HEAT TRANSFER ENHANCEMENT RATE OF A PIPEUSING DIFFERENT TYPES OF INSERTS

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***Abstract*:**

An Experimental work is carried out to enhance the heat transfer rate under turbulent flow condition in a pipe using different types of inserts. Experimental data obtained for friction factor and Nusselt number using the different types of inserts exhibited enhanced heat transfer rate. When using the inserts the maximum heat transfer advantage is obtained while using spiral- rectangle blocks insert. The Performance Evaluation Coefficient (PEC) has been taken into account the increase both in Nusselt number and friction coefficient with insert in relation to flow and heat transfer without inserts. The results for PEC at various Reynolds number indicate a true augmentation in heat transfer up to 126% increase in Nusselt number is obtained using spiral- rectangle blocks insert associated with 140% increase in friction factor.

Index Terms: *Nanofluid; Heat Transfer; Nusselt Number; HeatExchanger.*

I. INTRODUCTION

Augmentation of convective heat transfer in internal flows with tape inserts in tubes is a well-acclaimed technique employed in industrial practices. Most of the early work was concerned with the effect of twisted tape, louvered square leaf, spiral grooved twisted tape inserts etc. **S. Naga Sarada et al [1]**conducted a test examination on expansion fierce stream Heat move upgrade for air in a level cylinder utilizing louvered square leaf additions of various kind (90̊, 60̊ FW, 60̊ BW, 30̊ FW, 30̊ BW). The Friction factor and Nusselt number got tests were approved against those got from hypothetical qualities. It is seen that Nusselt number expanded by a limit of 128.39%, 121%, 81.31%, 30.03%, and 32.72% within the sight of 90̊, 60̊ forward and in reverse, 30̊ forward and in reverse square leaf embed separately. Rubbing component expanded by a limit of 441.31%, 369.17%, 143.43%, 116.48% & 80.39% within the sight of 90̊, 60̊ forward, 60̊ in reverse, 30̊ forward, 30̊ in reverse square leaf embed separately. Additionally watched the most extreme generally speaking improvement proportions were 1.30, 1.32, 1.34, 1.02, 0.79 within the sight of 90̊, 60̊ forward, 60̊ in reverse, 30̊ forward, 30̊ in reverse square leaf embed separately Grinding factor, heat move and upgrade effectiveness attributes in a roundabout cylinder fitted with funnel shaped ring tabulators and a contorted tape twirl generator were tentatively researched by **Promvonge and Eiamsa-ard et al [2]**. Reynolds number shifted from 6000 to 26000. Air is utilized as a working liquid. The turn proportions 3.75 and 7.5 are utilized for cone shaped and wind tape embed separately. The normal Heat move rates are observed to be 367% and 350% over the plain tube.

S. Naga Sarada et al [3] conducts an exploratory examination of the capability of decreased width wound tape additions to improve the pace of Heat move in a flat tube violent cylinder tempestuous stream with air as a liquid. Overall improvement proportion of the cylinders is 1.62 for full width wound tape and 1.39 for diminished width 22mm curved tape embed. Nusselt number diminished by a limit of 8% and 29% for tape widths of 22mm and 10mm separately when contrasted with full width curved tape embeds. The presentation of turned tape of width 10mm is 1.08-1.18 occasions superior to for a smooth cylinder. **Sunil Jamra et al[4]** directed the test examination of Heat move improvement in round two fold cylinder heat exchanger utilizing rectangular embeds and saw that the virus air in surrounding condition is taken as a working liquid and went through the internal pipe while high temp water is moving through external cylinder. Tests were performed for parallel stream and counter stream and after that the outcomes were contrasted with the plain cylinder heat exchanger and furthermore utilizing rectangular additions. Normal increment in Heat move rate was 100-172 % in correlation with the smooth cylinder with Reynolds number extending from 10000 to 110000. Increment in Nusselt number of roughly 1.9 occasions was gotten through this trial. Also, weight drop discovered most extreme 1.7 occasions contrasted with that of plain tube. **M. M. K. Bhuiya et al[5]**deals with the test examination on Nusselt number, grating variable and warm execution in a round cylinder furnished with punctured contorted tape embeds with four distinct porosities of R_p= 1.6, 4.5, 8.9 and 14.7 %. There will be increment in Friction factor, Nusselt number and warm execution factor with 110-340%, 110-360%, and 28-59% individually when contrasted and smooth cylinder. **S D Patil et al [6]** trial examination led for Heat move and erosion figure trademark a twofold pip heat exchanger fitted with straight delta winglet and normal curved tape. It is seen that with increment in contort proportion, heat move coefficient increment and yet weight drop additionally increments. The bend proportion straight delta winglet indicates more noteworthy Heat move coefficient and erosion factor than those with run of the mill turned tape. The attributes of Heat

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move and execution proportion of tempestuous stream wind current in a round cylinder fitted with louvered strip additions were examined by **A. W. Fan et al [7]**. The Nusselt number is expanded by a 2.75-4.05 occasions than the smooth cylinder. The estimation of execution assessment criteria (PEC) range will be changed with 1.60-2.05, which shows that the louvered strip supplement has a generally excellent by and large thermo water driven execution. The computational outcomes show the bigger inclination edge and little pitch can viably upgrade the Heat move rate, yet in addition increment the stream opposition. The Friction factor and Nusselt number are touchier to the inclination edge than the additions pitch. **Chintan Prajapati et al [8]** assessed the Heat move improvement utilizing curved tape and they saw that the wound tape rectangular winglet with d/W=0.3 yields the most noteworthy Nusselt number which is around 100% . Heat move and rubbing variable increments as the tape contort tape proportion and helical pitch proportion diminishes while the exhibitions appear inverse trends. Nusselt number expanded with lessening with of freedom proportion (c/D) and turn proportion (y/D) additionally expanded concerning Reynolds number. Heat move can be gotten in turned tape in clock astute and counter clockwise game plan and the expanded rate are observed to be 219% and 204% separately over the plain tube. **Sami D Salman et al [9]** directed an examination in CFD reproduction of Heat move enlargement in steady Heat fluxed tube with astounded curved tape additions and they saw that the numerical reenactment done of roundabout cylinder fitted with bent tape embeds in laminar stream (200≤Re≤2300) and consistent Heat motion. Reproduction done through Fluent for Heat move and rubbing factor for plain cylinder and confused contorted tape embeds with various bend tape embeds with various confound point (β=0̊, 30̊, 90̊) and diverse turn ratio(y=2.93, 3.91, 4.89) and Nusselt number and grating element for the cylinder with astounded bent tape are perceptibly higher than the qualities for the plain cylinder and cylinder with plain wound tape also. Astounded curved tape offered extra Heat move upgrade with less rubbing component contrast with right left helical tape embed. **Gurveer Sadhu et al [10]** trial study on the effect of supplement gadgets on the warm presentation of level plate sun oriented authority. Distinctive geometrical states of supplements were viewed as which incorporate wound tape, wire curl and wire work embed. The meh supplement played out the best in laminar stream system and increased Nusselt number by 270%. Concentric loops performed best in tempestuous stream and Nusselt number increments up to 460% when contrasted with smooth tube with no supplements. **M A K Choudhury et al [11]** directed a trial examination of violent stream Heat move through cylinder with pole stick embeds and established that four supplements with various longitudinal stick dividing (50mm, 100mm, 150mm and 200mm) are utilized in the trial. The Reynolds number Heat move coefficient for cylinder supplements is higher that of the smooth cylinder by up to 4.1 occasions when x=50, up to 4.2 occasions when x=100mm, up to 4.4 occasions higher when x= 150mm and up to occasions higher for x=200mm.The siphoning force required for cylinders withpole in additions might be up to multiple times higher than smooth cylinder. It is additionally watched cylinder with bar stick supplement having pin separation with performs better. **M A R Saarkar et al [12]** led an investigation on Heat move in violent course through a round cylinder with turned tape embeds. Three distinctive contort proportions Y=23, 11.5 and 8 are taken. Grinding variable is high close to the bay segmentand drops bit by bit to the completely created stream. Normal Heat move coefficient for cylinders with contorted tape supplements is about 1.3 to multiple times higher than the smooth cylinder. **Shashank et al [13]** directed a test study on impact of curl wire embed in heat transfer upgrade and rubbing element of twofold pipe heat exchanger. Three curl supplements are comprised of copper; aluminum and treated steel were utilized in internal container of twofold pipe heat exchanger. The pitches of copper additions are 5.0; aluminum supplements are 10.0mm and tempered steel additions is 15.0mm. Erosion factor and Nusselt number are determined from the trial esteems. The greatest Nusselt number is watched for copper coil wire embed than aluminum and hardened steel curl I wire embed. The copper, aluminum andtempered steel wire addition cause Heat move upgrade up to 1.58, 1.41 and1.31 % separately when contrasted with plain tube. Erosion factor saw to increment with the diminishing pitch of curl wire embed. Additionally it is higher for aluminum supplement of 5mm pitch than tempered steel and copper curl wire supplement of 10mm and 15mm pitch individually by **Smith Eiamsa-ard et al [14].** Cold and hot waters are utilized as the test liquids in shell and cylinder sides individually. Reynolds number fluctuates from 2000 to12000. Screw tape inclusion in the cylinder is considered asa free fit. The improvement proficiency fluctuates somewherein the range of 1 and 1.17, 1.98 and 2.14 with and without center bar individually. **N.B.Dhamne et al [15]** increase of tempestuous stream heat transfer in an even tube by methods for wavy curved tape embeds. Air as working liquid investigations were completed for plain tube with/without additions at consistent Heat transition and diverse mass stream rates. Three distinctive turn proportions 8.33, 9.79 &10.42 are utilized. The Reynolds number shifts from 4000 to 9500. The aftereffects of Heat move coefficient and weightdrop are contrasted and those of plain tube. It was seen that the upgrade of Heat move with wavy turned tape supplements fluctuated from 17 to 45 % contrasted with plain tube. Greatest erosion factor was about 100% for bend proportion 8.33 and 150% for contort proportion 10.42 for wavy bent tape embeds. The general improvement for the cylinders with 1.45 for wind proportion 10.42 for wavy turned tape addition and wavy curved tape supplements is 1.40 for contort proportion 8.33. **A.V.Gawandare et al [16]**, exploratory work is completed with copper turned tape embeds 3mm with 5.2, 4.2 and 3.2 contort separately. Assurance of contact factor and Heat move coefficient for different curved wire embeds with Reynolds number range from 5000 to 16000. Increment in Nusselt number by 19.5% for the 3mm thick with 3.2 contort copper embed when contrasted with the smooth cylinder. Tests were performed to gather Heat move

Pankaj. N. Shrirao et al [17]. The scope of Reynolds number from 3000-18000. Exploratory outcomes are accounted for three unique channels for example smooth rectangular conduit, rectangular channel and ceaseless V-formed ribs and rectangular pipe with discrete V-molded ribs. The Heat move coefficient and rubbing variable are contrasted and the consequence of smooth conduit under comparative stream conditions. The rubbing component increments with an expansion in a Reynolds number. The outcomes acquired that the discrete V -molded ribs produce less Heat move upgrade than the consistent V-formed ribs. Past investigations have not tended to the heat transfer in cylinders with plain pole of 8mm square, winding over bar, winding and square obstructs over pole, winding and square shape hinders over bar and winding and pyramid obstructs over pole embeds in violent area. Subsequently the present examination endeavors to tentatively explore the grating variable and heat transfer qualities of wind stream moving through a level round about cylinder with five unique kinds of additions and an endeavor is made to create relationship.

II. Experimental Details

A. Experimental Setup

The experimental setup comprises of blower unit fitted with pipe flat way. The warmer encases the test area and the length of the test segment is 610mm. 6 thermocouples are put in the examination. Among them, four are installed on mass of the cylinder, 2 thermocouples put at the passageway of the air stream and the other will be at out of test segment to gauge temperature of streaming air. An opening is associated with the test pipe to gauge the progression of air through the pipe. Speed of wind stream in cylinder estimated assistance hole plate and water manometer fitted in the mechanical assembly. The internal breadth of the testing cylinder is 27.5mm and is made of 3.2 mm thick copper plate. The unit comprises of voltmeter, ammeter temperature pointer and dimmer detail. Test pipe segment of the outlet is associated with an opening meter and a manometer so the weight drop, mass stream rate are estimated. Distinction in the degrees of manometer liquid speaks to the varieties in the weight because of the opening meter. The liquid properties were determined as the normal between the gulf and outlet mass temperature. By and large it typically takes an hour and a half to arrive at unfaltering state. Investigations are led at steady Heat info and distinctive mass stream rates, with and without supplements. The trials are completed with the five distinct sorts of additions and are probably going to be named as (1) plain rod, (2) spiral insert, (3) spiral-square insert, (4) spiral-rectangle blocks insert, and (5) spiral-pyramid blocks insert.

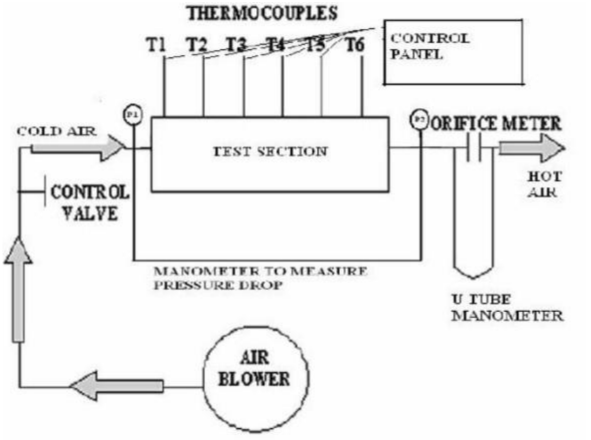

Fig 1: LINE DIAGRAM OF FORCED CONVECTION

T1= Inlet Temperature

T6= Outlet Temperature

T2, T3, T4, T5 = Surface Temperature of Pipe

The connection of the experimental setup is made as shown in the above figure 1 i.e. the inlet of the heating section is connected to the blower and outlet to the orifice meter. Thermocouples are placed on the test pipe section. The 2 of 5 different types of inserts used in the experiment are shown below:

Fig 2: (a) Spiral Insert, (b) Plain Rod

The main aim of the experimentation is to improve the heat transfer in a cylinder by utilizing various sorts of additions. Additionally decide Nusselt number & Friction factor for Reynolds number extending from 8000-14000. Nusselt numbers Friction elements of working liquid (air) streaming in the plain cylinder are contrasted and normal Nusselt numbers, Friction components of working liquid (air) streaming in cylinder with additions which upgrade heat transfer.

III. Calculations

The experimental calculations are presented for different types of inserts are presented below:

1. T1=35.1 , T6=36.3

$$T_b = \frac{T_1 + T_6}{2} = \frac{35.1+36.3}{2} = 35.7\,^{\circ}C \text{ or } 308.7 \text{ K}$$

2. $T_s = \frac{38+38.8+41.7+41.2}{4} = 39.9°C$ or 312.9

3. $h_{air} = \frac{\rho_w h_w}{\rho_a} = \frac{1000*5*2.54*10^{-4}}{1.147}$ =110m

4. d = $\frac{C_d A_p A_o \sqrt{2g\, h_{air}}}{\sqrt{(A_p^2 - A_o^2)}}$ = $\frac{0.64*5.93*10^{-4}*1.539*10^{-4}*\sqrt{2*9.81*110}}{\sqrt{(5.93*10^{-4})-(1.539*10^{-4})^2}}$

d=4.7*$10^{-3} m^3/s$

5. U $= \frac{d}{A_p} = \frac{4.7*10^{-3}}{5.93*10^{-4}}$ =7.9 m/s

6. m=$\rho AU =$1.147x5.93x10^{-4}x7.9=0.00537 m/s

7. Re = $\frac{\rho v D}{\mu} = \frac{1.147*7.9*0.0275}{18.875*10^{-4}}$ =13201.8

8. $Q_r = A\sigma\varepsilon_c\left(T_S^4 - T_b^4\right)$

= 5.87x10^{-4} x 3.14 x 0.0275 x 0.61 x 0.725 x ($312.9^4 - 308.7^{4})$ =1.09

9. $Q_c = \frac{\Delta T}{R_{th}} = \frac{36.3-27}{0.4944}$ =18.8

10. $Q_{net} = 30 - 18.8 - 1.09 = 10.09$

11. Hydraulic diameter = D_h = $\frac{4A}{P}$ = $\frac{4(\frac{\pi}{4}D_o^2 - insert\ area)}{\pi D + insert\ perimeter}$

= $\frac{4(\frac{\pi}{4}D_o^2 - (\frac{\pi}{4}(D_o^2 - D_i^2) + a^2))}{\pi D + (\pi D + 4a)}$ = 0.01556 m

Where,

D_0 = 15.3×10^{-3} m

D_i = 13.3×10^{-2} m

a = 8×10^{-3} m

$D = 0.0275$ m

12. $h_{exp} = Q_{net}/[\pi DL(T_s - T_b)]$

$= \frac{10.09}{3.14*0.0156*0.61*4.2}$ =80.6

13. $Nu_{exp} = (h_{exp} * D)/K$

$= \frac{80.6*.01556}{0.02735}$ =45.8

Pressure drop $\Delta p = \rho_2 g h_2$

$\rho_1 h_1 = \rho_2 h_2$

$1000 \times 1.3 \times 10^{-3} = 1.147 \times h_2$

$h_2 =$ 1.133 m

$\Delta p = \rho_2 g h_2$ = 1.147 × 1.133 × 9.81 =12.7

Where,

ρ_1 – Density of water, (m^3)

h_1 = Height of the water column, (m)

h_2 = Height of the air column, (m)

14. $f = \frac{2D\Delta p_{exp}}{LQ_a U^2} = \frac{2*0.01556*12.7}{0.61*1.147*7.9^2}$ =0.00905

$PEC = \frac{Nu_i/Nu}{(f_i/f)^{1/3}} = \frac{(45.8/36.4)}{(0.00905/0.00856)^{0.33}}$ = 1.18

By computation, Re number, mass stream rates, Nu number & friction factor are established and recorded in the accompanying tables.

Table 1: SMOOTH TUBE

Flow rate	Mass flow rate(kg/sec)	Reynolds number	Nusselt number	Friction factor
1	0.003447	8537.6	24.3	0.01217
2	0.004112	10165.1	28.7	0.01059
3	0.00482	11901.9	33.7	0.00905
4	0.00537	13248.7	36.4	0.00856

Table 2: PLAIN ROD

S. No	Mass flow rate(kg/sec)	Reynolds number	Nusselt number	Friction factor	PEC value
1.	0.00340	8353.4	34.8	0.02733	1.42
2.	0.00412	10243.4	35.5	0.01744	1.23
3.	0.00479	11834.6	40.4	0.01202	1.19
4.	0.00542	13467.5	43.1	0.008701	1.18

Table 3: SPIRAL INSERT

S.No	Mass flow rate(kg/sec)	Reynolds number	Nusselt number	Friction factor	PEC value
1.	0.00341	8389.2	32.7	0.02722	1.3
2.	0.004159	10212.4	38.4	0.0174	1.21
3.	0.00488	12073.0	42.2	0.01186	1.2
4.	0.00537	13201.8	45.8	0.00905	1.18

Table 4: SPIRAL-SQUARE BLOCKS INSERT

S.No	Mass flow rate(kg/sec)	Reynolds number	Nusselt number	Friction factor	PEC value
1.	0.00344	8465.1	50.0	0.02684	1.57
2.	0.00407	10384.1	51.8	0.0171	1.5
3.	0.00503	12361.3	52.9	0.01195	1.43
4.	0.00537	13303.0	55.2	0.00947	1.4

Table 5: SPIRAL-RECTANGLE BLOCKS INSERT

ρ_2 =Density of air, (m^3)

S.No	Mass flow rate(kg/sec)	Reynolds number	Nusselt number	Friction factor	PEC value
1.	0.00346	8594.8	55.0	0.0293	1.73
2.	0.00419	10405.8	59.1	0.019	1.71
3.	0.00486	12024.9	62.3	0.01345	1.63
4.	0.005416	13365.6	64.7	0.01035	1.6

Table 6: SPIRAL-PYRAMID BLOCKS INSERT

S.No	Mass flow rate (kg/sec)	Reynolds number	Nusselt number	Friction factor	PEC value
1.	0.00344	8558.5	53.2	0.02839	1.64
2.	0.004113	10134.9	54.1	0.019	1.57
3.	0.00486	12009.9	55.9	0.01283	1.48
4.	0.005417	13363.1	60.5	0.00983	1.45

IV. RESULTS AND DISCUSSIONS

Trial examinations on violent stream Heat move improvement utilizing plain pole, winding addition, winding square squares embed, winding square shape squares embed, and winding pyramid squares embed with Reynolds number fluctuating from 8000 to 14000. It was seen that by utilizing cylinder additions Heat move improvement could be acquired. Henceforth, for further examination Heat move upgrade by utilizing cylinder additions was mulled over. In light of the perceptions and the qualities got, the accompanying charts are attracted to speak to the outcomes. The present test study contains graphical portrayals for the different basic parameters associated with the procedure.

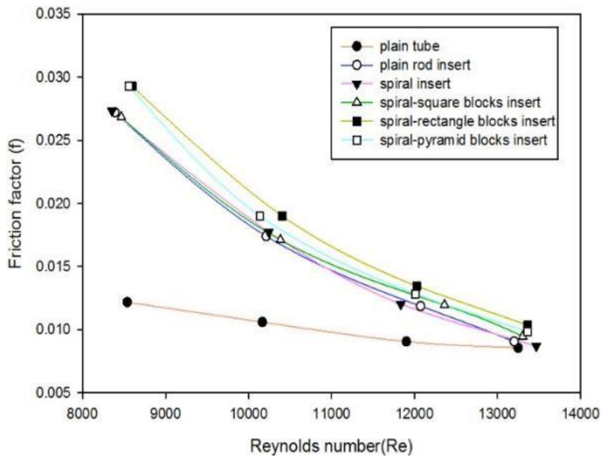

Fig 3: Variation of Friction factor with Reynolds number

Fig 3 demonstrates the variety of Friction factor with Reynolds number between the plain tube and the various kinds of additions utilized in the experiment. As the Reynolds number increment contact factor diminishes. Friction factor is higher for winding square pole with rectangular connection embed when contrasted with plain tube. This is because of the obstacle caused because of the wind stream at the sides of rectangular connection prompting the higher grating elements. Friction factor expanded by a limit of 140% for

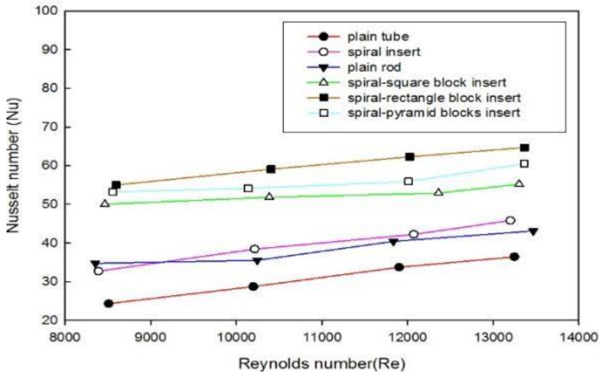

Fig 4: Variation of Nusselt number with Reynolds number

Fig 4 demonstrates the variety of Nusselt number with Reynolds number which contrasting the consequences of and embeds in the gear to without inserts. Nusselt number increments as the Reynolds number increments. The nearness of supplements inside the level cylinder caused choppiness bringing about improvement of convective Heat move.

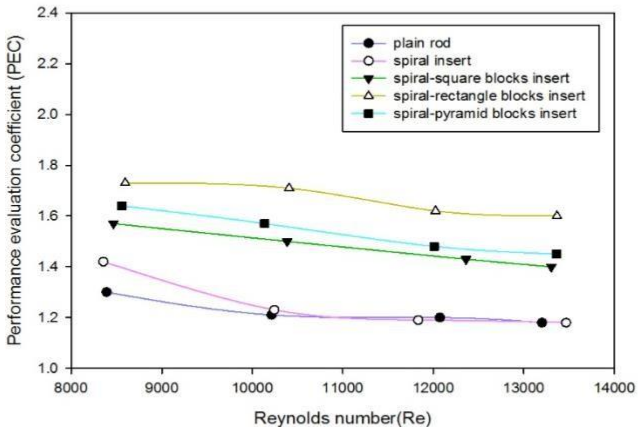

Fig 5: Variation of Performance evaluation coefficient with Reynolds number

Fig 5 demonstrates the variety of Performance assessment coefficient with Reynolds number and contrasting among and without inserts. Overall upgrade proportion is helpful to assess the nature of the improvement system. It is resolved that the ideal geometry of supplements that could give the most extreme Heat move improvement proportion with lesser grating element. Overall improvement proportion for the instance of rectangular connection addition is seen to be higher than every single other supplement utilized in the present work

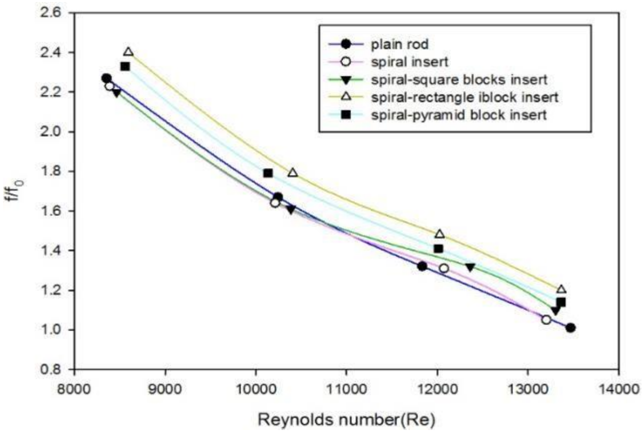

Fig 6: Variation of friction factor ratio with Reynolds number

Fig 6 demonstrates the variety of erosion factor proportion with Reynolds number for various kinds embeds. It is seen that the Reynolds number builds the erosion factor proportion diminishes. In the wake of looking at the charts the winding square shape squares addition got the best estimation of grating element proportion among every single other supplement.

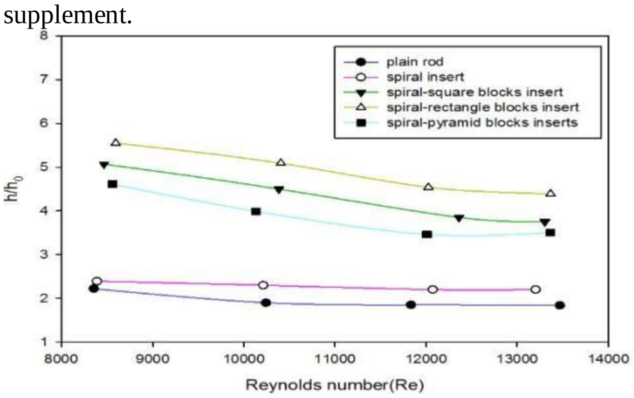

Fig 7: Variation of heat transfer coefficient ratio with Reynolds number

Fig 7 demonstrates the variation of heat transfer coefficient ratio with Reynolds number.as the Reynolds number builds the Heat move proportion diminishes. The winding square shape squares addition acquired the best estimation of Heat move proportion among every single other supplement when looked at. The Spiral-Rectangle squares supplement got the best and higher estimations of Nusselt number, contact factor, Performance Evaluation coefficient when contrasted and plain cylinder and every other addition utilized in the trial. The Heat transfer ratio and contact factor proportion likewise acquired the most astounding an incentive for the Spiral-Rectangle squares embed when contrasted and different supplements.

V. CONCLUSION

The investigation of wind current utilizing five distinct sorts of supplements in a flat round cylinder with 8000 to 14000 is appeared. The notable ends that can be drawn from the exploratory examination are:

- The Nusselt numbers increment with additions type (1) through type (5) in this experiment. The base is 18% with plain bar and a most extreme be 126% to the square shape squares embeds.
- The execution assessment coefficient fills in as a measure to decide the increase in Heat move with additions.
- The arrangement of examinations directed with five unique kinds of supplements would be helpful for application in mechanical Heat exchangers
- With the expansion in Reynolds number, Nusselt number increments and grating component diminishes.
- Enhancement of Heat move in contrast with plain cylinder is most elevated for Spiral-Rectangular square insert.

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