anybody esteem opening position note down the manometer perusing to discover wind current rate
- Waite till the relentless state is come to. Take note of the thermocouple readings.
- Repeat the analysis for various warmth data sources, for example, 300w, 400w, 500w.
- Repeat the analysis for various estimation of wind current rate by keeping up the warmth input unaltered

2.7 Temperature steady state

It is vital to guarantee the enduring condition of an any temperature to guarantee the viable outcomes with the time, amid the conduction of examination it is important to achieve the consistent state with the time. This inspires to create the correct outcome.

The examination has been directed for plain roundabout tube having ID=38mm, and OD=40mm with various warmth input and diverse stream control of air has been watched and the information acquired from the plain tube and ascertained estimations of various warmth info, for example, 300w,400w,500w are classified in the table (1)

In the table it is plainly said that by shifting the speed of the air, variety of the Reynolds number may saw, for 300w,400w,500w warmth contribution with three diverse speed. What's more, by utilizing "Dittus-Boelter condition", Nusselt number is ascertained and after that test Nusselt number is additionally processed by utilizing exploratory warmth exchange coefficient. Furthermore, grinding variable is additionally found and it is mostly relies on upon the Reynolds number. From the table it is watched that with expanding speed, expanding the warmth exchange coefficient. What's more, higher the Nusselt number esteem higher will be the warmth exchange coefficient.

2.9 Data Obtained From the Plain Circular Tube:

Sl no	Q (W)	V (m/s)	Re	Nu_{th}	Nu_{exp}	h_{th} (w/m^2k)	h_{exp} (w/m^2k)	f
1	300	22.0697	51337.55	117.08	63.0926	83.1842	44.8290	0.0205
2		20.7257	47376.004	109.726	78.5028	78.7434	56.3361	0.021
3		18.2499	41123.062	97.9289	73.2082	70.8623	52.9800	0.0215
1	400	22.3102	50559.96	115.521	96.1685	83.2913	69.3372	0.0208
2		20.910	46309.59	107.646	105.137	78.4680	76.6400	0.0213
3		18.448	39935.38	95.5995	90.5721	70.39140	66.6900	0.0220
1	500	22.3668	50256.52	114.94	97.7751	83.2150	70.7842	0.0209
2		20.952	46004.693	107.074	97.6953	78.3340	71.4740	0.0213
3		18.43389	39569.99	94.9045	91.3984	70.1294	67.9390	0.022

2.10 Data Obtained From the horizontal Tube With Fin

Table 3.4. Showing the Result of the Tube With Pin Fin

Sl no	Q (W)	V (m/s)	Re	Nu_{th}	Nu_{exp}	h_{th} (w/m^2k)	h_{exp} (w/m^2k)	f
1	300	22.250	50868.569	352.81	293.395	253.18	210.55	0.02104
2		20.7823	46287.323	289.274	245.35	210.02	177.109	0.02328
3		18.292	41335.39	248.31	213.594	179.24	155.0823	0.02216
1	400	22.352	50367.778	349.572	345.75	252.78	249.306	0.02109
2		20.9521	46004.69	321.94	320.644	235.52	234.577	0.0216
3		18.8484	39790.59	292.27	287.255	215.74	212.04	0.02237
1	500	22.494	49390.22	343.3084	313.79	251.15	229.564	0.02119
2		20.9379	45197.84	316.7807	272.13	233.54	200.63	0.02167
3		18.573	39320.907	279.2058	249.46	207.64	185.525	0.0224

Table 3.2 Showing the Result of the Tube with Pin Fin inclined to 60^0:

Sl no	Q (W)	V (m/s)	Re	Nu	h_{exp} (w/m^2k)	ΔT (^{0}C)	ΔP	f
1	300	10	19886.90	54.83	273.14	21.9	14.75	0.0266
2		12	25064.28	65.97	277.662	22.7	20.90	0.0251
3		14	31165.31	78.55	287.18	42	31.56	0.0237
1	400	10	18683.63	52.04	191.164	39.5	14.61	0.0270
2		12	23522.34	62.611	232.20	34.5	21.246	0.0255
3		14	27425.71	70.826	265.85	32.9	27.23	0.0245
1	600	10	18262.2	51.022	234.67	46.4	15.076	0.0271
2		12	22421.38	60.14	237.78	52.9	21.47	0.0258
3		14	26622.22	69.06	271.09	53.6	27.45	0.0247

Table 3.3 Showing the Result of the Tube with Pin Fin inclined to 90^0:

Sl no	Q (W)	V (m/s)	Re	Nu	h_{exp} (w/m^2k)	ΔT (^{0}C)	ΔP	f
1	300	10	19824.87	54.690	232.937	27	14.77	0.0266
2		12	24033.554	63.763	234.67	26.2	21.17	0.0253
3		14	28107.41	72.314	316.045	19.9	27.066	0.0244
1	400	10	18882.788	52.477	212.80	58.1	14.95	0.0269
2		12	22387.480	60.072	257.86	43.1	21.49	0.0258
3		14	27238.170	70.414	276.26	33.2	27.28	0.0245
1	600	10	18125.09	50.72	183.62	61.5	15.10	0.0272
2		12	21675.204	58.489	204.53	59.5	21.67	0.0260
3		14	26524.720	68.848	275.846	45.6	27.418	0.0247

III. RESULT AND DISCUSION

The experiments conducted in the present work are summarized as follows:

Plain circular tube: Experimental investigation of plain tube is carried out at three different heat input, 300w, 400w, 500w.

Tube with fins; similar procedure has been followed same as in the plain tube to produce the results.

The outcomes are gotten for both plain tube and tube with blades are delineated in charts with differing heat information and Reynolds number as appeared. For each warmth input Nusselt number, rubbing element, warm exchange coefficient is exhibited.

Variety of warmth exchange coefficient, Nusselt number and grinding component: The variety of warmth exchange coefficient is seen by information got from the plain tube and the information got from the tube having inward balances.

3.1 Results of Nusselt number at 300w heat input

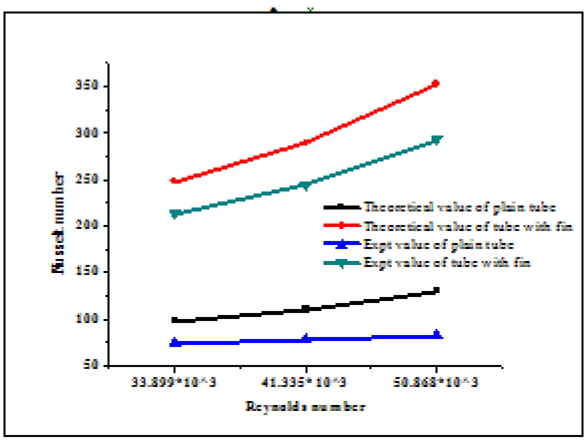


Fig 3.1(a) Variation of Nusselt number V/s Reynolds number

Tentatively decided Nusselt number qualities for plain roundabout tube (without inner balances) and tube with balances are thought about utilizing the above eqn.

Fig. 3.1(a) demonstrates the correlation between Nusselt numbers got tentatively and by utilizing Dittus-Boelter condition for plain tube. It is watched that the estimation of Nu (trial) is not as much as Nu (Dittus-Boelter). Also Nusselt number is anticipated by connected Nusselt number eqn for tube with blades, it demonstrates a similar condition yet the test Nusselt number is higher than the exploratory estimation of plain tube because of higher warmth is diverted by the tube having balances inside, and Actual warmth diverted by breezing through air through the test area is the mix of convective and radiative warmth exchanges. As the warmth exchanged by convection alone is considered while figuring the outcome.

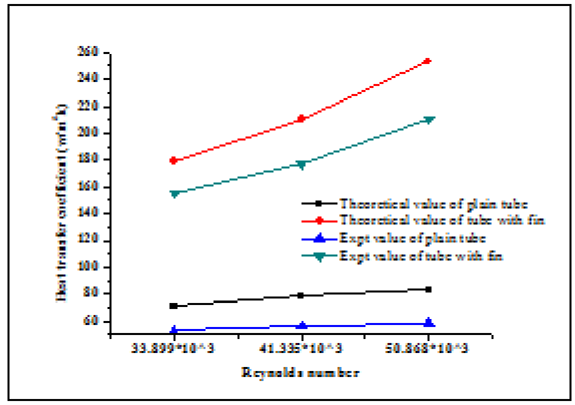


Fig 3.1 (b) Variation of the heat transfer coefficients V/s Reynolds Number

Fig 3.1(b) shows the both theoretical and experimental values for plain tube and tube having fins inside data's are depicted graphically, in the plain tube experimental heat transfer coefficient is less than the theoretical value due to the some amount of heat loss from the surface and leakage loss, but in the tube with fins experimental value is also less than the theoretical value but from the graph it is clear that experimental value of heat transfer coefficient is higher than the value of plain tube due to increase in the surface area and heat carrying capacity of air by fins provided inside the tube.

3.1.2 Results of friction factor at 300w heat input:

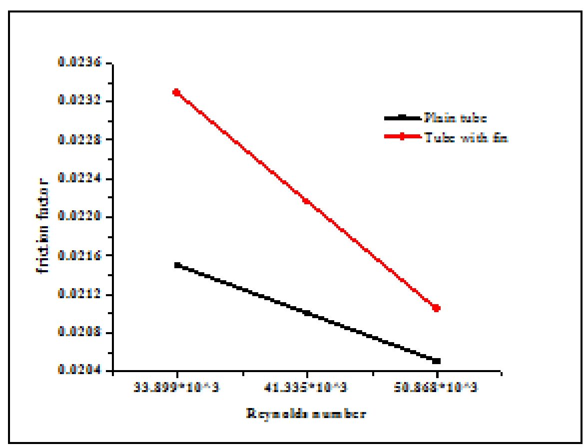


Fig 3.1 (c) Variation of Friction factor V/s Reynolds number

Figs 3.1(c) demonstrating the outcomes acquired by the plain tube and tube with blades are portrayed and grating element is plotted against the Reynolds number. By observing the plots obviously the erosion calculate is higher the instance of tube having the inside set balances, however the rubbing variable is less in the plain tube because of smooth surface inside the plain tube, in the tube with blades having interior balances and it goes about as deterrents for the stream of air and smooth relentless stream is impractical and i.e. considered as unpleasant surface.

3.2 Result showing the Nusselt number at 400w heat input

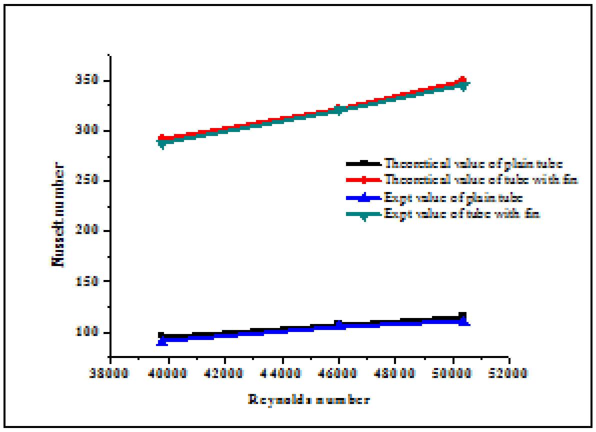


Fig 3.2 (a) Variation of Nusselt number V/s Reynolds number

Fig 3.2(a) exhibits the Nusselt number qualities plotted against the Reynolds number. The data's are plotted at the glow commitment of 400 watt warm farthest point which is measured by voltmeter and ammeter, from the outline it is watched that exploratory qualities are closer to the foreseen a motivator due to proper insurance and addition in the glow input. The examinations have made between plain tube and tube with sharp edges inside, and higher estimation of Nusselt number is found in the tube having equalizations which is illuminated some time recently.

3.2.1 Result of heat transfer coefficient at 400w heat input

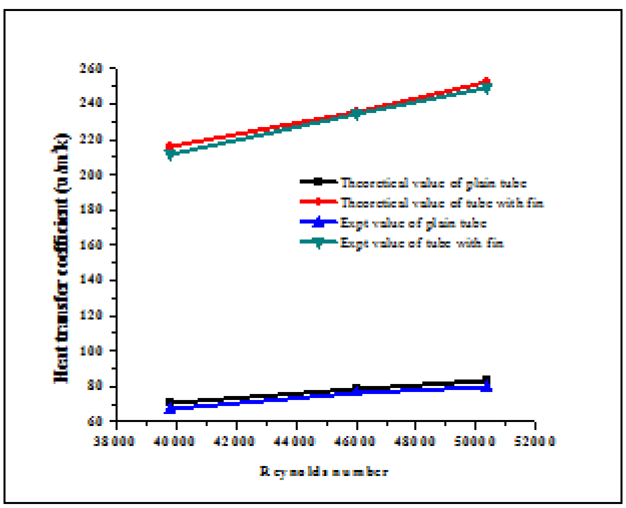


Fig 3.2 (b) Variation of heat transfer coefficient V/s Reynolds number

Fig 3.2(b) demonstrates the warmth exchange coefficient against the Reynolds number for the warmth contribution of 400 watt warm information limit is provided and for this situation likewise warm exchange coefficient is higher on account of tube having balances inside the tube, it is because of high warmth conveying limit of the air.

3.2.2 Results of friction factor at 400w heat input:

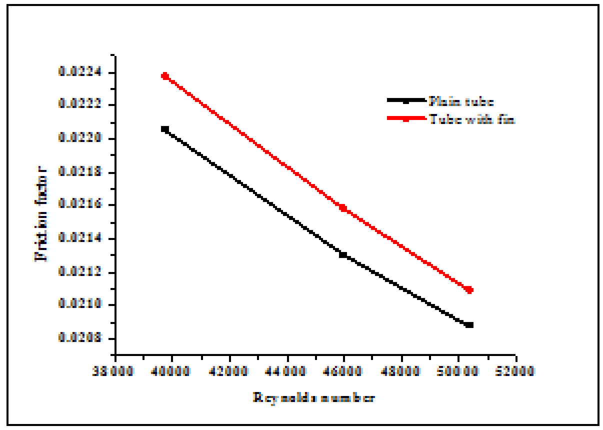


Fig 3.2 (c) Variation of friction factor V/s Reynolds number

Fig 3.2(b) demonstrates the warmth exchange coefficient against the Reynolds number for the warmth contribution of 400 watt warm info limit is provided and for this situation additionally warm exchange coefficient is higher on account of tube having blades inside the tube, it is because of high warmth conveying limit of the air.

3.3 Results of Nusselt number at 500w heat input

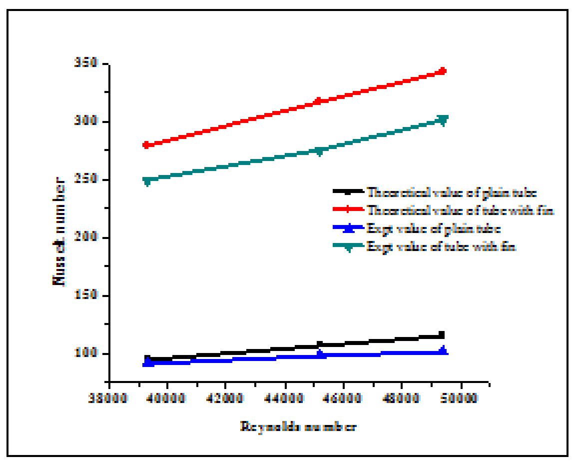


Fig 3.3 (a) Variation of Nusselt number V/s Reynolds number

Fig 3.3(a) demonstrates the variety of Nusselt number v/s Reynolds number in the plain tube and tube embedded with blades inside are seen at various rates of speed. It is watched that for all cases, Nusselt number increments with expanding Reynolds number. It is watched that for tube with inside set balances the warmth exchange rates are higher than those from the plain tube.

3.3.1 Results of heat transfer coefficient at 500w heat input:

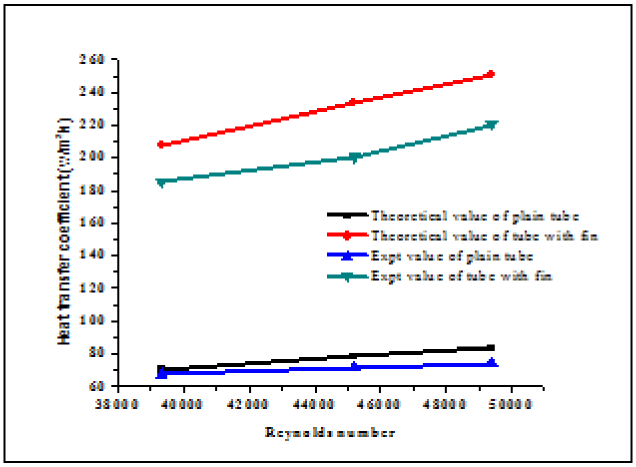


Fig 3.3 (b) Variation of Heat transfer coefficient V/s Reynolds number

Fig 3.3(b) demonstrates the variety of warmth exchange coefficient with the Reynolds number in the plain tube and the tube with the balances, at warmth contribution of 500 watt warm provided to the test area. From the chart it demonstrates that warmth exchange coefficient is higher on account of tube with balances because of increment in the surface region and turbulence is created because of the balances and which is contrasted and the both hypothetical estimations of plain tube and tube with balance.

3.3.2 Result of friction factor at 500w heat input

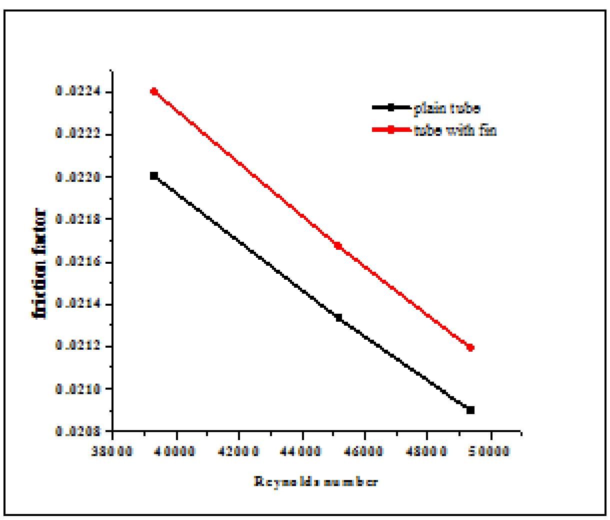


Fig 3.3 (c) Variation of Friction factor V/s Reynolds number

Fig 3.3(c) demonstrates the grating element v/s Reynolds number for the instance of 500watt warmth contribution to the test segments and is contrasted and the erosion consider information got by the plain tube. From the diagram it demonstrates that the rubbing component is high in the tube with balance. As Reynolds number increments there is increment in the grating component for both the tube can watched.

In the above outcomes and talk information acquired by the plain tube and the tube with balance component inside the container of both hypothetical and test information's are analyzed and they are exhibited in the charts 3.1(a), 3.1(b), 3.1(c), for the warmth contribution of 300watt warmth limit. 3.2(a), 3.2(b), 3.2(c) plotted for the warmth limit of 400 watt warm info and the 3.3(a), 3.3(b), 3.3(c) are plotted at the warmth limit of 500watt warmth input. By looking at the outcomes acquired at various Reynolds number in both the tube shows that every one of the components, for example, warm exchange coefficient, Nusselt number erosion figure all have expanded the tube having blades than plain tube.

IV.CONCLUSION

Test examinations of warmth exchange coefficient, Nusselt number and erosion element of a plain roundabout tube and a round tube with stick balances inside are depicted in the present report. The conclusions can be drawn as takes after:

1. The warmth exchange coefficient increments for a test tube with blades inside than those for plain tube this is because of the way that there is increment in the surface zone of the tube gave by the stick balance, which builds the turbulence of air.
2. The rubbing component increments for a test tube with balances than the plain tube, on the grounds that in the test tube with balances whirl stream is created and blades oppose the stream of air.
3. The improvement of Nusselt number is higher on account of tube with blades, than plain tube as a result of the amplified surface and high turbulence and higher Reynolds number.
4. The heat transfer coefficient increases for the tube inclined at 60, 90 degrees this is due to increasing the velocity. Heat transfer coefficient is increased in the 60 degree inclination compared to 90 degree.
5. The enhancement of Nusselt number is higher in the tube inclined at 60^0, compare 90 degrees at the velocity of air increases with increasing the nusselt number and also the heat input increases with decreasing the Nusselt number.

V. SCOPE OF THE FUTURE WORK

1. Varying the state of the blade inside the tube, and differing the measurement and dividing of balance Future work can be done.
2. By utilizing diverse material and distinctive rate of warmth info examination of those materials with the others can be made.
3. Numerical demonstrating can be completed.
4. CFD reenactments can be completed.
5. Similar reviews can be brought for test segment with various embeds and watch the warmth exchange marvel.

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