Enhancement of heat transfer in the double pipe heat exchanger using different twisted tapes

Katkoori Sandeep Kumar¹, Battu Satish Kumar², Sai kumar A³, N Mahesh Reddy⁴

¹Assistant professor, Mechanical Department, MLR Institute of Technology.
²M.tech student (thermal engg), Mechanical Department, MLR Institute of technology
³Assistant professor, Aeronautical Department, MLR institute of technology .
⁴B.tech student, Mechanical Department MLR institute of technology.

katkoori.sandeep@gmail.com,battusatish94@gmail.com,ask.mraj@gmail.com, mahesh.narsing@gmail.com.

Abstract. In this project deals with the utilization of various twisted tape inserts as Passive Heat transfer improvement device. result of twisted tape insert (TTI), Baffled twisted tape insert (BTTI) & Baffled twisted tape insert with holes (BTTHI) on heat transfer and friction factor for heating of water for Reynolds range vary 2600-32000, was studied through an experiment during a double pipe heat exchanger. Three tapes of various twist magnitude relation (TR=3.60, TR=4.30, TR=5.20) for TTI, BTTI & BTTHI were used. The parameter which we are calculating in this is heat transfer coefficient and friction factor.

1. Introduction
The need to increase the thermal performance of heat exchangers, thereby effecting energy, material & value savings have led to development & use of the many techniques termed as Heat transfer Augmentation. These techniques are also referred as Heat transfer improvement or Intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance during a device.

Use of heat transfer enhancement techniques cause increase in heat transfer coefficient however at the value of increase in pressure drop. So, whereas designing a device using any of these techniques, analysis of heat transfer rate & pressure drop should be done. Except this, issues like future performance economic analysis of heat exchanger ought to be studied, to achieve high heat transfer rate in associate existing or new heat exchanger whereas taking care of the increased pumping power, several techniques are projected in recent years and are mentioned within the following sections.

Twisted tapes-a sort of passive heat transfer augmentation techniques have shown considerably sensible leads to past studies. For experimental work, Reduced dimension twisted tapes, having width but ID of within tube (W/da=0.727)) are used. Completely different designs of twisted tapes used area unit twisted tapes insert (TTI), Baffled with twisted tapes insert (BTTI) & Baffled with twisted tape insert with holes (BTTHI). All these tapes have been studied with three completely different twist ratios (TR =3.60, TR =4.30, TR = 5.20)

2. Literature review:-
Classification of enhancement techniques
Heat transfer enhancement or augmentation techniques refer to the improvement of thermo-hydraulic performance of heat exchangers. Existing enhancement techniques can be broadly classified into three different categories:

- Passive Techniques
  1. Treated Surface
  2. Rough surfaces
  3. Extended surfaces
  4. Displaced enhancement devices
  5. Swirl flow devices
  6. Coiled tubes
  7. Surface tension devices
  8. Additives for liquids

- Active Techniques
  1. Mechanical Aid
  2. Surface vibrations
  3. Fluid vibrations
  4. Electrostatic fields
  5. Injections
  6. Suction
  7. Jet impingement

- Compound Techniques

Saha et al. [1] He has done a experimental study on a circular tube exploitation completely different twisted tape (short length, full length, swimmingly varied pitch, and often spacing tapes) he has determined that friction and nusselt range are low for brief length tape and it additionally needs little pumping power and also thermo hydraulic performance is same for multiple and single twisted tapes. And he additionally ended that uniform pitch perform higher than the step by step decreasing pitch. and every one the observation were done on streamline flow.

Bergles et al. [2] He has studied on experiment in circular tube by exploitation full-length twisted tape. In his experimental study he has ended that nusselt variety may be a function of twist ratio, Reynolds number and prandtel number. Friction is affected by tape twist solely at high Reynolds number and nusselt number is nine times that of empty tube.

Manglik et al. [3] He has studied regarding the experiment in equal tube by exploitation completely different twisted ratios like (3, 4, 5 and6). during this he has planned a correlation for friction and nusselt number and physical description of improvement mechanism. And he additionally compared twisted tape with thin rod .he has used glycol and water during this study.

Saha et al. [4] He has done his experimental study on circular tube exploitation twisted tape having regular spacing. In his study he has ended that pinching of twisted tape offers higher results than connecting skinny rod for thermo hydraulic performance and by reducing tape width provides poor result if it’s larger than zero section angles not effective.

Missal et al. [5] He done his experimental study on plate heat exchangers and shell and tube heat exchangers by victimization twisted tape .he conclude that enormous value of overall heat transfer constant produced in water-to-water mode with oil-to-water mode.

Lokanath et al. [6] He has studied through an experiment on horizontal tube. By victimization full length and half length twisted tapes .he has concluded that on unit pressure drop basis and on unit pumping poor basis, half length twisted tape is simpler than full length twisted tape.

Liao et al. [7] He has done his study on tube flow by using segmental twisted tape and 3 dimensional extended surfaces. during this he had concluded that during a tube with 3 dimensional extended surfaces and twisted tape increase average stanton range up to 5.8 times compared with empty sleek tube. during this he has used water, ethylene glycol and turbine oil.
Ujhidy et al. [8] He has done his experimental study on experiment in channel by victimization twisted tape. In his experiment he has explain flow structure and established existence of secondary flow in tubes with coiled static components. He has used water as operating medium.

Suresh Kumar et al. [9] He has done his experiment in giant diameter annulus by victimization twisted tape. In his experiment he has determined that comparatively massive value of friction factor measured heat transfer in annulus with completely different configurations of twisted tapes by victimization water as working medium.

Saha et al. [10] He has done his experiment in circular tube flow by using twisted tape of regular spacing. In his experimental study he has observed that larger number of turns yield improvement in thermo hydraulic performance compare with the single turn tape.

3. Specifications of Heat Exchanger Used

The experimental study is done in a double pipe heat exchanger having the specifications as listed below

Specifications of Heat Exchanger

- Inner pipe ID = 20mm
- Inner pipe OD=23mm
- Outer pipe ID =51mm
- Outer pipe OD =59mm
- Material of construction= Copper
- Heat transfer length= 2.43m
- Pressure tapping to pressure tapping length = 2.458m

Water at room temperature was allowed to flow through the inner pipe while hot water (set point 60°C) flowed through the annulus side in the counter current direction.

Standard formulas

- The heat transfer rate of the cold water is
  \[ Q_c = m_c c_p (T_{c,\text{out}} - T_{c,\text{in}}) \]
- The velocity of the water can be calculated by
  \[ v = \frac{m_c}{\rho A} \]
- Reynolds number
  \[ \text{Re} = \frac{v d_i}{\nu} \]
- Nusselt number from Gnielinski equation
  \[ \text{Nu}_{\text{Gnielinski}} = \frac{\left( \frac{X}{X - 1000} \right) \left( \frac{\text{Pr}^{0.5}}{\text{Pr}^{0.5}} \right) \left( \frac{\text{Re} - 1000}{\text{Re} - 1} \right)}{(1 + 12.7 \left( \frac{X}{X - 1000} \right) \left( \frac{\text{Pr}^{0.5}}{\text{Pr}^{0.5}} \right) \left( \frac{\text{Re} - 1000}{\text{Re} - 1} \right))} \]
  valid for \( 2300 < \text{Re} < 5^6, 0.5 < \text{Pr} < 2000 \) And \( f = (1.58 \ln(\text{Re}) - 3.2)^3 \)
- Heat transfer coefficient
  \[ h_c = \frac{(\text{Nu})}{d_i} \]
- The heat transfer rate of the hot water is
  \[ Q_h = m_h c_p (T_{h,\text{in}} - T_{h,\text{out}}) \]
- Velocity of the hot water can be calculated by
  \[ v = \frac{m_h}{\rho A} \]
- Reynolds number for hot water
  \[ \text{Re} = \frac{v d}{\nu} \]
• Nusselt number from Gnielinski equation

\[
    \mathrm{Nu} = \frac{f_2 X (Re - 1000) \times Pr}{(1 + 12.7f_2^{0.32}) (Pr^2 - 1)}
\]

valid for \(2300 < Re > 5^6, 0.5 < Pr < 2000\) and \(f = (1.58 \ln(Re) - 3.2)^2\)

• For LMTD

\[
    \Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}
\]

• Average of heat

\[
    Q = (Q_c + Q_h) / 2
\]

• Overall heat transfer

\[
    U_i = \frac{Q_i}{A \times \Delta T_{LMTD}}
\]

• Experimental heat transfer coefficient

\[
    \frac{1}{u_i} = \frac{1}{h_{i,exp}} + \frac{1}{h_o}
\]

\[
    \frac{1}{h_{i,exp}} = \frac{1}{u_i} - \frac{1}{h_o}
\]

• Friction factor \((f)\) calculations

For \(Re < 2100\)

\[
    f = \frac{16}{Re}
\]

• For theoretical heat transfer coefficient

\[
    \mathrm{Nu} = F[0.023(1 + (\pi/2y)^2)]^{0.4} \times \text{Re}^{0.8} \times \text{Pr}^{0.4} + [0.193(\text{Re}/y)^2(\text{d}_h/\text{d})^2(\text{Dde}/d)\times \text{Pr}]^{1.3}
\]

4. Experimental setup
Tables and graphs

Tables and graphs are drawn for both friction factor and heat transfer

- Smooth tube double pipe heat exchanger without insert.
- Double pipe heat exchanger with inserting Twisted tape insert with ratio 3.60.
- Double pipe heat exchanger with inserting Twisted tape insert with ratio 4.30.
- Double pipe heat exchanger with inserting Twisted tape insert with ratio 5.20.
- Double pipe heat exchanger with inserting Baffled twisted tape insert with ratio 3.60.
- Double pipe heat exchanger with inserting Baffled twisted tape insert with ratio 4.30.
- Double pipe heat exchanger with inserting Baffled twisted tape insert with ratio 5.20.
- Double pipe heat exchanger with inserting Baffled twisted tape with holes insert with ratio 3.60.
- Double pipe heat exchanger with inserting Baffled twisted tape with holes insert with ratio 4.30.
- Double pipe heat exchanger with inserting Baffled twisted tape with holes insert with ratio 5.20.

**Table 1:** Friction Factor
Reynolds number Vs frictional factor for smooth tube

| Mass (kg/sec) | Temperature | Reynolds | Height of manometer | Difference of pressure | Friction experimental | Friction theoretical | F exp/f the |
|---------------|-------------|----------|---------------------|------------------------|-----------------------|----------------------|------------|
| 0.0331        | 47.125      | 4138     | 0.09                | 6.8                    | 41.43                 | 40                    | 1.03       |
| 0.0497        | 47          | 6216     | 0.3                 | 13.9                   | 38.04                 | 36.1                  | 1.05       |
| 0.0654        | 46.25       | 8177     | 0.5                 | 22.5                   | 34.75                 | 33.7                  | 1.02       |
| 0.0819        | 37.475      | 8620     | 1.2                 | 34.2                   | 31.2                  | 32.9                  | 0.94       |
| 0.1034        | 40.925      | 10905    | 1.7                 | 51.6                   | 28.56                 | 31.0                  | 0.91       |

**Table 2:** Friction Factor
Reynolds number vs frictional factor for twisted tape with twisted ratio 3.60

| Mass (kg/sec) | Temperature | Reynolds | Height of manometer | Difference of pressure | Friction experimental | Friction theoretical | F exp/f the |
|---------------|-------------|----------|---------------------|------------------------|-----------------------|----------------------|------------|
| 0.0331        | 43.375      | 3489     | 1.5                 | 7.0                    | 46.79                 | 41.33                 | 1.13       |
| 0.0497        | 43.925      | 5242     | 2.9                 | 14.3                   | 40.09                 | 37.33                 | 1.07       |
| 0.0654        | 45.25       | 6902     | 4.5                 | 23.2                   | 36.10                 | 34.85                 | 1.03       |
| 0.0819        | 44.975      | 8644     | 6.5                 | 34.3                   | 33.15                 | 32.95                 | 1.00       |
| 0.1034        | 43.375      | 10906    | 8.26                | 51.6                   | 30.34                 | 31.08                 | 0.97       |

**Table 3:** Friction Factor
Reynolds number vs frictional factor with baffled twisted tape twisted ratio 4.30

| Mass (kg/sec) | Temperature | Reynolds | Height of manometer | Difference of pressure | Friction experimental | Friction theoretical | F exp/f the |
|---------------|-------------|----------|---------------------|------------------------|-----------------------|----------------------|------------|
| 0.0331        | 48.45       | 4046     | 2.3                 | 6.77                   | 89.8                  | 39.67                 | 2.26       |
| 0.0497        | 48.2        | 6074     | 6.5                 | 13.7                   | 77.9                  | 35.83                 | 2.17       |
| 0.0654        | 46.1        | 6902     | 9.8                 | 23.2                   | 74.5                  | 34.85                 | 2.13       |
| 0.0819        | 45.825      | 8643     | 12.5                | 34.3                   | 68.8                  | 32.94                 | 2.08       |
| 0.1034        | 45.375      | 10910    | 15.8                | 51.7                   | 63.4                  | 31.08                 | 2.04       |
Table 4: Friction Factor
Reynolds number vs frictional factor with baffled twisted tape with holes having twist ratio of 5.20

| Mass (kg/sec) | Temperature | Reynolds | Height of manometer | Difference of pressure | Friction experimental | Friction theoretical | F exp/f the |
|--------------|-------------|----------|---------------------|------------------------|----------------------|----------------------|-------------|
| 0.0331       | 46.725      | 4042     | 3.8                 | 6.76                   | 101.9                | 39.6                 | 2.56        |
| 0.0497       | 45.975      | 5244     | 5.26                | 14.3                   | 92.21                | 35.8                 | 2.47        |
| 0.0654       | 45.125      | 6898     | 12.68               | 23.18                  | 82.97                | 34.8                 | 2.38        |
| 0.0819       | 43.85       | 8634     | 9.23                | 34.34                  | 76.10                | 32.9                 | 2.30        |
| 0.1034       | 43.05       | 10897    | 29.35               | 51.61                  | 69.58                | 31.0                 | 2.23        |

Table 5: Heat Transfer
Smooth tube heat transfer vs reynolds number

| MASS | T1 | T2 | T3 | T4 | LMTD | Re  | Ui  | h(exp) | h(theo) |
|------|----|----|----|----|------|-----|-----|--------|---------|
| 0.0331 | 22.6 | 41.6 | 63.5 | 60.8 | 29.29 | 4138 | 304 | 821.2  | 823.097 |
| 0.0497 | 22.7 | 38.1 | 65.4 | 61.8 | 32.84 | 6216 | 357 | 1136  | 1140.83 |
| 0.0654 | 22.5 | 36.6 | 64.5 | 61.4 | 33.09 | 8177 | 422 | 1419  | 1433.46 |
| 0.0819 | 22.6 | 30.2 | 49.6 | 47.5 | 22.03 | 8620 | 448 | 1569  | 1620.68 |
| 0.1034 | 22.2 | 30.8 | 57  | 53.7 | 28.76 | 10905 | 531 | 1853  | 1924.65 |

Table 6: Heat Transfer
Heat transfer vs. Reynolds number for twisted tape of ratio 3.60

| MASS | T1 | T2 | T3 | T4 | LMTD | Re  | Ui  | H(exp) | H(theo) |
|------|----|----|----|----|------|-----|-----|--------|---------|
| 0.0331 | 29.6 | 42.5 | 51.5 | 49.9 | 13.89 | 3489 | 429 | 577    | 750     |
| 0.0497 | 30  | 41.2 | 53.3 | 51.2 | 16.22 | 5242 | 506 | 959.7  | 1247    |
| 0.0654 | 30.5 | 41.1 | 56  | 53.4 | 18.61 | 6902 | 576 | 1277.3 | 1660    |
| 0.0819 | 30.3 | 39.6 | 56.4 | 53.6 | 19.87 | 8644 | 620 | 1491.4 | 1938    |
| 0.1034 | 29.9 | 37.5 | 54.5 | 51.6 | 19.25 | 10906 | 701 | 1842   | 2394    |

Table 7: Heat Transfer
Heat transfer vs reynolds number for twisted tape with baffle of ratio 4.30

| MASS | T1 | T2 | T3 | T4 | LMTD | Re  | Ui  | H(exp) | H(theo) |
|------|----|----|----|----|------|-----|-----|--------|---------|
| 0.0331 | 33.9 | 49.3 | 56.2 | 54.5 | 12.48 | 4046 | 566 | 693.12 | 901     |
| 0.0497 | 34.2 | 47.4 | 56.8 | 54.4 | 14.11 | 6074 | 682 | 1109.73 | 1442    |
| 0.0654 | 34.3 | 44.1 | 54.2 | 51.8 | 13.46 | 6902 | 737 | 1271.52 | 1652    |
| 0.0819 | 34.2 | 42.9 | 54.4 | 51.8 | 14.33 | 8643 | 802 | 1483.76 | 1928    |
| 0.1034 | 34.5 | 41.5 | 54.1 | 51.4 | 14.64 | 10910 | 851 | 1804.08 | 2345    |
Table 8:- Heat Transfer
Heat transfer vs Reynolds number for twisted tape with baffle and holes of ratio 5.20

| MASS   | T1   | T2   | T3   | T4   | LMTD | Re   | t       | h(exp) | h(theo) | Per |
|--------|------|------|------|------|------|------|---------|--------|---------|-----|
| 0.0331 | 33.4 | 47.6 | 53.4 | 51.8 | 10.66| 4042 | 582     | 697    | 901     | 0.80|
| 0.0497 | 34.4 | 45.5 | 53.1 | 51.1 | 11.63| 5244 | 706     | 950    | 1442    | 0.80|
| 0.0654 | 34.1 | 43.4 | 52.3 | 50.1 | 11.85| 6898 | 747     | 1277   | 1652    | 0.78|
| 0.0819 | 34   | 41.5 | 51   | 48.8 | 11.91| 8634 | 820     | 1496   | 1928    | 0.76|
| 0.1034 | 34.6 | 39.9 | 50.3 | 48   | 12.19| 10897| 870     | 1841   | 2345    | 0.76|

GRAPHS

Graph 1:- Heat transfer (theo) vs. Reynolds number

Graph 2:- Heat transfer (exp) vs. Reynolds number
5. **Scope for future work**

Further studies can be done using this study as base. Some of the possibilities are mentioned below:

- Experimental work can be done at **below Reynolds number of 1000** using viscous liquids, as the twisted tapes have shown comparatively good results at low Reynolds number.

- **And by changing Distance between two consecutive baffles & holes** we can see their effect on heat transfer & friction factor.

**Geometry of baffles:**

1. Square and semi-circular baffles can be used instead of rectangular baffles.
2. Instead of keep the baffles perpendicular to the flow of fluid we can keep the baffles at certain angle to the flow of fluid.
3. Changing the dimensions of the baffles.

The proposed design can also be used for cooling the liquids also.

**References**

[1] Saha, S. K. and Dutta, A. -Thermo-hydraulic study of laminar swirl flow through a circular tube fitted with twisted tapes. *Trans. ASME, J. Heat Transfer*, 2001, 123, 417–421.

[2] Hong, S. W. and Bergles, A. E. Augmentation of laminar flow heat transfer in tubes by means of twisted-tape inserts. *Trans. ASME J. Heat Transfer*, 1976, 98, 251–256.

[3] Manglik, R. M. and Bergles, A. E. -Heat transfer and pressure drop correlations for twisted tape insert in isothermal tubes. *Part 1: laminar flows. Trans. ASME, J. Heat Transfer*, 1993, 116, 881–889.

[4] Saha, S. K., Dutta, A. and Dhal, S. K. Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements. *Int.J. Heat and Mass Transfer*, 2001, 44, 4211–4223.
[5] Lokanath, M. S. and Misal, R. D. An experimental study on the performance of plate heat exchanger and an augmented shell and tube heat exchanger for different types of fluids for marine applications. In Proceedings of 5th ISHMT– ASME Heat and Mass Transfer Conference, India, 2002, pp. 863–868 (Tata McGraw-Hill, New Delhi).

[6] Lokanath, M. S. -Performance evaluation of full length and half length twisted tape inserts on laminar flow heat transfer in tubesl. In Proceedings of 3rd ISHMT–ASME Heat and Mass Transfer Conference, India, 1997, pp. 319–324 (Tata McGraw-Hill, New Delhi).

[7] Q. Liao, M.D. Xin -Augmentation of convective heat transfer inside tubes with three-dimensional internal extended surfaces and twisted-tape inserts’ Chemical Engineering Journal 78 (2000).

[8] Ujhidy et. al, Fluid flow in tubes with helical elements, Chemical Engineering and Processing 42 (2003), pp. 1–7.

[9] Suresh Kumar. P., Mahanta, P. and Dewan, A. Study of laminar flow in a large diameter annulus with twisted tape inserts. In Proceedings of 2nd International Conference on Heat Transfer, Fluid Mechanics, and Thermodynamics, Victoria Falls, Zambia, 2003, paper KP3.

[10] Saha, S. K. and Chakraborty, D. -Heat transfer and pressure drop characteristics of laminar flow through a circular tube fitted with regularly spaced twisted tape elements with multiple twistsl. In Proceedings of 3rd ISHMT–ASME Heat and Mass Transfer Conference, India, 1997, pp. 313–318 (Tata McGraw-Hill, New Delhi).