# Comparison of Thermohydraulic Performance in Heat Exchanger Tube with Inserts

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**Abstract** - Heat transfer enhancement by modifying the surface of heat exchanger has become a very interesting area of research for the researchers. The heat exchanger is the most commonly used thermal device in different thermal and mechanical systems such as Automobiles, Chemical industries, Refrigeration and Air conditioning systems, etc. Hence, many techniques have been investigated on enhancement of heat transfer rate and decrease the size and cost of the involving equipment especially in heat exchangers. This paper compares some of the very similar kind of experimental work carried out by some of the researchers in this area by taking air as the working fluid in heat exchanger tube. The comparison is made between some of the work on "core fluid disturbance", "disturbance by surface modification" and "combination of core and surface disturbance". The comparison is made on the basis of 'heat transfer, friction factor, and thermal performance factor' under the turbulent flow regime. On comparison and graph obtained it is found that the Heat transfer and friction factor is higher in case of Conical ring with twisted tape insert and the thermal performance factor is higher in case of perforated twisted tape and twisted tape separated from the wall.

**Index Terms** : Heat Transfer, Friction factor, Thermal performance factor, Twisted Tape, Conical Ring, Perforation, Passive Method.



## 1 Introduction

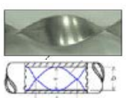
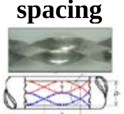
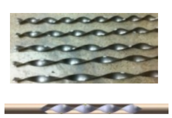
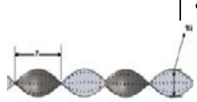
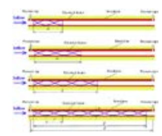
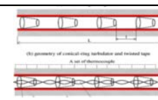
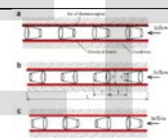
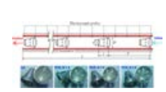
The heat exchangers are most commonly use thermal devices for different industrial and engineering applications. Nowadays high prices of energy, motivate industry to apply energy saving methods as much as possible in their facilities. Heat transfer enhancement techniques are one of the most important tools to save energy in different processes. Researching and optimizing the thermo-hydraulic performance of tube or duct flow with inserts has gained continuing attentions in related scientific and industrial fields. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate, efficiency and pressure drop apart from issues such as long-term performance and the economic aspect of the equipment. Whenever inserts technologies are used for the heat transfer enhancement, along with the improvement in the heat transfer rate, the pressure drop also increases, which induces the higher pumping cost. Therefore, any augmentation device or methods utilized into the heat exchanger should be optimized between the benefits of heat transfer coefficient and the higher pumping cost owing to the increased frictional losses. Because of the call for energy and cost saving heat transfer enhancement is a topic of pursuit for the researchers that how to improve techniques to increase the heat transfer rate and to achieve high efficiency with less cost and strength.

| **Nomenclature** | | | |
|---|---|---|---|
| STT | Single Twisted Tape | $\eta$ | Thermal performance factor |
| DTT | Double Twisted Tape | PR | Pitch ratio |
| Re | Reynolds number | DR | Diverging Ring |
| Nu | Nusselt number | CR | Converging Ring |
| $f$ | Friction factor of tube with insert | $f_s$ | Friction factor of plane Tube |
| $Nu_s$ | Nusselt number of plane tube | Pr | Prandtal number |
| CDR | Converging-Diverging Ring | PCR | Perforated conical ring |
| SWTT | Twisted Tape Separated From Wall | PTT | Perforated Twisted Tape |
| SLTT | Short Length Twisted Tape | CRTT | Conical Ring with Twisted Tape |

## 2 Methodology

The work is carried out by comparing results and correlations of very similar kind of experimental work. Some different insert geometry has been taken, which includes Single Twisted Tape, Double Twisted Tape, Conical ring, Conical ring with Twisted tape, Perforated Twisted tape, etc. Each of the experiments has been performed on similar kind of experimental setup and because of their different geometry different result and correlation have been obtained by different researchers. In this paper all the work had been compared in order to get optimum result and future aspect. The different insert geometry and parameters used with their result and citation with reference number is shown in Table 1. All the correlations for heat transfer, friction factor and thermal performance factor is shown in Table 2. And Table 3., shows the values of parameters on which the correlation in each case shows the maximum result for heat transfer, friction factor, and thermal performance factor respectively.

**Table no: 1 Insert geometry and parameters used.**

| REF. NO. | INSERT TYPE | INSERT PARAMETER | RESULT |
|---|---|---|---|
| [1] |  **Single TT with no wall spacing**  **Double TT with no wall spacing** | • Reynolds number from 4000 to 19,000. • Twist ratios (y/w=3.0, 4.0 and 5.0) • Space ratios (s/D=0.75, 1.5 and 2.25). | The average Nusselt Numbers on the tube fitted with the regularly-spaced dual twisted tapes (s/D) of 0.75, 1.5 and 2.25 are, respectively, 140%, 137% and 133% of that in the plain tube. |
| [2] |  **Single TT separated from the tube wall.** | • Twist ratios (y/D = 2, 2.5, 3, 3.5 and 4) • Clearance ratios (c/D = 0.0178 & 0.0357) • Reynolds number from 5132 to 24,989 | The highest heat transfer enhancements are obtained at 1.756 for c/D = 0.0178, as 1.744 for c/D = 0.0357 and use 1.789 for the typical twisted tape (c/D = 0) at y/D = 2 of all TR. |
| [3] |  **Perforated TT** | • Reynolds number from 7200 to 49,800 • Porosities (Rp) = 1.6, 4.5, 8.9 and 14.7%. | Over the range investigated, Nu, f & n in the tube with perforated TT inserts was found to be 110–340, 110–360 and 28–59% higher than those of the plain tube values, respectively. |
| [4] |  **Short Length TT** | • Reynolds number from 4000 to 20,000. • Tape length ratios (LR=ls/lf) = 0.29, 0.43, 0.57 and 1.0. | The experimental result indicates that the short length tapes of LR = 0.29, 0.43 and 0.57 perform lower heat transfer & friction factor values than the full length tape around 14%, 9.5% and 6.7%; and 21%, 15.3% and 10.5%. |
| [5] |  **Conical Ring with Twisted Tape** | • Twist ratios, Y=3. 75, and 7.5 • Reynolds number 6000 to 26,000 | A maximum heat transfer rate of 367% and enhancing efficiency of around 1.96 is found for using the conical-ring and the twisted-tape of Y=3.75. |
| [6] |  **Conical ring arranged as CR, DR and CDR.** | • Reynolds number from 6000 to26,000 • Diameter ratios of the ring to tube diameter (d/D = 0.5, 0.6, 0.7) | An augmentation of up to 197%, 333%, and 237% in Nusselt number is obtained in the turbulent flow for the CR, DR and CDR arrays, respectively. |
| [7] |  **Perforated Conical Ring** | • Reynolds number from 4000 to 20,000 • Pitch ratios (PR=p/D =4, 6 and 12). • Numbers of perforated holes | Over the range investigated, the maximum thermal performance factor of around 0.92 is found at PR=4 and N=8 holes with Reynolds number of 4000. |

ISSN 2229-5518

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|---|---|---|---|
| | | (N=4, 6 and 8 holes). | |

**Table no: 2 Correlations obtained in case of different geometries**

| REF. NO. | CORRELATIONS<br>**Nu:** Nusselt number, **f:** Frictional factor, **η:** Thermal performance factor | | |
|---|---|---|---|
| **[1]** | 1. **Nu** = 0.06 $Re^{0.75} Pr^{0.4} (y/w)^{-0.26}$ [STT]<br>2. **f** = 10.02 $Re^{-0.46} (y/w)^{-0.48}$ [STT]<br>3. **η** = 2.4$Re^{-0.08} (y/w)^{-0.2}$ [STT] | 1. **Nu** = 0.069 $Re^{0.74} Pr^{0.4} (y/w)^{-0.26} (1.5(s/D) + 1)^{-0.1}$ [DTT]<br>2. **f** = 30.5 $Re^{-0.56} (y/w)^{-0.54} (1.5(s/D) + 1)^{-0.2}$ [DTT]<br>3. **η** = 1.9 $Re^{-0.05} (y/w)^{-0.08} (1.5(s/D) + 1)^{-0.034}$ [DTT] | |
| **[2]** | 1. **Nu** = 0.406903 $Re^{0.586556} (y/D)^{-0.443989} (c/D)^{-0.055072} Pr^{0.38}$<br>2. **f** =6.544291 $Re^{-0.452085} (y/D)^{-0.730772} (c/D)^{-0.1579}$<br>3. **η** =9.750184 $Re^{-0.177983} (y/D)^{-0.183513} (c/D)^{-0.009558} Pr^{0.38}$ | | |
| **[3]** | 1. **Nu** = $\{0.0002R_p^3 - 0.0046R_p^2 + 0.0334R_p + 0.6569\} Re^{\{0.00005R_p^3 - 0.0013R_p^2 + 0.0073R_p + 0.5501\}} Pr^{0.33}$<br>2. **f** =$\{-0.0027R_p^3 + 0.0583R_p^2 + 0.0455R_p + 24.536\} Re^{\{0.00009R_p^3 - 0.0022R_p^2 + 0.012R_p - 0.6006\}}$<br>3. **η** = $36.995.C.C_1^{-06761} Re^{\{-0.000011y3 + 0.000187y2 - 0.000808y - 0.07168\}}$ | | |
| **[4]** | 1. **Nu** =0.0664 $Re^{0.693} Pr^{0.4} LR^{0.122}$<br>2. **f** = 2:8 $Re^{-0.386} LR^{0.19}$<br>3. **η** = 1.82 $Re^{-0.068} LR^{0.067}$ | | |
| **[5]** | 1. **Nu** = 1.356 $Re^{0.433} Pr^{0.4} (d/D)^{-1.23} Y^{-0.053}$<br>2. **f** = 24.87 $Re^{-0.43} (d/D)^{-3.99} Y^{-0.16}$<br>3. **η** = 14.9 $Re^{-0.277} (d/D)^{-0:129} Y^{-0:01}$ | | |
| **[6]** | 1. **Nu** =0.09155$Re^{0.655} Pr^{0.4} (d/D)^{-1.31}$<br>2. **f** =1.12$Re^{-0.258} (d/D)^{-4.4}$<br>**[CR]**<br>3. **η** =2.37$Re^{-0.103} (d/D)^{-0.091}$ | Nu=0.863$Re^{0.459}$Pr0:4$(d/D)^{-1.32}$<br>f =12.52$Re^{-0.42} (d/D)^{-4.31}$<br>**[DR]**<br>**η** =11.46$Re^{-0.255} (d/D)^{-0.126}$ | Nu=0.1986$Re^{0.586} Pr^{0.4} (d/D)^{-1.3}$<br>f=1.038$Re^{-0.23} (d/D)^{-4.58}$<br>**[CDR]**<br>**η** =5.25$Re^{-0.1799} (d/D)^{-0.076}$ |
| **[7]** | 1. **Nu** = 1.258$Re^{0.606} PR^{-0.39} N^{-0.32} Pr^{0.4}$<br>2. **f** = 985.48$Re^{-0.368} PR^{-0.747} N^{-1.253}$<br>3. **η** = 1.596$Re^{-0.067} PR^{-0.142} N^{-0.095}$ | | |

**Table no: 3 Result showing peak values of correlations**

| REF. NO. | PARAMETERS AT WHICH THE RESULT GIVES THE MAXIMUM VALUE | | |
|---|---|---|---|
| | Nu | f | η |
| [1] | y/w=3; s/D=0 | y/w=3; s/D=0 | y/w=3; s/D=0 |
| [2] | Twist ratio (y/D) = 2<br>Clearance ratio (c/D) = 0.0178 | Twist ratio (y/D) = 2<br>Clearance ratio (c/D) = 0.0178 | Twist ratio (y/D) = 2<br>Clearance ratio (c/D) = 0.0178 |
| [3] | $R_p$=4.5% | $R_p$=4.5% | $R_p$=4.5% |
| [4] | LR=1 | LR=1 | LR=1 |
| [5] | Y=3.75 & d/D=0.5 | Y=3.75 & d/D=0.5 | Y=3.75 & d/D=0.5 |
| [6] | DR(d/D)=.5, CR(d/D)=.6, CDR(d/D)=.5 | DR(d/D)=.5, CR(d/D)=.6, CDR(d/D)=.5 | DR(d/D)=.5, CR(d/D)=.6, CDR(d/D)=.5 |
| [7] | N=8 , PR=4 | N=8 , PR=4 | N=8 , PR=4 |

## 3. Results and Discussion

On the basis of comparison between the different inserts used in the Heat exchanger tube for the enhancement of heat transfer rate and to improve the overall thermal performance factor of Heat exchanger tube following results can be formulated:

### *3.1 Effect of different parameters on Heat Transfer.*

On the basis of comparisons made and graph obtained, it is concluded that Heat transfer variation depends on the geometry of inserts used and their parameters. From the graph obtained as shown in Fig. 1 (a & b), it can be said that heat transfer is maximum in case of CRTT [5] and minimum in case of CDR [6]. In case of Twisted tapes, as the twist ratio decreases the heat transfer increases and for porosity of 4.5% the heat transfer shows maximum value. Similarly for the diameter and pitch ratio also, as the value or these parameters decreases the heat transfer increases and vice-versa.

But if we talk about Reynolds number, it can be easily seen that as the value of Reynolds number increases the heat transfer decreases for all the parameters.

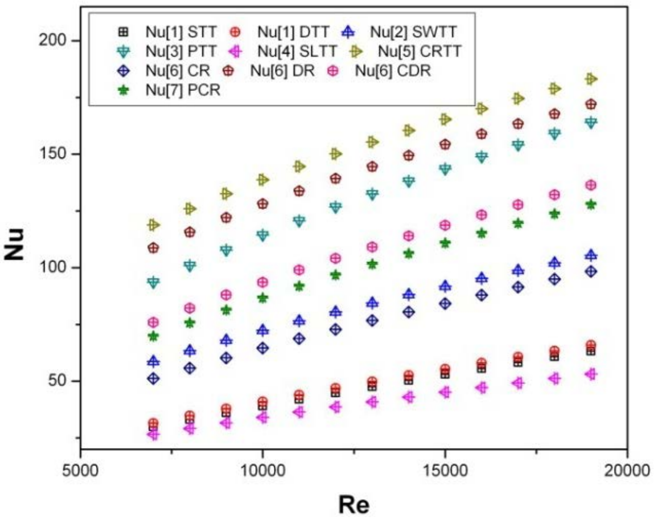


Fig.1 (a) Nusselt No.(Nu) Verses Reynolds No. (Re)

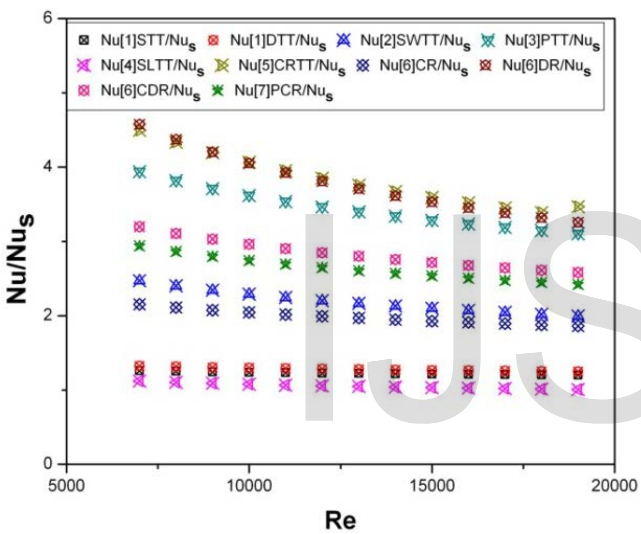


Fig.1 (b) Nusselt No.(Nu/Nu$_s$) verses Reynolds No.(Re)

*3.2 Effect of different parameters on Friction factor.*

On the basis of comparison made and graph obtained, it is concluded that Friction factor variation depends on the geometry of inserts used and their parameters. From the graph obtained as shown in Fig. 2 (a & b), it can be said that friction factor is maximum in case of CRTT [5] and minimum in case of STT [1], DTT [1], SWTT [2], PTT [3] and SLTT [4]. In case of Twisted Tapes, as the twist ratio decreases the friction factor increases and for porosity of 4.5% the friction factor shows maximum value. Similarly for the diameter and pitch ratio also, as the value or these parameters decreases the friction factor increases and vice-versa. But if we talk about Reynolds number, it can be easily seen that as the value of the Reynolds number increases the friction factor value also increases for all the parameters.

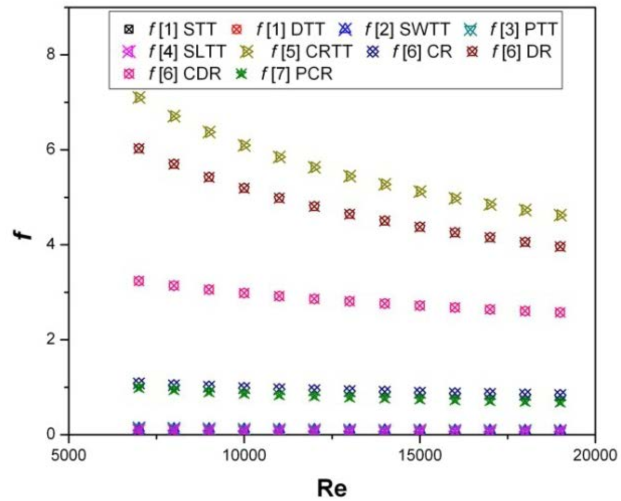


Fig.2 (a) Friction factor (f) verses Reynolds No. (Re)

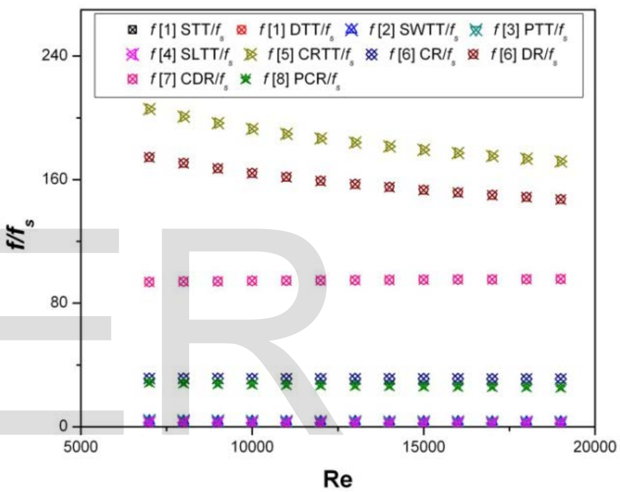


Fig.2 (b) Friction factor (f/f$_s$) verses Reynolds No. (Re)

*3.3 Effect of different parameters and different geometries on Thermal Performance factor.*

On the basis of graphs obtained which is shown in Fig. 3, it is found that Thermal performance factor improves significantly by the use of some of the insert geometries and also diminishes by some of the insert geometries. In this situation the use of SWTT [2] and PTT [3] gives the maximum improvement in the thermal performance factor as compared to other geometries. Similarly the use of STT [1], CR [6] & SLTT [4] shows poor result.

For the lower values of Reynolds number the thermal performance factor is higher and as the value of the Reynolds number increases the net thermal performance factor also decreases to lower values. For the Twisted tape inserts, twisted tape separated from the wall shows good result as compared to twisted tape with no clearance from wall. As the twist ratio, pitch ratio, diameter ratio decreases the value of thermal performance factor improves.

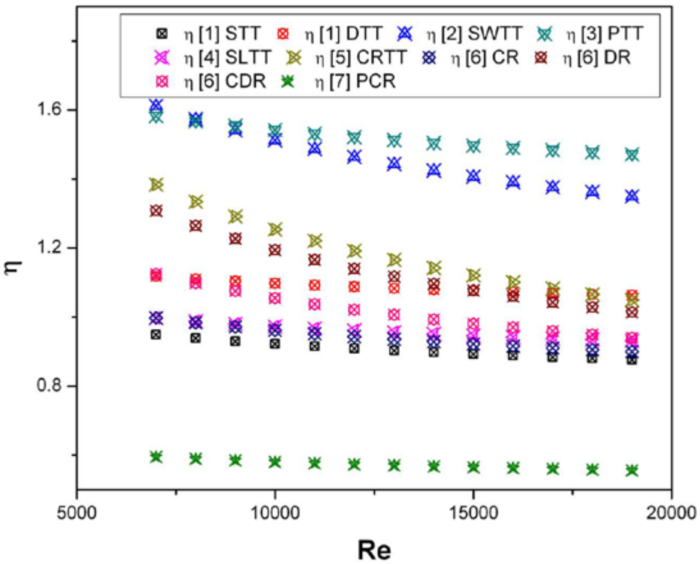


Fig. 3 Thermal performance factor (η) verses the Reynolds number (Re)

## 4. Conclusion

According to comparison which is made between all the different insert geometries, it can be concluded that the thermal performance factor of Heat exchanger tube with single twisted tape insert separated from wall [2] is higher and it gives 1.6 times improved results as compared to the plane tube Heat exchanger. After SWTT, perforated twisted tape [3] shows good result by giving around 1.5 times better results as compared to smooth surface Heat exchanger tube. It is also seen that at the low Reynolds number of the turbulent flow region the value of thermal performance factor is maximum in all the situations, and as the value of the Reynolds number increases the value of thermal performance factor decreases. In other words, it can be also said that for better results and better thermal performance factor the Heat exchanger should be operated at lower values of the Reynolds number.

So it can be easily said that for better result and cost efficient, it is good to use single twisted tape insert separated from the tube wall as tuberatorss in Heat exchanger tube for enhancing its overall thermal performance.

But if we consider only heat transfer, the use of conical rings and conical rings with twisted tapes will give a good amount of heat transfer as compared to other insert geometries.

## Acknowledgment

The authors wish to thank Tula's Institute, Dehradun for providing research facility.

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