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Experimental study of passive heat transfer enhancement technique by using twisted tape insert inside a tube in tube heat exchanger

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***Abstract*—Heat transfer augmentation techniques are used in heat exchanger systems in order to enhance heat transfer & improve thermal performance. There are various methods to enhance the performance of heat transfer devices such as treated surface, rough surfaces as well as incorporations of insertssuch as tabulators & swirl flow devices. My project focuses on reviewing the passive methods in heat pipe exchanger. The passive heat transfer augmentations,external power source input is not required.For the efficient heat transfer,two parameters are very important 1.Increase the surface area 2.Resistance time of the heat transfer fluid.These passive methods is based on the principle,by applying various techniques increase the effective heat transfer area,resistance time & consequently heat transfer coefficient.So that enhancement of convective heat transfer takes place in tube in tube heat exchanger.For that enhancement technique the expected outcome is done by using twisted tape insert inside a tube in tube heat exchanger.The expected outcome is to find the effects of the Typical Twisted tapes (TT) on the heat transfer enhancement and friction factor behaviors in turbulent flow regimes (5000 ≤ Re ≤ 17,100) are described. The Typical twisted tape, twisted tapes with different twist ratio (y/w=2.5, 3 and 3.5) are tested using the water as the working fluid.**

***Keywords*— Twisted tapes, Twist ratio, swirl flow,Tabulators**

I. INTRODUCTION

Heat exchangers are used in different processes such as conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation, condensation in power & cogeneration plants, sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products, fluid heating in manufacturing & waste heat recovery etc. To save energy, material & cost saving related to heat exchange process, the performance of heat exchanger should be high. It also lead to improve economy as well as design of heat exchanger. The need to increase the thermal performance of heat exchangers, thereby effecting energy, material &cost savings have led to development & use of many techniques termed as Heat transfer Augmentation .Augmentation techniques enhance the convective heat transfer by minimizing the thermal resistance of heat exchanger. So the heat transfer enhancement techniques improve heat transfer coefficient but at the same time cost increases due to pressure drop. So at the time of designing a heat exchanger by using any technique, it is necessary to analysis.Heat transfer rate & pressure drop.

The various issues like pressure drop, long term performance & economic analysis of heat exchanger studied. To achieve high heat transfer rate in present or new heat exchanger, taking care of increased pumping power cost. Various technique such as surface roughness,fins, twisted tape insert, coiled tube are also call as heat transfer enhancement or intensification technique. From the above technique twisted tapes, type of passive heat transfer augmentation technique have shown significantly result in past studies.

Heat Transfer Enhancement

Heat transfer enhancement is a way to modified heat transfer surface area, heat transfer coefficient between surface & fluid so as to effectively handle higher heat loads with a smaller treated temperature difference. I have some practical examples of heat transfer enhancement. 1.The technique which do not required external power input called as passive methods i.e. fins, coiled tube, surface roughness, twisted tape inserts etc. 2. The technique which required an external power input such as fluid vibration, electrostatic fields or mechanical stirrer.These techniques are called as active technique. For active method the applications are very limited. Therefore i focus on some specific example of passive techniques. i.e.Those based on modification of the heat transfer surface a more complete and extended discussion of the full spectrum of enhancement techniques can be

found in reference. Increases in heat transfer due to surface treatment can be brought about by increased turbulence, increased surface area, and improved mixing or flow swirl. These effects generally result in an increase in pressure drop along with the increase in heat transfer. However, with appropriate performance evaluation and concomitant optimization, significant heat transfer improvement relative to a smooth (untreated) heat transfer surface of the same nominal (base) heat transfer area can be achieved for a variety of applications. The increasing attractiveness of diff. heat transfer enhancement techniques are gaining industrial importance because heat exchanger offer the opportunity.
1) To reduce the heat transfer surface area which is required for a corresponding application which helps to minimize heat exchanger size and cost.
2) Increase the heat duty of the exchanger and
3) Permit closer approach temperature.
All of these can be visualized from the expression for heat duty for a heat exchanger.

$$Q=UA\ LMTD.$$

Any enhancement technique that increases the heat transfer coefficient also increases the overall conductance U. therefore in conventional and compact heat exchangers, one can reduce the heat transfer area A, increase the heat duty or decrease the temperature diff. LMTD, rsp., for fixed Q and LMTD. Fixed A and LMTD, or fixed Q and A. enhancement can also be used to prevent the overheating of heat transfer surface in system with a fixed heat generation rate such as in the cooling of electrical and electronic device. In any practical application a complete analysis is required to determine the economic benefits of enhancement. Such an analysis must include to possible increased first cost because of the enhancement, increased heat exchanger heat transfer performance, the effect on operating costs. Another concern in some industrial applications is the possibility of increased fouling of the heat exchanger surface caused by the enhancement. Accelerating fouling can quickly eliminate any increase in the heat transfer coefficient achieved by enhancement of a clean surface. Nevertheless in the present day concerns of sustainable energy utilization and the need for conservation the benefits of using enhancement techniques in most heat exchanger system cannot be overstated.

II AUGMENTATION TECHNIQUE

They are broadly classified into three different categories:
1. Passive Techniques
2. Active Techniques
3. Compound Techniques.
1) **Passive Techniques**: These techniques do not require any direct input of external power; rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop. They generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior except for extended surfaces. Heat transfer augmentation by these techniques can be achieved by using;
2) Active Techniques: In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by
(i) **Mechanical Aids**: In this technique the fluid is rotating by stirrer. This technique includes rotating tube heat exchanger, scrap surface heat as well as mass exchanger.

(ii) **Surface vibration**: It is applicable to single phase flow to get higher heat transfer coefficient.
(iii) **Fluid vibration**: This is mostly use practical type of vibration enhancement technique.
.(iv) **Electrostatic fields**: It can use in the form of electric or magnetic field or combination of two, which can use in heat exchange system.
(v) **Injection**: In this method injecting same fluid or different fluid in main bulk take place.
(vi)**Suction**: In this technique vapor removal take place by field boiling or fluid withdrawn through porous heated surface.
(vii) **Jet impingement**: In this technique direction of heating or cooling fluid are perpendicular or obliquely to the heat transfer surface.
3**) Compound Techniques**: These techniques are employed when one or more things are used. This technique is combination of active as well as passive technique to enhance heat transfer rate. It has limited application therefore it can’t be used widely.

III TREATED SURFACES

These are primarily applicable in two phase heat transfer and they consist of a variety of structured surfaces (continuous or discontinuous integral surface roughness or alterations) and coatings. Through the treatment provides a roughness to the surface, it is not large enough to influence single phase heat transfer.The principle of providing treated surfaces for enhanced boiling is to produce a large number of stable vapor traps or nucleation sites on the surface. This is applicable for highly wetting fluids like refrigerants, organic liquids, cryogens and alkali liquid metals where the normal cavities present on the heated surfaces tend to experience sub-cooled liquid flooding. For less wetting or relatively higher surface tension fluids, coatings of non-wetting material(e.g.Teflon) on either the heated surface or its pits and cavities have been found to improve stable nucleation and reduce the required wall super heat were proposed by Griffith and Wallis, Young and Hummel,(1965); Gartner,(1967);Vachon,(1969). When the stainless steel surface along with Teflon is spread to create spots of the no-wetting material on the heated surface it was found to promote nucleate boiling in water with relatively low wall super heat and three to four times higher heat transfer coefficients, was proposed by Young and Hummel(1965). In a more recent study of boiling of alcohols (methanol, ethanol and isopropanol) at atmospheric and sub-atmospheric pressures on a horizontal brass tube coated with poly-tetra-fluoro-ethylene (PTFE) 10, found a significant enhancement in heat transfer.Conditions with wall sub-cooling of about 16°C and 6°C respectively showed that condensation heat transfer coefficients increased by factors of 2.3 to 3.6 compared to those for un-coated tubes.

Rough Surfaces

The use of surface roughness in turbulent single phase flow is one of the simplest and highly effective techniques; small scale roughness has little effect in laminar flows.

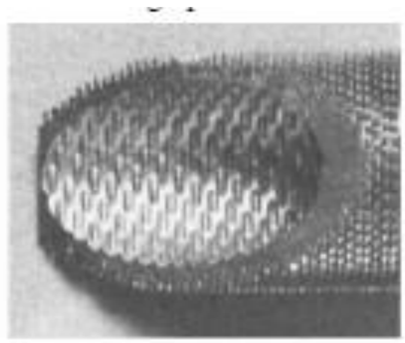


Figure 1 Three-Dimensional roughness[10]

It essentially disturbs the viscous laminar sub-layer near the wall to promote higher momentum and heat transport. Surface roughness can be introduced in the form of wire-coiled type inserts or it may be integral to the surface.Rough surfaces [10] have been employed to enhance heat transfer in single phase flows both inside tubes and outside

Dong et al. (2001) developed a new set of analogy based friction factor and Nusselt number correlations for turbulent flows of water and oil in spirally corrugated tubes. Adopting an empirical approach, combined with a statistical analysis of a fairly large database for heat transfer coefficients and friction factors for various roughness shown above, Ravigururajan and Burgles (1996) These above correlations have been shown very good compared with more than 1800experimental data points. Tubes with grooves provide an external rough surface and have been used in double pipe and shell and tube bundles to enhance annulus or shell side heat transfer. Variable roughness can be obtained by using a wire-coil insert made of a shape memory alloy (SMA) that alters its geometry in response to change in temperature proposed by Burgles and Champagne, 1999. With a fixed roughness height (e/d), the wire coil inserts change from a compressed shape, which occupies a smaller fraction of the tube length, to an expanded shape that has the desired roughness pitch (p/d) and helix pitch (α/90) upon being heated. Champagne and Burgles (2001) have also shown that by using SMA (NiTi) wire coil inserts, heat transfer coefficients can be increased from 30 to 64% in single phase turbulent flow.

Some of the recent work with water and propylene glycol flows in annuli with corrugated tubes indicate up to four times higher Nusselt number, with up to ten times higher friction factor in turbulent flow regime proposed by Garimella and Christensen,1995; Salim etal.,1999; Kang and Christensen,2000. Durant et al. (1965) have reported that by using three dimensional diamond- knurls type of roughness on the inner heated tube’s outer surface, the heat transfer coefficient can be increased up to 75% higher than those for the equivalent smooth annuli. In case of pyramid shaped roughness element considered by Achenbach(1977) and Zhukauskas et al. (1978), with air and water flows, 150% increase in Nusslenumber is reported

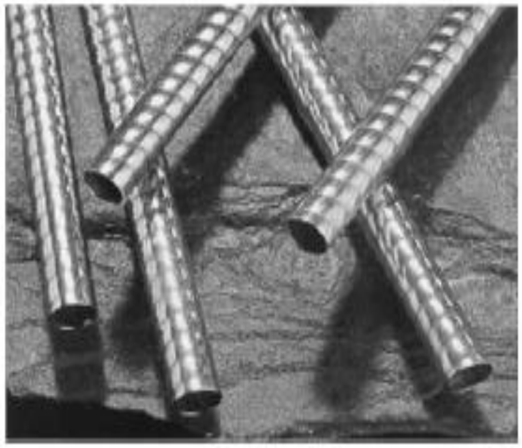


Figure 2 Two-Dimensional Roughness (Corrugated tubes)[10]

Swirl Flow Devices:
Swirl flow devices [11] generally consist of a variety of tube inserts, geometrically varied flow arrangements and duct geometry modifications that produce flows. These techniques include twisted tape inserts, periodic tangential fluid injection and helically twisted tubes.

Single-Phase flows: Twisted tape inserts are the most widely used swirl flow device for single-phase flows. These inserts increase the heat transfer coefficient significantly with relatively small pressure drop penalty as reported by Smithburg and Landis (1964); Lopina and Burgles (1969); Date and Singham (1972); Manglik and Burgles (1992); Manglik and Yera (2002). Twisted tapes can be used in the existing shell and tube heat exchangers to upgrade their heat duties or when employed in a new exchanger for a specified heat duty, significant reduction in size can be achieved. The ease of fitting multiple bundles with tape inserts and their removal makes them useful in fouling situations, where frequent tube-side cleaning may be required. When swirl flow devices are placed inside a circular tube, the flow field gets altered in several ways like an increase in axial velocity and wetted perimeter due to the blockage and partitioning of the flow cross-section, longer effective flow length in the helically twisting partitioned duct and tape's helical curvature induces secondary fluid circulation or swirl. Swirl generation is the most dominant mechanism which effects transverse fluid transport across the tape partitioned duct, thereby promoting greater fluid mixing and higher heat transfer coefficients.

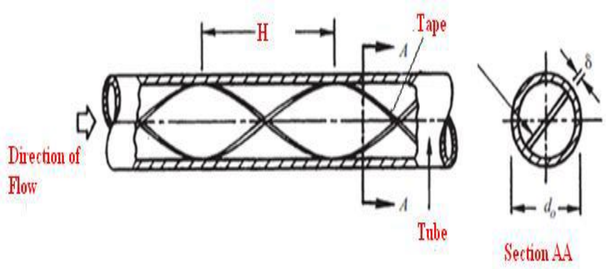
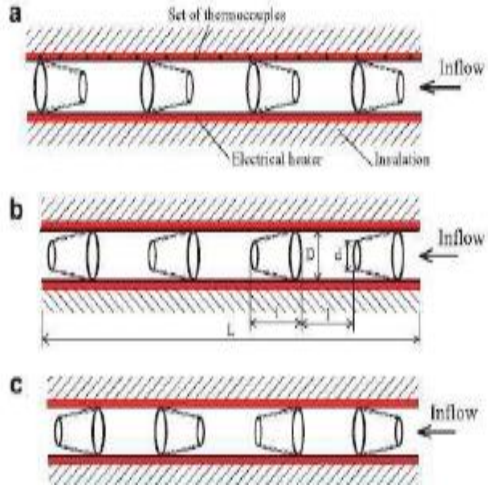


Figure 0 Example of full-length twisted tape[4]

Displaced Enhancement Devices:
Single-Phase Flow:
Several types of inserts which are categorized as displaced enhancement devices [11] include static mixer elements (e.g. Kenics, Sulzer), metallic mesh, discs, wire matrix inserts, rings or balls which tend to displace the fluid from the core of the channel to its heated or cooled wall and vice versa, keeping the heat transfer surface unaltered. Rings and round balls have comparable heat transfer improvements, but the friction factors are exorbitantly high. Most of the devices are effective only in laminar flows, as in turbulent flows, the pressure drop penalties are extremely high as reported by Bergles (1998). The applications of static mixers are generally restricted to chemical processing with heat transfer, where fluid mixing is the primary need.



a:- Diverging Ring, b:- Converging Ring, c:- Converging and Diverging Rings

Figure 4 Conical Ring inserts in circular tubes[3]

Spiral brush inserts in short channels with turbulent flows and high wall heatflux have been shown by Megerlin et al. (1974) and found out that heat transfer coefficient can be improved as much as 8.5 times that in a smooth tube, but pressure drop was exorbitantly high; which restricted its use in practical applications.

Single-Phase Flow: The single phase flow behavior, thermal-hydraulic performance and applications of curved and coiled tubes of circular as well as noncircular cross section have been proposed by Nandakumar and masliyah, 1986; Shah and Joshi, 1987; Berglesetal., 1991; Ebadian and Dong, 1998.The curvature induced swirl flow characteristics of curved or helically coiled tubes are strongly dependent on their geometrical attributes. The tube curvature acts to impose a centrifugal force on the fluid motion, thereby generating secondary circulation in laminar flows which consist of two symmetrical counter-rotating helical vortices was proposed by Mori and Nakayama,1965;Collin andDennis,1975;Nandakumar and masliyah, 1982;Prusa and Yao,1982;Cheng andYuen,1987.The thermal entrance region for curved tubes is significantly smaller than that for straight tubes for the same flow conditions.

IV EXPERIMENTAL WORK

Convective heat transfer through pipe is studied by inserting surfaces roughness parameter such as twisted tapes, internal fins etc. it is seen from literature review that twisted tape is of prime importance which affects the heat transfer through wall of pipe for carrying out the experimental work on the twisted tapes, test section, expt. Setup used is as shown in below.Development of the test section is the main task of dissertation work. Here Copper tube is used at the inner side of test section having 1500 mm length and 25.4mm inside dia. At the outer side G.I pipe is used having 1500mm length and 52 mm inner dia. &At the one end of outer pipe opening for cold water and at the opposite end outlet of cold water is provided.

Figure 5 Experimental Setup

V RESULT AND DISCUSSION

The experimental investigation and the calculations were discussed in the last chapter. Now the present chapter deals with interpretation of the obtained results. Effect of different Reynolds numbers on the Nusselt's Number, pressure drops and performance evaluation criteria R1 are studied. These parameters are considered for plain tube, typical twisted tube, straight twisted tapes with different twist ratio. Then the comparative study was carried out which is summarized in the current chapter.

Nusselt Number Results:

Table No 1& 2 gives the Nusselt's Number results for Plain Tube and typical twisted tapes .The results are used to study the effect of twist ratio on the Nusselt's number for varying Reynolds numbers.

Table 1for Plain Tube.

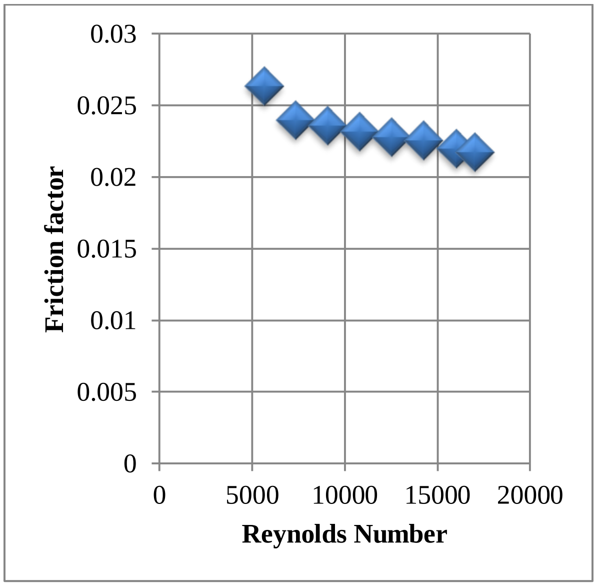
Sr.No	Qc LPH	Qh LPH	mh (kg/sec)	Vh (kg/sec)	q c watt	q h watt	Q average watt	h inner w m2/k	Nu	Re
1	1050	240	0.066	0.13157	970.299	1019.265	994.782	711.229	28.2887	5655.95
2	1050	312	0.086	0.17104	1091.21	1219.465	1155.338	996.553	31.672	7343.31
3	1050	384	0.106	0.21051	1333.7	1411.262	1372.482	979.7	38.9487	9087.13
4	1050	456	0.125	0.2499	1453.45	1578.999	1517.224	1074.91	42.719	10817.6

5	1050	528	0.145	0.2895	1576.73	1698.384	1637.558	1159.88	46.0904	12537.6
6	1050	600	0.165	0.3289	1698.02	1803.142	1750.582	1235.36	49.0743	14267.4
7	1050	672	0.185	0.3684	1576.19	1774.901	1675.547	1166.44	46.3219	16020.7
8	1050	744	0.196	0.39142	1455.45	1640.381	1547.915	1063.26	42.2111	17064

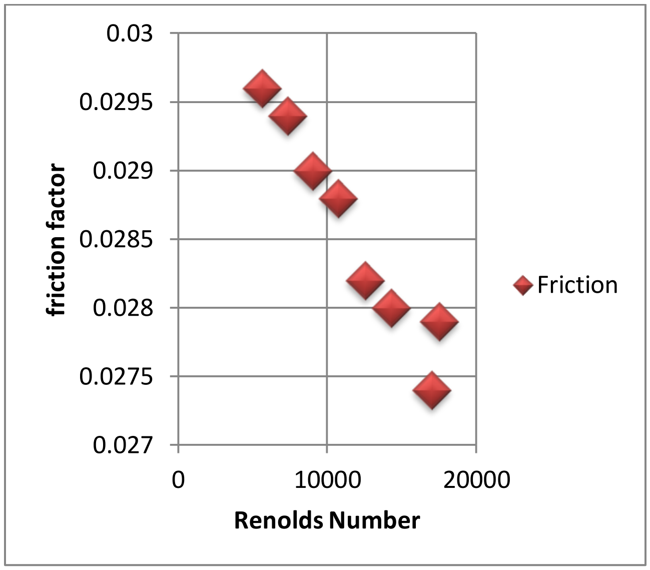
Table 2for Typical Twisted Tape having (y/w=2.5)

Sr.No	Qc LPH	Qh LPH	mh (kg/sec)	Vh (m/sec)	q c watt	q h watt	Q average watt	h inner w m2/k	Nu	Re
1	1050	240	0.06598	0.1315	1091.59	1158.395	1125.261	821.969	32.7241	5633.39
2	1050	312	0.0857	0.171	1212.87	1397.152	1305.013	945.99	37.6616	7340.8
3	1050	384	0.1055	0.2105	1576.74	1387.644	1582.19	1158.17	46.0657	9056.55
4	1050	456	0.1253	0.2499	1819.31	18323.25	1826.279	1325.69	52.7122	10760.5
5	1050	528	0.1451	0.2895	1698.02	1880.327	1789.175	1276.57	50.727	12579
6	1050	600	0.1649	0.3289	1940.52	1930.737	1935.327	1347.68	53.1956	14302.8
7	1050	672	0.1846	0.3684	1939.92	2006.406	1973.163	1392.61	55.295	17523.4
8	1050	744	0.1962	0.3914	1455.45	1722.404	1588.926	1091.18	43.3263	17039.8

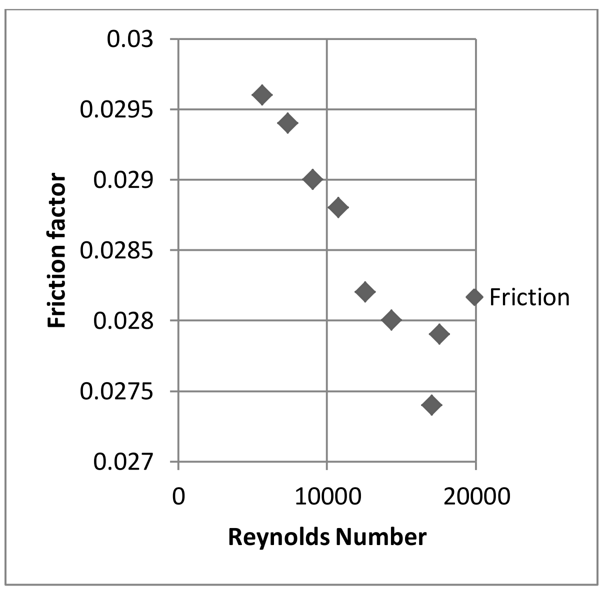
Graph 1, 2, 3, and 4 show variation of friction factor with Reynolds number for plaintube& typical twisted tapes having twist ratio of 2.5,3 & 3.5 As found the friction factor increases with decreasing twist ratio (y/w). Because twisted tape with shorter twist length provides longer flowing path, resulting in larger tangential contact between flowing stream and tube surface. Therefore loss due to friction increases .



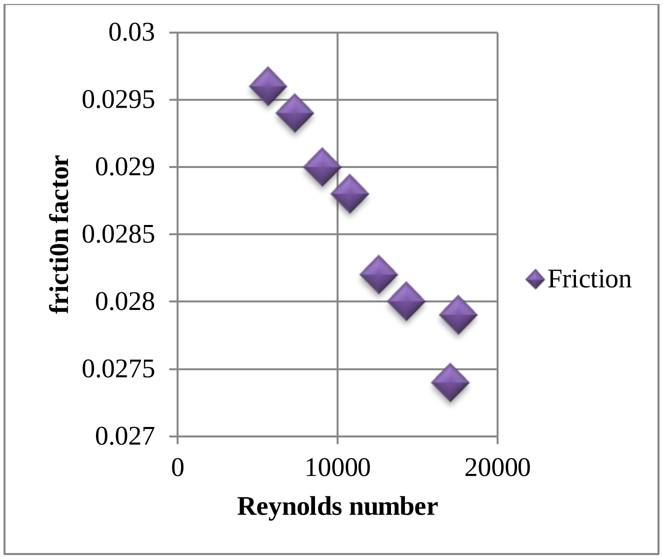
Graph 1. Friction Factor Vs Reynolds Number for Plain Tube



Graph 2. -Friction Factor Vs Reynolds Number for Typical Twisted Tape having (y/w=2.5)



Graph 3.-Friction Factor vs. Reynolds Number for Typical Twisted Tape having (y/w=3)



Graph 4. -Friction Factor Vs Reynolds Number for Typical Twisted Tape having (y/w=3.5)

IV CONCLUSION

TheTypical Twisted tapes (TT) effect on the heat transfer enhancement and friction factor in turbulent flow regimes (5000 ≤ Re ≤ 17,100) are described. The Typical twisted tape, twisted tapes with different twist ratio (y/w=2.5, 3 and 3.5) are tested using the water as the working fluid. The conclusions are drawn as follows:

1. As the twist ratio decreases, Nusselt's Number increases but at the same time pressure drop also increases.

2. For higher twist ratio, show greater Nusselt's Number, heat transfer coefficient and friction factor than the lower twist ratio , because of higher degree of turbulence generated.

3. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on therequirement, one of the above mentioned inserts can be used for heat transfer augmentation

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REFERENCES

[1] M.M.K. Bhutiyaa, M.S.U. Chowdhury c, M. Saha , M.T. islam ,"Heat transfer and friction factor characteristics in turbulent flow through a tube fitted with perforated twisted tape inserts", International Communications in Heat and Mass Transfer 46 ,(2013), pp. 49–57.

[2] S Naga sarada, A.V Sita Rama Raju , K KalyaniRadha, "Enhancement of heat transfer using varying width twisted tape inserts" International Journal of Engineering Science & Technology, Vol 2 No.6 2010 pp 107-118.

[3] S. Liu , M. Sakr, " A comprehensive review on passive heat transfer enhancements in pipe exchangers". Renewable & Sustainable Energy Reviews 19 (2013) 64-81

[4] SubhankarSaha, Sujoy Kumar Saha, "Enhancement of heat transfer of laminar flow of viscous oil through a circular tube having integral helical rib roughness and fitted with helical screw-tapes", Experimental Thermal and Fluid Science 47,(2013), pp. 81–89.

[5] V. Vivek , L. viveknath& N. Vinayagam, "Experimental investigations of augmentation in heat transfer coefficient by single &multy start helical tape inserts." 37 National & 4 th international conference on Fluid Mechanics & Fluid Power , December 16-18, 2010 , IIT Madras , Chenai , India.

[6] M.M. K Bhutiya , A.S. M Sayen , M.Islam , M.S.U Choudhary , M.Sahabudhidin, "Performance assessment in a heat exchanger tube fitted with double counter twisted tape inserts". International Communications in Heat and Mass Transfer xx ,(2013),

[7] HatitBas ,VeyselOzceyhan,"Heat transfer enhancement in a tube with twisted tape inserts placed separately from the tube wall. " Experimental Thermal &Fluid Science 41(2012) 51-58.

[8] 8.) JianGuo, Aiwu Fan, Xiaoyu Zhang, Wei Liu, A numerical study on heat transfer and friction factor characteristics of laminar flow in a circular tube fitted with center-cleared twisted tape, International Journal of Thermal Sciences 50 (2011) 1263-1270

[9] S.W. Chang, T.L. Yang, J.S. Liou, Heat transfer and pressure drop in tube with brokentwisted tape insert, Experimental Thermal and Fluid Science 32 (2007) 489–501.

[10] Bergles, A.E., Blumenkrantz, A.R. Performance evaluation criteria for enhanced heat transfer surfaces. 5th International Heat Conference, Tokyo (1974), Vol. 2, pp. 239-243

[11] R.M.Manglik.HeatTransferEnhancement,Thermal-Fluids and Thermal Processing Lab.Chapter No-14, 1029-1101

[12] P Murugensan , A K Mayisamy, S Suresh, " Heat Tranfer& Friction Factor in a tube Equipped with U cut Twisted Tape Inserts." Jorden Journal of Mechanical & Industrial Engineering, Volume 5 , November 6 Dec 2011, ISSSN 1995-1665, Pages 559-565.

[13] R.L. Webb, Performance evaluation criteria for use of enhanced heat transfer surfaces in heat exchanger design, Int. J. Heat Mass Transfer 24 (1981) 715–726.