

# Heat Transfer Augmentation in Tube with Modifies Spring Inserts

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**Abstract:** Compact heat exchanger has a broad scope of applications that include air conditioning devices, heat pumps, automotive radiators etc. This is because of the fewer amounts of required volume and lower weight compared to other cases of heat exchangers. To raise the high temperature transfer rate in compact heat exchanger different strategies are employed that are an addition of fins, use of vortex generators or the exercise of any novel materials. The current research effort deals with analysis of heat transfer distinctiveness of tubes fit by the spiral, conical and convergent-divergent spring inserts. Experiment is carried off along the downy tube exclusive of inserts, tube fitted with conical, helical and modified convergent-divergent conical spring inserts. The increases transfer rate of high temperature is studied by varying the position of helical, conical and convergent-divergent spring inserts for the range of 4500 to 14500 for Reynolds number. The friction factor and Nusselt number values of the helical spring inserts are 1.9 times higher than to the downy tubes respectively. Compared to the down tube with pitch ratio ( $p/d$ ) of 1.5 and the wire diameter ratio ( $e/d$ ) of 0.8 in convergent divergent spring inserts, the peak improvement in Nusselt number is discovered to be 2.2 times higher. Experimentally, the friction decreases as the Reynolds number increases.

**Keywords:** Insert, Convergent-Divergent Spring Insert, Friction Factor, Nusselt Number Enhancement

## I. Introduction

Over the last two centuries, in the parliamentary procedure, considerable attempts have been made to develop various innovative heat transfer augmentation techniques and to perk up the on the whole functioning of different thermal systems used in the various industries. Heat transfer augmentation techniques are more often than not applied to raise the operation of heat transport systems like heat exchangers, solar air heaters, refrigeration systems, machines, chemical processes, etc. Different researchers have been engaged in various heat transfer augmentation method to increase thermal system operation.

Augmentation techniques in heat transfer, mainly include some active and passive techniques, but when compared the two, the reflexive heat transfer increase techniques shows a considerable advantage over the active heat transfer augmentation techniques [1], [2]. The heat exchangers are the very important system used in most of the manufacturing industries and the heat transfer augmentation techniques can be effectively integrated into these existing schemes. Thereflexive techniques can be developed by introducing adapted geometries or customized surfaces like treated surface, rough surface, extended surface, insert advertising. Several heat inserts are widely used as reflexive heat transfer system and can be any geometry such as twisted tapes, delta winglet twisted tapes, conical, helical. Garcia et al. [3]. When performed the investigational analysis in laminar and alteration regimes on three wire coils of dissimilar pitch inserted in a downy tube. At Reynolds number around 1000, the wire inserts add to the heat transfer coefficient went up to eight times with regard to the downy tube. The friction factor for the fully laminar expanse increased from 5% to 40%. Promvong et al. [4] Investigated experimentally, when the result of the narrowed ring tabulator inserts on the heat transfer rate and friction factor on various conical rings used as lozenges. The Reynolds numbers in the area of 6000 to 26000 were used for the analysis. It was noted the diverging conical ring array had a higher rate of transfer of temperature compared to the other example selected. It was likewise noted that the enhanced efficiency increases as the Reynolds number and diameter ratio decreases. Salam et al [5]. When the heat transfer enhancement was

investigated, water efficiency for turbulent flow in a circular tube was inserted into the downy tube using rectangular cut twisted tape inserts. A rectangular stainless steel cut twisted tape inserts of 5.25 twist ratio was inserted into the downy tube and the number of Reynolds varies with range 10,000-19,000. It has been observed that the Nusselt number increased with increasing Reynolds number. 68% improvement of heat flux was pragmatic for tube with rectangular-cut twisted tape insert compared to downy tube. The investigational factor of Friction with inserts was discovered to be 39% - 80% higher than the friction factor for the downy tube. Suresh et al. [6]. The high temperature relocation of water for laminar flow in a circular pipe fit with full-length helical screw components of varying twist ratio, increasing and decreasing twist ratio was explored experimentally and was compared with the simple tube. It was found that the heat transfer coefficient and the friction factor improves with the spin ratio. There was no significant change in the heat transfer coefficient magnitude with decreasing twist ratio or increasing twist ratio. Date et al. [7]. Experiments conducted to assess pressure drop and heat transfer characteristic of Laminar water flow to fully turbulent ranges from 75-start spiral ribbed pipe with twisted tape insert. The grooves were clockwise with admiration for the direction flow and the heat transfer escalation owing to spiral grooves was further enhanced by inserting twisted tapes with twist ratios of  $Y = 10.15, 7.95$  and  $3.4$  compared to the downy pipe. Spiral grooved pipe with twisted tape demonstrates a maximum laminar range improvement over the turbulent range. Eren et al. [8]. Studied the circular coil-spring tabulator heat transfer features. The numbers of Reynolds ranged in the orbit from 2500 to 1200. It was found that an improvement in spring diameter, spring turn and angle of incline resulted in a moderate rise in heat transfer from 1.5 to 2.5 times the outcomes of an empty downy tube. Friction factor rises to about 40 to 80 times for a downy tube. The inclined angle appears at the design parameter and has the predominant effect on elevated temperature transfer and friction loss while the spring number has the weakest force. Raju et al. [9]. Using mesh inserts, the expansion of unstable heat transfer flow in a horizontal pipe was experimentally investigated and compared to the simple tube. They discovered that the heat transport enrichment by using mesh insert was more by factor by 2 times compared to the simple tube at the same mass flow rate. It was discovered that pressure drops were boosted by raising the porous cloth proportion. Tandiroglu. [10]. Demonstrate the impact of fluid geometry parameters on the transfer of transient forced convection heat in a round pipe with flummox inserts for turbulent flow. It differed with distinct geometric parameters like the H spacing of the baffle and the angel  $\beta$  orientation of the baffle. It has been settled that the pipes with baffle inserts offer the downy tube a high heat transfer rate. In the baffle pipes inserted for fleeting flow conditions, the rate of average pressure drop was greater than that of the secure state flow conditions. Noothonget al. [11]. The improvement of the elevated temperature transfer and the friction characteristics factor of heat exchange in the Plexiglas material heat exchanger concentrate double pipe was explored experimentally. As an operating fluid, cold water as an annulus and hot air as an internal fluid were used. The swirling flow was carried out with distinct twist ratios using twisted tape placed in the heat exchanger's internal test tube. It was discovered that with the declining twist ratio and friction factor increases with the declining twist ratio, the Efficiency and the Nusselt number increase. It has been observed that the swirl flow helps to decrease the thickness of the boundary layer of the warm air stream and boost the warm air residence time in the inner tube. Uttarwar [12]. The isothermal pressure drop and convective heat transfer to servo herm medium grade oil in laminar flow in one downy pipe and seven wire coil-inserted pipes with variable wire diameter and pitch of wire coils were experimentally explored. It was established that the amount of Nusselt was the affair of the angle of helix, the number of Reynolds and the number of Prandtl. Garcia et al. [13]. The efficiency of helical wire coils as fit inside the pipe was further explored. The conduct in laminar, transition and turbulent flow was discovered using water and water glycol combination at unlike temperature. Result showed that in turbulent flow wire coils; reduced stress dropped to nine times and thermal transfer improved up to four times compared to the empty downy pipe. Wire coil inserts in the transition area increased the rate of thermal transfer. Solano et al. [14]. The efficiency of 23 circular helicoidally wire-coils with distinct geometric characteristics and with a range of Reynolds from 50-8000 was explored experimentally. It was found that the wire coils showed better efficiency as the amount of Reynolds differs from 200-2000 to an improvement of reflexive shell and tube heat exchanger method. Sunder et al. [15]. Experimentally studied nanodiamond-nickel (ND-Ni) hybrid nanofluid flow in tube with and without longitudinal strip inserts. The Reynolds number range was from 3000-22000 for the volume concentrations of

0.1% and 0.3% and for different aspect ratios. Result discovered that the Nusselt number increased without insert by 35.43 percent and was further enhanced by 93.30 percent with longitudinal strip insert for 0.3 percent Nano fluid volume concentration. Changet al [16]. The improvement of compound heat transfer in a pipe fit with serrated twisted tape was explored experimentally. They conclude that as the twist ratio in the pipe fits with downy or serrated bent tape reduces the local Nusselt number and Fanning friction factor.

In the current research work, Experimental investigation of high temperature transfer through copper tube is analyzed. Differently three types of inserts are applied that includes helical coil inserts, conical coil inserts and convergent divergent coiled inserts. Pitch (P), diameter (d) ratio varied 0.5 and the diameter of the tube (e) to the diameter of coil (d) ratio is varied from 0.3 to 0.8. The experimental results with the downy pipe are primary validated with standard DittusBoelter and Pitco equations. Validated experimental set up is then employed for the analysis of different cases of P/d and e/d ratio.

## II. Experimental Analysis:

An investigational test configuration is intended and composed in accordance with the literature rules. In parliamentary law, rubbing and heat transfer information are encountered in a downy pipe by raising the present rate to validate the experimental configuration. Rubbing and thermal transfer information are gathered for various kinds of helical coiled spring inserts and conical convergent –divergent spring inserts under growing liquid flow conditions. The raw information collected during the test runs are used to evaluate the improvement features of heat transfer

### A. Experimental setup and operation

The experimental observations are taken away by employing water as the working fluid to investigate the high temperature transfer and factor of friction characteristics of circular tube with helical coiled spring inserts and conical convergent divergent spring inserts. The test setup involves a water tank, a circular pipe for the test segment, a Rota meter for measuring the flow rate and the test section as shown in Fig.1 given below. A 1000 mm long copper tube with an inner diameter of 20.22 mm is used as a test segment. The test section is finished by using Nichrome wire to provide the uniform heat flux across the tube's exterior surface. With the assistance of dimmer stat, the electrical input energy is altered by controlling the potential difference across the heating factor. To minimize heat loss to the environment, the outer surface of the teas section is easily isolated with an insulation. The temperatures of the tube wall are evaluated using exposed pipe thermocouples. A manometer is used to evaluate the pressure drop across the sample segments. The tests are taken away while providing a uniform heat flux over the trial department by raising the fluid flow rate through the arrangement.

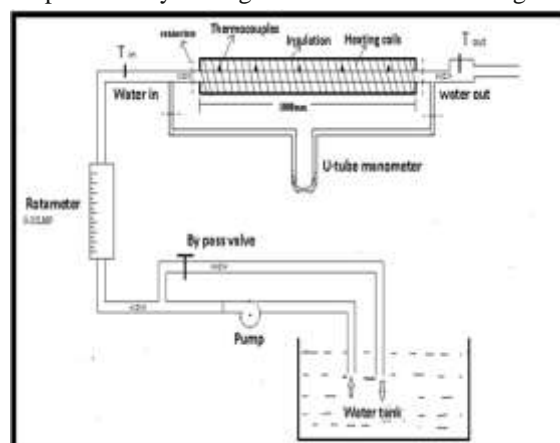
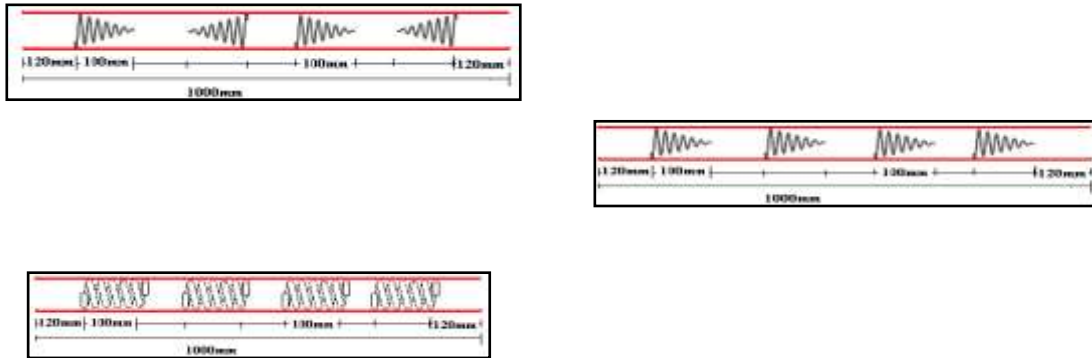


Fig.1 Experimental Set Up

The test section is heated with uniform heat flux during the experiments for a fixed flow rate, and the measurable parameters such as pressure drop over the test section, temperature, volumetric flow rate, and

electrical energy input are observed after the system approaches to the stable state. By applying the measured parameters, the Reynolds number, Nusselt number and friction factor are achieved.

Two types of inserts are used for the analysis, they include helical spring inserts and the conical spring inserts with different geometrical arrangements like inline, convergent and convergent-divergent as shown in fig. 2.



**Fig: 2 Helical, Conical and Convergent-Divergent spring insert in tube**

### B.Design of Helical spring inserts

The helical coiled spring inserts with continuous proportion are placed into the circular tube to retrieve and record information during the testing phase. The helical spring inserts are made from aluminum spring with a diameter of 22.22 mm and a length of 100 mm. The geometry of helical spring inserts is shown in Fig.3



**Fig: 3. Helical spring Inserts**

### C.Design of Conical Spring inserts

During the experiment process, conical spring inserts are introduced into the circular tube in order to gather and enter information. Aluminum spring having diameter 22.22 mm and length 100 mm are used to set up the conical spring inserts. The details of the geometry of conical spring inserts are indicated in Fig.4.



**Fig: 4. Conical spring Inserts**

### III. Data reduction features.

The calculation of heat added to the water,

$$Q = m C_p (T_{out} - T_{in})$$

The coefficient of heat transfer was calculated by,

$$Q = Ah(T_w - \frac{T_{out} + T_{in}}{2})$$

Where,  $A = \pi dl$

Tube surface temperature calculated

$$T_w = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5}$$

The bulk temperature,

$$T_b = \frac{T_{out} + T_{in}}{2}$$

The theoretical Nusselt number calculation from Gnielinski, 1976, correlation

$$Nu_{th} = \frac{(f/8)(Re - 1000)Pr}{1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)}$$

### IV. Experimental setup validation

Before experimenting on a downy pipe without insert, the experimental configuration is verified. Using the information reduction operation, the mean values of Nusselt number and friction factor are determined

. **Table 1: Validation Analysis**

Parameters	% Uncertainty
Coefficient of heat transfer (h)	3.8 %
Nusselt Number	2.9 %
FrictionFactor	2.2 %

The Nusselt number and friction factor experimental scores were contrasted with the results extracted from the correlations as Dittus-Boelter equation [6] for the Nusselt number and Petukhov equation [3] for the downy pipe flow friction factor. The downy tube reference data is acquired from the following equations:

$$f = (0.79 \ln Re - 1.64)^{-2}$$

$$Nu = 0.023(Re)^{0.8}(pr)^{0.4}$$

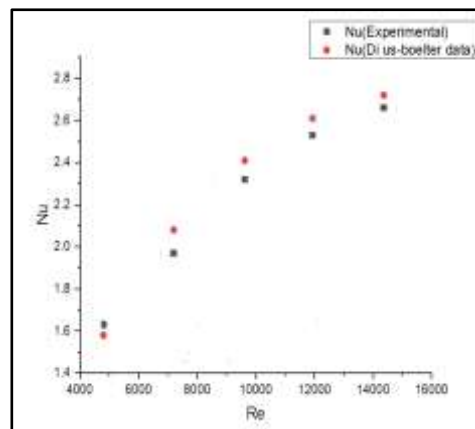


Fig. 5. Comparison Number of Reynolds with Dittus-Boelter data

These graphs indicate that for all values of the Reynolds number, the experimental findings acquired from the experimental setup work tightly with the conventional information. The experimental values of the Nusselt number deviate from Dittus-Boelter data by 2.9%. While the deviation of the experimental value factor of friction from Petukhov data is found to be 2.2%. The validation test reveals that the recorded experimental data values do not deviate significantly from the standard values and are in full agreement and can therefore be used for data collection in case of a downed tube with inserts.

## V. Result and Discussion.

Improvement of heat transfer with the different geometrical arrangements of inserts like helical, convergent and convergent-divergent arrangement is studied, tried out, tested and put down in the current research study. Characteristics of heat transfer and friction factor are measured for the different Reynolds number ranging from 4500 to 14500. The heat transfer enhancement in the pipe with different types of inserts is compared to the down pipe without inserts. The experimental analysis has been taken out at different pitches and the wire diameter ratio.

### A. Enhancement of Nusselt number

The impact on the inserts of different kinds Nusselt number enhancement of the pitch to tube diameter ratio of 0.5, at various Reynolds numbers is shown in Fig 6. Three different cases of inserts as conical insert, helical insert and converging diverging insert are used during experimentation. Wire diameter ratios ( $\epsilon/d$ ) are selected to be 0.3, 0.5 and 0.8.

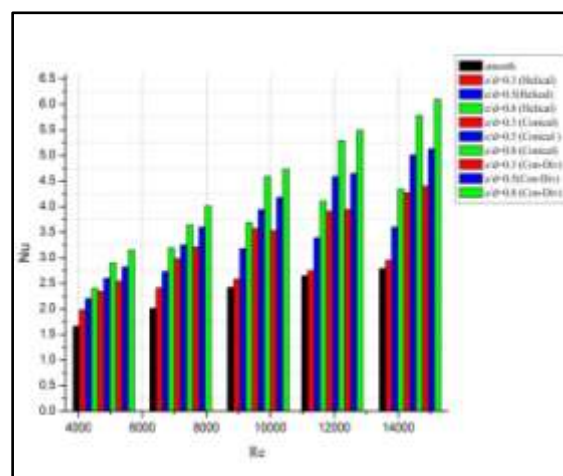


Fig. 6 Number of Reynolds with Nusselt number at  $(p/d)$  of 0.5

It is observed from the fig 6 that in all the cases, As the  $(e/d)$  ratio rises, the amount of Nusselt rises. The upper limit value of the Nusselt number enhancement is obtained in the case of converging, diverging insert with wire diameter ratio  $(e/d)$  of 0.8. The conical insert with wire diameter ratio  $(e/d)$  of 0.8 shows the higher Nusselt number in all ranges of Reynolds number compared to converged diverging insert with wire diameter ratio  $(e/d)$  of 0.3 and 0.5. Similarly conical insert with wire diameter ratio  $(e/d)$  of 0.5 have higher Nusselt numbers than the converging, diverging insert with wire diameter ratio  $(e/d)$  of 0.3 in the entire range of Reynolds number.

The variation of the Nusselt number with the change in the Reynolds number for three different cases of inserts like conical insert, helical insert and converging, diverging insert for the pitch to tube diameter ratio of 1 is shown in Fig 7. Wire diameter ratios  $(e/d)$  of 0.3, 0.5 and 0.8 are used for the psychoanalysis.

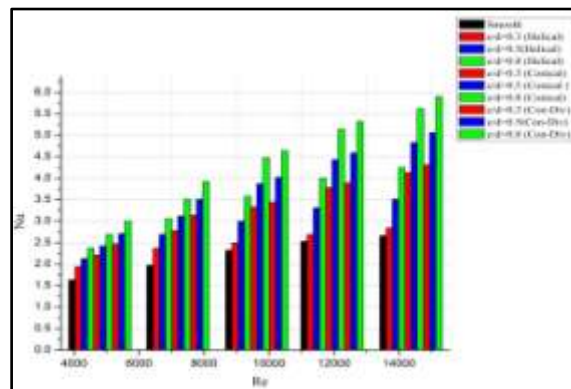


Fig:7 Number of Reynolds with Nusselt number as  $(p/d)$  of 1

The graph shows that, at lower Reynolds numbers the increase in Nusselt number with the wire diameter ratio  $(e/d)$  is less on all types of inserts, but as the Reynolds number increases the increment in Nusselt number as the wire diameter ratio  $(e/d)$  increases gradually. In instances of identical wire diameter ratio  $(e/d)$  the duct with converging, diverging inserts have only a very small Nusselt number enhancement compared to ducts with conical insert. The helical insert with wire diameter ratio  $(e/d)$  of 0.8 have slightly lower Nusselt number than converging, diverging inserts with wire diameter ratio  $(e/d)$  of 0.3 and 0.5 at low Reynolds number. Only in the former case of inserts with a pitch to tube diameter ratio  $(p/d)$  of 0.5 the conical insert with wire diameter ratio  $(e/d)$  of 0.8 were experiencing a greater Nusselt number than the converging, diverging inserts with wire diameter ratio  $(e/d)$  of 0.3 and 0.5 in the entire range of Reynolds number. Nevertheless, the maximum Nusselt number attained by inserts with a pitch to tube diameter ratio  $(p/d)$  of 1 is lesser than that attained by inserts with a pitch to tube diameter ratio  $(p/d)$  of 0.5 in all types of inserts.

Fig:8 Shows the variation of the Nusselt number with the alteration in the Reynolds number for three different cases of inserts like conical insert, helical insert and converging, diverging insert for the pitch to tube diameter ratio of 1.5. Wire diameter ratios  $(e/d)$  of 0.3, 0.5 and 0.8 are used for the psychoanalysis.

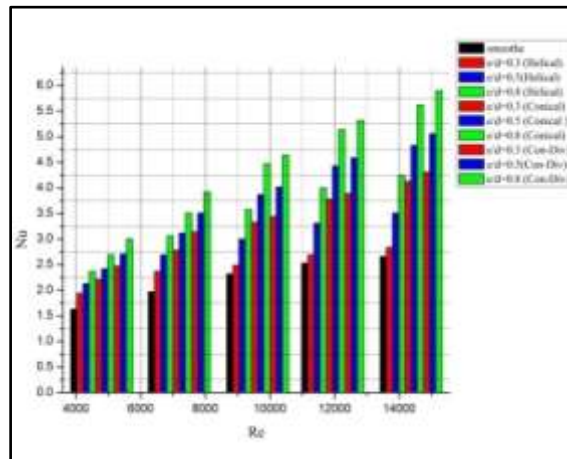


Fig:8 Number of Reynolds with Nusselt number as (p/d) of 1.5

Similar to the previous cases of pitch to diameter ratios (p/d) of 0.5 and 1 at lower Reynolds numbers, the increase in Nusselt number with the wire to diameter ratio (e/d) is less on all types of inserts, but as the Reynolds number increases the increment in Nusselt number with the wire to diameter ratio (e/d) gradually increases in all types of inserts. It is noted that all the other trends noted in the case of inserts with a pitch to tube diameter ratio (p/d) of 1 are likewise repeated in the case of inserts with a pitch to tube diameter ratio (p/d) of 1.5. Yet, in all the examples of inserts with a pitch to tube diameter ratio (p/d) of 1.5, the Nusselt number is fairly smaller than that of the inserts with a pitch to tube diameter ratio (p/d) of 1.

Hence it can be concluded from all the three above mentioned graphs that, as the pitch to tube diameter ratio (p/d) increases, the increment in Nusselt number enhancement is going down. The maximum Nusselt number is possible with converging, diverging inserts at pitch to tube diameter ratio (p/d) ratio of 0.5 and the wire diameter ratio (e/d) of 0.8. However the conical insert with wire diameter ratio (e/d) of 0.8 shows a considerable Nusselt number enhancement, which is slightly lower than converging, diverging inserts with wire diameter ratio (e/d) of 0.8, but it is higher than the converging, diverging inserts with wire diameter ratio (e/d) of 0.3 and 0.5 in almost all the three values of pitch to tube diameter ratio (p/d) except in the instances of pitch to tube diameter ratio (p/d) of 1 and 1.5 with lower Reynolds number.

**B. Friction factor enhancement**

It is essential to determine the friction factor in the operation. The friction component is immediately related to the pressure drop across the test section and inversely proportional to fluid velocity's second power.

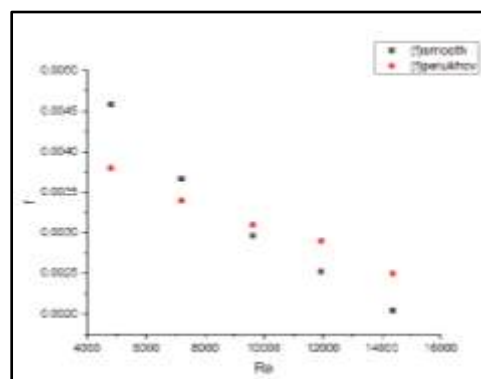
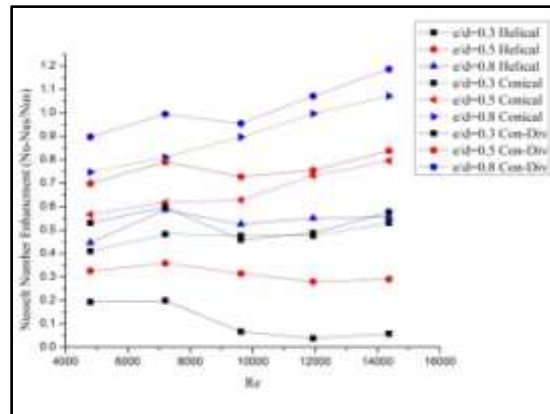


Fig: 9 Number of Reynolds with factor of friction from petukhov

Consequently, a reduced friction factor value corresponds to the greater amount of Reynolds. Applying inserts in a heat exchanger pipe results in heat transfer improvement with a simultaneous increase in pressure fall owing to greater fluid flow turbulence.

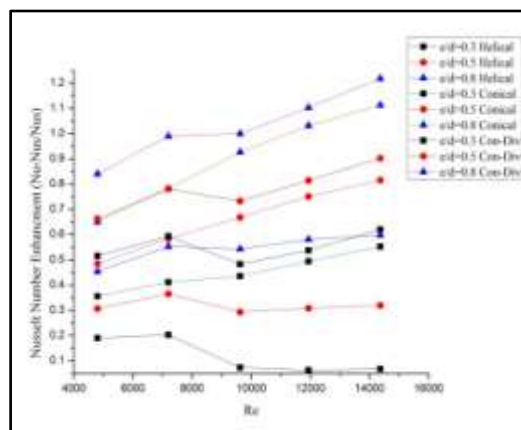
**C. Enhancement of Nusselt Number**

Fig 10 shows the effect of Reynolds number on the enhancement in the Nusselt number using different types of inserts like helical, conical and modified convergent-divergent spring inserts with respect to a downy pipe. The pitch ratio (p/d) is kept constant at 0.5 and the wire diameter ratio (e/d) varies in between about 0.3-0.8. The minimum value of enhancement in Nusselt number is observed corresponding to the case of the pitch ratio (p/d) of 0.5 and the wire diameter ratio (e/d) of 0.3, while the maximum value of enhancement in Nusselt number is obtained for the case of the pitch ratio (p/d) of 1.5 and the wire diameter ratio (e/d) of 0.8. It is observed that the enhancement in the case of convergent-divergent insert with pitch ratio (p/d) of 1.5 and wire diameter (e/d) ratio of 0.8 is 1.8 times more than that of the helical spring inserts with pitch ratio (p/d) of 0.5 and the wire diameter ratio (e/d) of 0.3. It is clear from the graph that in cases of a constant pitch ratio (p/d), as the wire diameter ratio (e/d) increases, an enhancement in the Nusselt number also increases.



**Fig:10 Nusselt Number enhancement with Reynolds Number for (p/d) of 0.5**

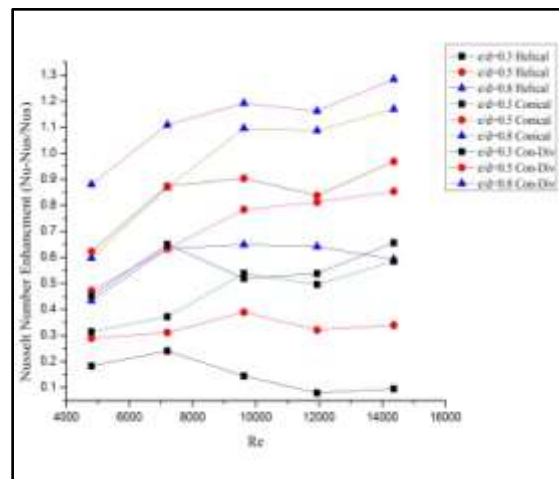
Fig 11 demonstrates the effect of Reynolds number on the enhancement in the Nusselt number using dissimilar types of inserts like helical, conical and modified convergent-divergent spring inserts with respect to a downy pipe. The pitch ratio (p/d) is kept constant at 1 and the wire diameter ratio (e/d) is varied in between about 0.3 to 0.8.



**Fig: 11 Nusselt Number enhancement with Reynolds number for (p/d) of 1**

The graph shows that the maximum enhancement in Nusselt number is obtained corresponding to the case of the wire diameter ratio ( $e/d$ ) of 0.8 for all values of the Reynolds number, whereas the minimum enhancement in Nusselt number is noted in the case of the wire diameter ratio ( $e/d$ ) of 0.3 among the entire range of Reynolds number taken into thoughtfulness. It is found that the maximum enhancement in Nusselt number in the case of convergent-divergent insert with pitch ratio ( $p/d$ ) of 1.5 and the wire diameter ratio ( $e/d$ ) of 0.8 is 2 times than the helical spring inserts for pitch ratio ( $p/d$ ) of 0.5 and the wire diameter ratio ( $e/d$ ) of 0.3.

The effect of Reynolds number on the enhancement in the Nusselt number using different types of inserts like helical, conical and modified convergent-divergent spring inserts with respect to a downy tube show in the Fig 12.



**Fig: 12 Nusselt Number enhancement with Reynolds Number for ( $p/d$ ) of 1.5**

The pitch ratio ( $p/d$ ) is kept constant at 1.5 and the wire diameter ratio ( $e/d$ ) is varied in between from 0.3 to 0.8. The enhancement in Nusselt number by using modified convergent-divergent spring insert is gradually increasing with respect to the increase in the pitch ratio ( $p/d$ ). It is observed that enhancement in Nusselt number is increasing as Reynolds number reaches to the higher values in all different cases. The graph reveals that in the instance of convergent-divergent spring inserts with wire diameter ratio ( $e/d$ ) of 0.8 has significantly 2.2 times enhancement in Nusselt number in comparison to helical inserts with wire diameter ratio ( $e/d$ ) of 0.3.

## VI. Conclusions

Observation outcomes for heat transfer and friction factor were defined as working liquid for water in circular pipe equipped with helical coiled and conical convergent and convergent-divergent inserts. The impact on heat transfer and friction losses of distinct helical and conical coiled setting was examined for the pitch ratio ( $p/d$ ) ranged from 0.5 to 1.5 wire diameter ratio ( $e/d$ ) ranged from 0.3 to 0.8 for 4500 to 14500 Reynolds number range. The friction factor and enhancement of Nusselt number characteristic of the circular tube is experimentally studied and validated with the standard relation available in the literature.

With increasing number of Reynolds for all geometrical parameters, the Nusselt number of conical, helical and modified convergent-divergent spring inserts increases. The maximum enhancement in Nusselt number is observed to be 2.2 times greater as compared with the pitch ratio ( $p/d$ ) of 1.5 and the wire diameter ratio ( $e/d$ ) of 0.8 in convergent-divergent spring inserts.

As the wire diameter ratio ( $e/d$ ) increases for all cases considered in the experimental analysis: The Nusselt number increases. It is noted that convergent, divergent helical spring inserts performed better than conical and helical types of inserts considered in this work. The maximum number of inserts with a pitch-to-tube diameter ratio ( $p/d$ ) of 1 is lower than that of inserts with pitch-to-tube diameter ratio ( $p/d$ ) of 0.5 in all kinds of inserts considered for the current research survey. The factor of friction decreases as the Reynolds number

increases. Factor of friction values for modified convergent divergent inserts are enhanced with 0.074 to 0.038 compared to the downy tubes. The percent increase in Nusselt number is found to be 130% more in convergent, divergent inserts compared to downy tube. It can therefore be concluded that the convergent, divergent spring inserts can very efficiently improve smooth pipe heat transfer efficiency and can be helpful for multiple heat transfer technologies available in the production.

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