Heat Transfer Augmentation in Concentric Tube Heat Exchanger Using Twisted Tapes

Maughal Ahmed Ali Baig*, Ibrahim Nouzil**, Azzam Sheik**, Ferraz Mohammed**, Thameez**
*Associate Professor, Dept. of Mechanical Engg., Bearys Institute of technology, Mangalore, Karnataka, India.
** Final Year Students, Dept. of Mechanical Engg., P. A. College of Engineering, Mangalore.

ABSTRACT

The present paper deals with the results of an experimental investigation carried out to find the overall performance of suitably designed concentric tube heat exchanger with passive heat transfer augmentation technique. The desired augmentation is attained with the help of twisted tape inserts. In addition to this, the performance of twisted tapes with holes and with baffle plates is carried out to find the suitable design for the heat transfer augmentation. The effect of twisted tape inserts on effectiveness of heat exchanger is analyzed at different mass flow rates. It is found that full length twisted tapes produce a better performance as compared to other designs tested.

Keywords- **Effectiveness, Heat exchangers, Inserts, Twisted Tapes**

I. INTRODUCTION

Effective utilization of available energy becomes need of hour today. This obviously requires effective devising. When it concerns heat energy the devices are heat exchangers. Heat exchangers are used in variety of applications. Some of the applications of heat exchangers are in process industries, thermal Power plants, air-conditioning equipment's, refrigerators, radiators for space vehicles, automobiles etc. Increase in Heat exchanger performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. To increase the thermal performance of heat exchangers Heat transfer augmentation techniques are used. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. These techniques broadly divided in two groups viz. passive, and active. Active techniques involves some external power input for the enhancement of heat transfer, some examples of active techniques include induced vibrations in the setup, the use of a magnetic field to disturb the seeded light particles in a flowing stream etc. Passive techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices, for example, use of inserts, use of rough surfaces etc. In present work passive technique of augmentation is used. The Concentric tube heat exchanger is fitted with different types of twisted tapes and its effect is studied.

Passive heat transfer augmentation methods: Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and repository time of the fluid in the effective region. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system. Following Methods are generally used,

1. Inserts
2. Extended surface
3. Surface modifications
4. Use of additives.

Inserts: Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer. Different types of inserts are

- Twisted tapes and coils
- Ribs and baffles
- Fins

In the present study effect of different types of twisted tapes are studied.

Twisted Tape:

Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow. Following are the main categories of twisted tape which are analyzed in this study:

i. **Full length twisted tape:** These tapes have length equal to length of test section.
ii. **Varying length twisted tape**: These are distinguished from first category with regards that they are not having the length equal to length of test section, but half length, ¾ th length, ¼th length of section etc.
iii. **Regularly spaced twisted tapes:** These are short length tapes of different pitches spaced by connecting together.

iv. **Tape with attached baffles:** Baffles are attached to the twisted tape at some intervals so as to achieve more augmentation.
v. **Tapes with holes**: Slots and holes of suitable dimensions made in the twisted tape so as to create more turbulence.

Common attributes of tape:

i. **Width:** Small width tapes are preferred to minimize pressure drop.
ii. **Thickness:** Thickness of the tape plays important role in its fabrication and also has contribution in fin effect
iii. **Pitch:** It is the distance between two consecutive twists measured axially.
iv. **Twist ratio:** It is the ratio of pitch of tape to tape width. So, if width of the tape considered as a constant (as found generally) twist ratio depends on pitch only. Under this condition if pitch is more it means less number of turns.
v. **Fin effect:** If the tape material is conductive then during the flow some heat will be absorbed by the tape material itself till its saturation. This is simply the loss of available heat energy.

II. EXPERIMENTAL SET-UP

Fig1.1: Experimental setup

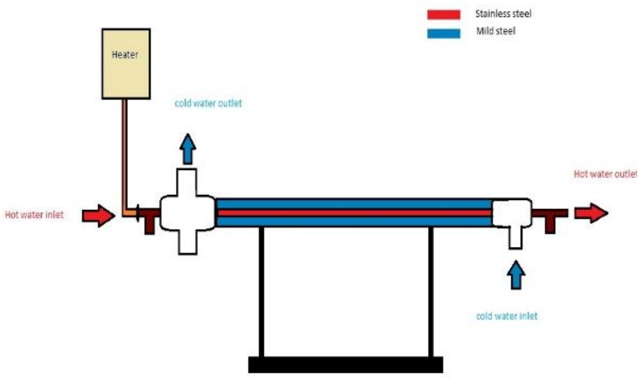


Fig1.2: Schematic Diagram of the setup

Fig1.1 shows the experimental setup used to conduct the experiments. It consists of double pipe heat exchanger consisting of a test section & a 3 KW 3Lit, electric geyser to supply constant hot water & the control system. The test section is a smooth stainless steel as an inner tube; and an outer mild steel pipe. The outer pipe is well insulated using glass wool held with jute rope to reduce heat losses to the atmosphere. Tap water is sent to geyser and then the heated water is directed to the inner tube through a control valve. Three temperature measuring devices to measure the inlet& outlet temperature of hot water & outlet of cold water. The inlet temperature of cold water is measured using mercury thermometer.

Specifications:

Inner diameter	= 12.7mm
Inner pipe material	= Stainless Steel
Outer diameter	= 38.1mm
Outer pipe material	= Mild Steel
Effective length	= 1175mm

Inner Twisted Tape:

The table below shows the actual view of the twisted tapes used. Three tapes with stainless steel material are prepared with different attributes. Width, Length and pitch for all Tapes are kept same, i.e. width=3 mm, length=1000 mm and pitch=60 mm.

Details of tape used in the present experiment:

Tape I	Full length tape	
Tape II	Tape with holes	
Tape III	Tape with baffles	

III. EXPERIMENTATION

A series of experimentation is carried out with the heat exchanger set-up. Initially the experiment is conducted without utilizing any heat transfer augmentation method (**case I**). Case I is set as benchmark for the analysis of other augmentation methods. The flow rate for both hot and cold water is varied between 200cc/min to 800cc/min, considering the capacity of the electric geyser used, and at a time both the mass flow rates are kept almost constant. Four temperatures (cold water inlet and outlet, hot water inlet and outlet) are measured with the digital temperature indicator. The mass flow rate is measured manually with help of measuring jar and stopwatch. The same procedure is repeated for all cases as following

i) **Case II:** Experimentation on Heat exchanger set up with full length twisted tape.
ii) **Case III:** Experimentation on Heat exchanger set up with twisted tape with drilled holes.
iii) **Case IV**: Experimentation on Heat exchanger set up with twisted tape with attached baffles.

Process Variables:

Inlet temperature of Cold water	= Tci
Outlet temperature of cold water	= Tco
inlet temperature of hot water	= Thi
Outlet temperature of hot water	= Tho
Cold water mass flow rate	= Mc
Hot water mass flow rate	= Mh

Formulae Used:

Heat transfer from hot water

$Q_h = m_h C_{ph} (T_{hi}-T_{ho})$

Heat Transfer from cold water

$Q_c = m_c C_{pc} (T_{co}-T_{ci})$

LMTD= $(\Theta_2-\Theta_1)/ \ln (\Theta_2/\Theta_1)$

$\Theta_1=T_{ho}-T_{ci}$ $\Theta_2=T_{hi}-T_{co}$

Overall heat transfer co-efficient

U = Q/(A*LMTD)

Effectiveness E = $(T_{hi}-T_{ho})/ (T_{hi}-T_{ci})$

IV. RESULT AND DISCUSSIONS:

Experimentation is performed with all four cases mentioned earlier. Effectiveness, Overall heat transfer coefficient and LMTD calculated for all conditions. Parameters plotted for different values of mass flow rate.

Case I: Without any augmentation technique

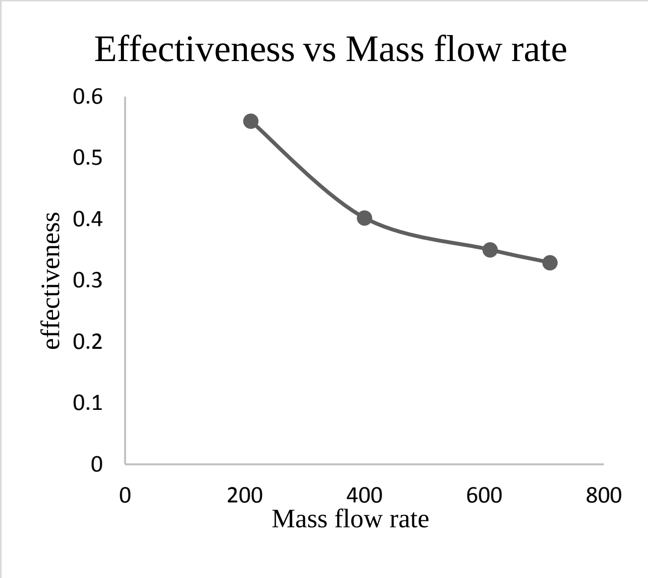


Fig1.3: Effectiveness vs. Mass flow rate for case I

From the fig1.3 it is clear that as the flow rate increases the effectiveness decreases. This is due to the increase in velocity of the working fluid which reduces the repository time of the fluid in the effective region of the heat exchanger.

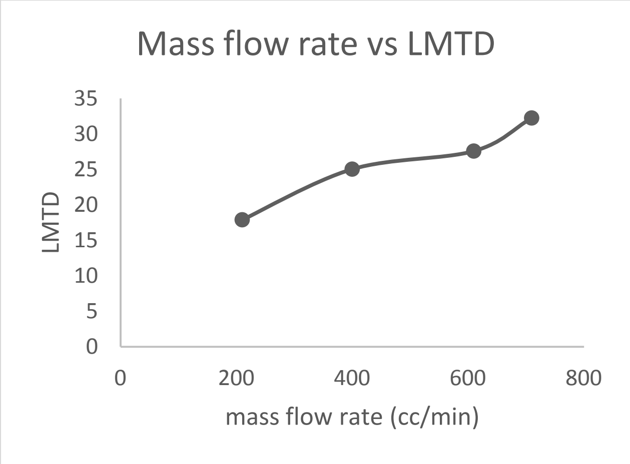


Fig1.4: LMTD vs. Mass flow Rate for case I

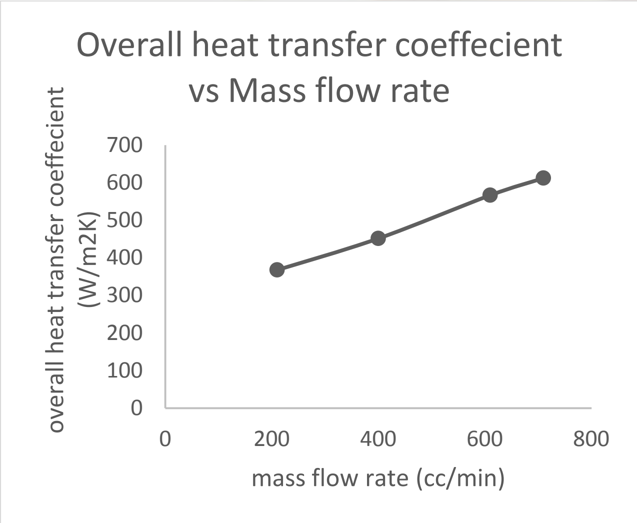


Fig1.5: Overall heat transfer coefficient vs. mass flow rate for case I

From fig1.5, as the flow rate increases the turbulence induced in flow also increases. Therefore the overall heat transfer coefficient also increases.

Case II: With Twisted Tape

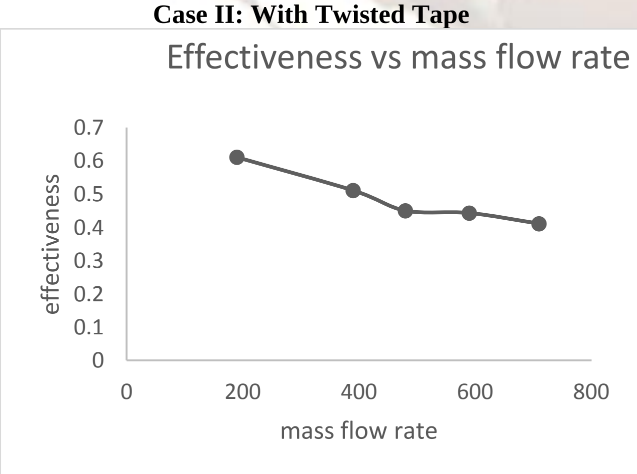


Fig2.1: Effectiveness vs. mass flow rate for case II

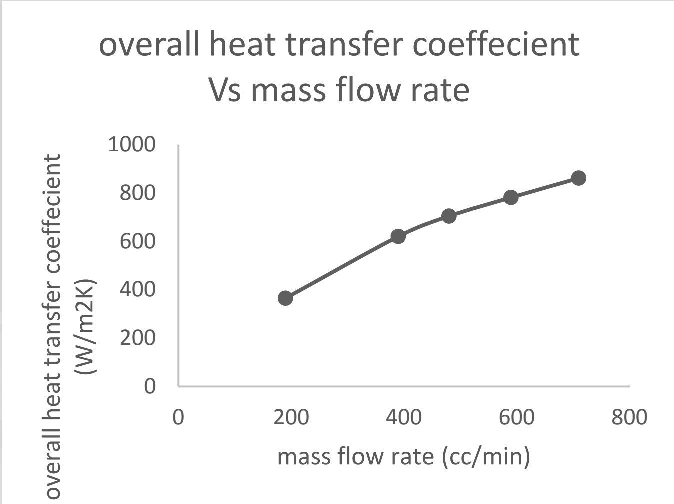


Fig2.2: Overall heat transfer coefficient vs. mass flow rate for case II

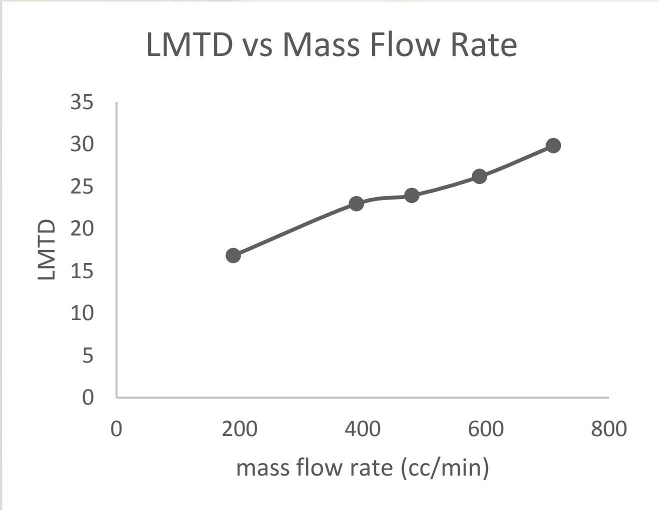


Fig2.3: LMTD vs. Mass flow rate for case II

From fig 2.1 and fig 2.2 it is clear that the effectiveness and overall heat transfer coefficient increase when twisted tape is inserted into the inner pipe. The twisted tape induces swirling motion in the water, thereby increasing the repository time of the fluid in the effective region and as a result heat transfer increases.

Case III: For Twisted Tape with Holes

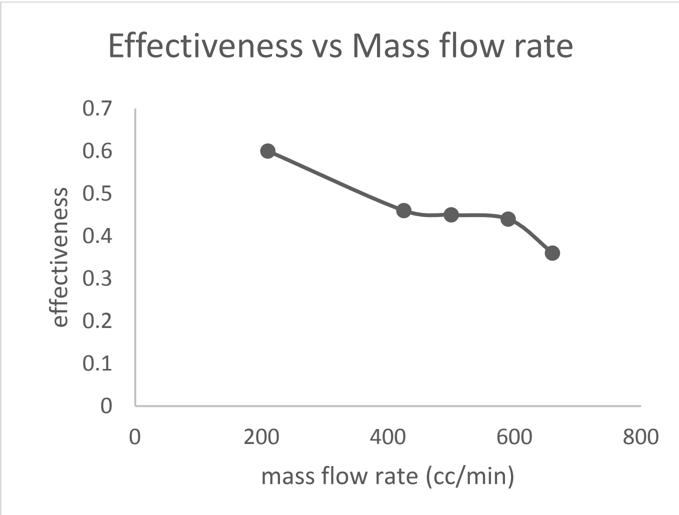


Fig3.1: effectiveness vs. mass flow rate for case III

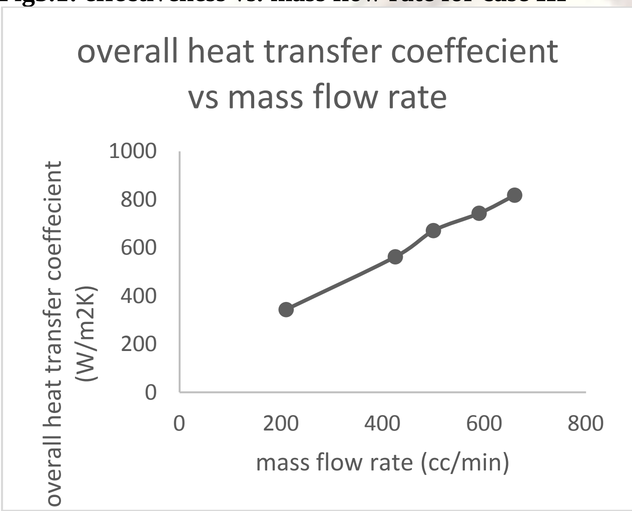


Fig3.2: overall heat transfer coefficient vs. mass flow rate for case III

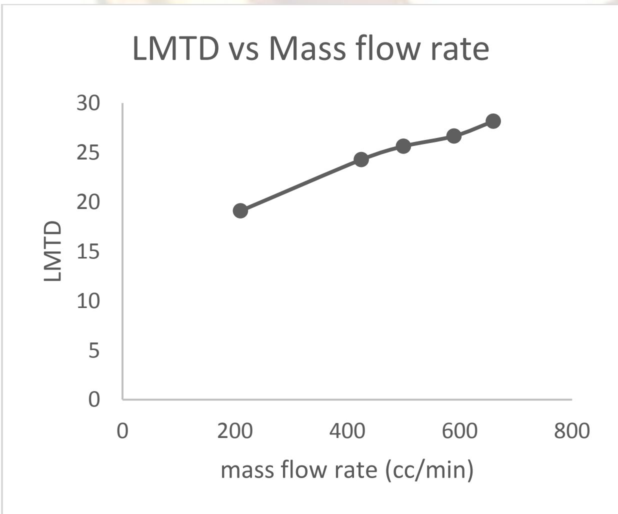


Fig3.3: LMTD vs. Mass flow rate for case III

From the fig 3.1 and fig 3.2 for twisted tape with holes the effectiveness is better than the benchmark. But compared to case II the effectiveness is lower. This may be due to discontinuous swirl motion of the fluid.

Case IV: Twisted Tape with Baffles

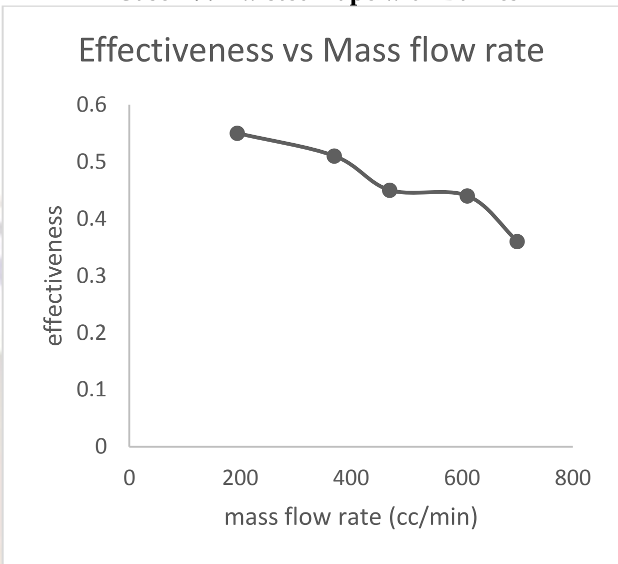


Fig4.1: Effectiveness vs. mass flow rate for case IV

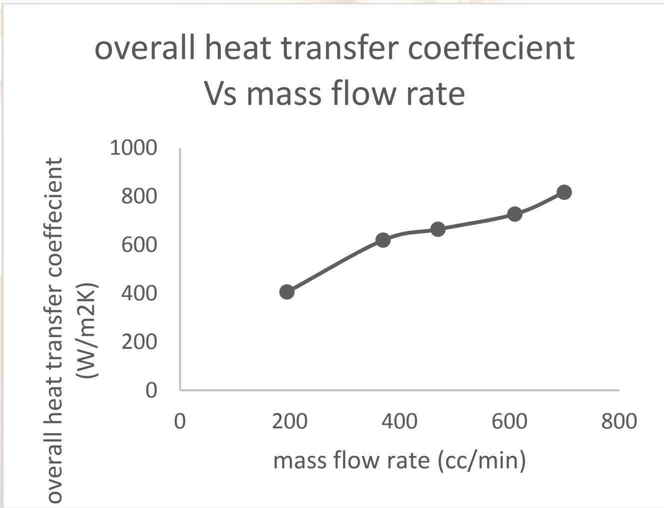


Fig4.2: overall heat transfer coefficient vs. mass flow rate for case IV

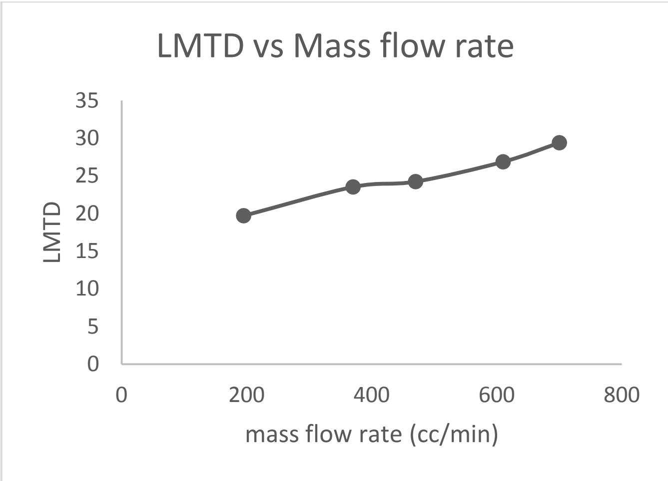
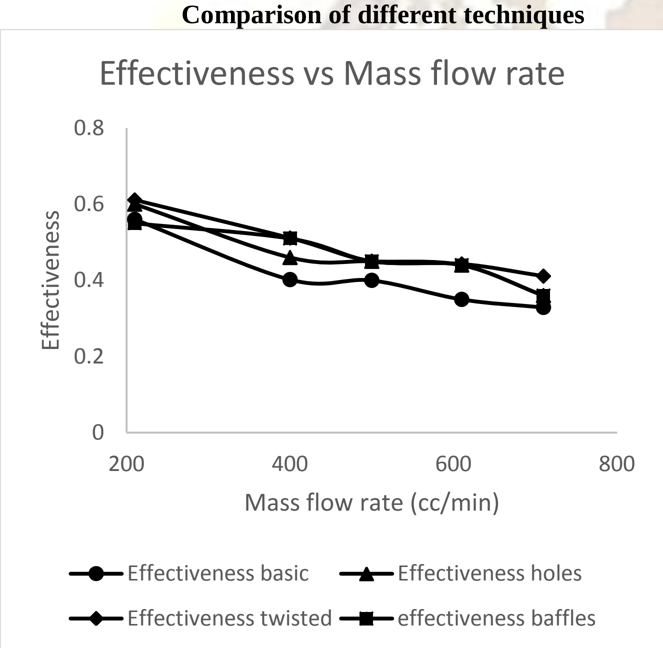


Fig4.2: LMTD vs. Mass flow rate

From fig4.1 and fig4.2 it is observed that there is substantial increase in effectiveness for increased mass flow rate. The result may be further enhanced by attaching more number of baffles in the twisted tape.

Comparison of different techniques



V. CONCLUSIONS

Experimental investigations have been carried out to study the effects of tape inserts on the performance of concentric tube heat exchanger. Effectiveness, overall heat transfer coefficient and LMTD are analyzed using mentioned heat transfer augmentation methods. From the graphs plotted the following conclusions are made

1. The heat transfer in the heat exchanger could be enhanced by using Tapes.
2. The full length twisted tape increases heat transfer by a percentage of 8.9%.
3. Twisted tape with holes and baffles of present configuration underperform compared to full twisted tape.

REFERENCES

[1] S.K.Saha A.Dutta " Thermo hydraulic study of laminar swirl flow through a circular tube fitted with twisted tapes" Trans. ASME Journal of heat transfer June 2001, Vol-123/ pages 417-427.

[2] Zhi-Min Lin, Liang-Bi Wang "Convective heat transfer enhancement in a circular tube using twisted tape" Trans ASME journal of heat transfer Aug 2009,Vol- 131/081901-1-12.

[3] Watcharin Noothong, Smith Eiamsa-ard and Pongjet Promvonge" Effect of twisted tape inserts on heat transfer in tube" 2nd joint international conference on "sustainable Energy and Environment 2006" Bangkok, Thiland.

[4] Paisarn Naphon "Heat transfer and pressure drop in the horizontal double pipes with and without twisted tape in-sert" 2005 Elsevier Ltd.

[5] Smith Eiamsa-ard , Chinaruk Thianpong, Pongjet Promvonge " Experimental investigation of heat transfer and flow friction in a Circular tube fitted with regularly spaced twisted tape elements" International Communications in Heat and Mass Transfer Vol. 33, Dec 2006.

[6] Ashis K. Mazumder, Sujoy K. Saha "Enhancement of Thermo hydraulic Performance of Turbulent Flow in Rec-tangular and Square Ribbed Ducts With Twisted-Tape Inserts" Journal of Heat Transfer AUGUST 2008, Vol. 130.

[7] A Dewan1 , P Mahanta1, K Sumithra Raju1 and P Suresh Kumar "Review of passive heat transfer augmentation techniques" Proc. Instn Mech. Engrs Vol. 218.