CFD ANALYSIS OF HEAT TRANSFER ENHANCEMENT BY USING PASSIVE TECHNIQUE IN HEAT EXCHANGER

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ABSTRACT

The heat transfer enhancement is very important many engineering applications to increase the performance of heat exchangers. The active techniques required external power like surface vibrations, electrical fields etc and the passive techniques are those which does not required any external power but the inserts are required to disturb the flow like tape inserts etc moreover literature survey says passive techniques gives more heat transfer rate without external power requirement by keeping different tape inserts. However CFD tool is very important and effective tool to understanding heat transfer applications. Computational heat transfer flow modelling is one of the great challenges in the classical sciences. By incorporating the inserts the heat transfer enhancement is increased due to its importance in different applications. By CFD modelling by taking concentric tube by considering with and without inserts we conclude that heat transfer enhancement by using ANSYS Fluent version 14.5.

KEYWORDS

Heat transfer, parallel flow heat exchanger, heat transfer agumentation, CFD Analysis, passive technique, Reynolds no, Nussult no, twisted tape insert.

1. INTRODUCTION

Heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. They facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other. Different applications of heat exchanger are condensers, evaporators, boilers conditionation and refrigeration etc. Heat exchanger is used in automobile radiators and coolers. Heat exchangers are also abundant in chemical and process industries. We will consider only the more common types here for discussing some analysis and design methodologies. Heat exchangers are popular used in industrial and engineering applications. 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. By incorporating different techniques we conclude that heat transfer coefficient increases with the cost of pressure drop. Heat transfer enhancement techniques are classified as follows

1.1 Passive Techniques:

Passive techniques are geometrical change or with disturbing the fluid by keeping inserts. They promote higher heat transfer coefficients by disturbing or altering the existing flow behaviour (except for extended surfaces) which also leads to increase in the pressure drop. Heat transfer augmentation achieved by following

Treated Surfaces: Treated surfaces are applicable primarily in two-phase heat transfer, and they consist of a variety of structured surfaces (continuous or discontinuous integral surface roughness or alterations) and coatings. In the event that this treatment provides a “roughness” to the surface, its size (normal protrusion to the surface) is not large enough to influence single-phase forced convection

Rough surfaces: Structured roughness can be integral to the surface, or the protuberances can be introduced in the form of wire-coil-type inserts. The former can be produced by machining (e.g., knurling, threading, grooving), forming, casting, or welding, and the resulting surface protuberances or grooves can be two dimensional or discrete three-dimensional in their geometrical arrangement

Extended surfaces: Extended or finned surfaces are perhaps the most widely used and researched of all enhancement techniques. Enhanced heat transfer from finned surfaces by buoyancy-driven natural or free convection has been considered primarily for cooling of electrical and electronic devices and for hot-water baseboard room heaters. building/room heating equipment, the use of baseboard heaters has declined considerably; in fact, this practice is close to being discontinued.

Swirl flow devices: Swirl flow devices generally consist of a variety of tube inserts, geometrically varied flow arrangements, and duct geometry modifications that produce secondary flows. Typical examples of each of these techniques include twisted-tape inserts, periodic tangential fluid injection, and helically twisted tubes.

Coiled tubes: A coiled or curved tube has long been recognized as a swirl-producing flow geometry. The secondary fluid motion is generated essentially by the continuous change in direction of the tangential vector to the bounding curved surface of the duct, which results in the local deflection of the bulk flow velocity vector.

Configuration sketches of various twisted tapes.

Configuration	Name	Reference	Configuration	Name	Reference
Typical twisted tape	[5]		Twisted tape with various widths	[7]
Twisted tape with various twist ratios	[6]		Short-length twisted tape	[8]
Left and right twist tape with rod and spacer	[9,14]		Peripherally-cut twisted tape with an alternate axis	[22]
Left-right twisted tapes	[18]		Twist tape with alternate axis	[15]
Dual twisted tapes	[12]		Multiple twisted tape	[13]
Left and right twisted tape with varying space	[15]		Twisted tape with centre wing	[10]
Delta-winglet twisted tape	[19]		Twisted tapes with alternate-axes and triangular, rectangular and trapezoidal wings	[20]
Twisted tape with trapezoidal-cut	[21]		Serrated twisted tape at various serration depth ratios	[30]
Peripherally-cut twisted tape	[23]		V-cut twisted tape insert	[24]
Jagged twisted tape	[37]		Butter fly inserts	[37]
Helical screw-tape with varying spacers	[25]		Helical screw tape with various spacer length	[28]
Right and left helical screw tape	[27]		Twisted-tape with oblique teeth	[37]
Dimpled tube fitted with twisted tape	[32]		Twisted tape consisting wire nails	[31]

Table 1. Configuration sketches of various twisted tapes.

By incorporating helical tape inserts as literature survey says there is a heat transfer enhancement. For the experimental set up by Reducing width of the helical twisted tape inserts with ID of inside tube ($W/d_i=0.675$) are shown in Table 1. Configuration sketches of various twisted tapes.

2. METHODOLOGY

Following methodology used to evaluate performance by using CFD analysis.

- Identification of flow domain
- Geometry Modeling.
- Grid generation.
- Specification of boundary Conditions.
- Selection of solver parameters and
- Convergence criteria.
- Results and post processing.

2.1 Modelling

Heat exchanger is modelled using CATIA V5 software. It is an assembly of all the parts. A concentric tube heat exchanger (with twisted tape), heat exchanger (without inserting any twisted tape) is modelled according to the dimensions of practically available heat exchanger. Heat exchanger with twisted tape

Figure 1. Heat exchanger with twisted tape

SpecificationsHeat exchanger

Outer diameter of the outer tube	: 39mm
Inner diameter of the outer tube	: 36mm
Outer diameter of the inner tube	: 25mm
Inner diameter of the outer tube	: 19mm
Length of the heat exchanger	: 200mm

Figure 2.twisted tape

Twisted tape

Length of the twisted tape	: 200mm
Pitch of the twisted tape	: 40mm
Cross section of twisted tape	: rectangular (7*5)

Heat exchanger without twisted tape

Figure 3. Heat exchanger without twisted tape

Specifications Heat exchanger

Outer diameter of the outer tube	: 39mm
Inner diameter of the outer tube	: 36mm
Outer diameter of the inner tube	: 25mm
Inner diameter of the outer tube	: 19mm
Length of the heat exchanger	: 200mm

2.2 Meshing

The designed heat exchanger is imported into the ANSYS Workbench. It is meshed by using mesh module. Meshing is done as discussed in the previous units. In this regard 3D unstructured meshing is used to mesh the object regard 3D unstructured meshing is used. The following fig shows the meshing parts.

Figure 4. Meshed heat exchanger with twisted tape

Details of meshing

Details of "Mesh"	
Size	
Use Advanced Size Fun...	On: Proximity and Curvature
Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
☐ Curvature Normal A...	Default (18.0 °)
☐ Proximity Accuracy	0.5
☐ Num Cells Across Gap	Default (3)
☐ Min Size	Default (3.0661e-005 m)
☐ Proximity Min Size	Default (3.0661e-005 m)
☐ Max Face Size	Default (3.0661e-003 m)
☐ Max Size	Default (6.1323e-003 m)
☐ Growth Rate	Default (1.20)
Minimum Edge Length	2.5e-003 m

Table 1. Meshing details

Nodes	: 37366
Elements	: 105486

2.3 Analysis

After the completion of meshing the design is opened in ANSYS Fluent. In fluent boundary conditions are given as per requirement and the solution is initialized and calculations are iterated. After the calculation is converged the contours are to be plotted.

Boundary conditions:

- Fluid domain is to be specified
- Temperature

At inlet

Hot fluid – water (335k)

Cold fluid – water (300k) at normal pressure

Figure 5. Boundaries of the heat exchanger

In the analysis report the mainly Reynolds number, pressure, velocity, temperature contour to be viewed. The results obtained are to be tabulated.

Boundary specifications

Coil surface	: wall
Coil edges	: wall
Cold tube outer surface	: wall
Hot tube outer surface	: wall
Cold water inlet	: velocity inlet
Hot water inlet	: velocity inlet
Cold water outlet	: pressure outlet
Hot water outlet	: pressure outlet
Cold domain	: mass flow
Hot domain	: mass flow

2.4 Reynolds number variation

Heat exchanger with twisted tape

Figure 6. Reynolds number variation in heat exchanger with twisted tape

Figure 7. Reynolds number at inlet in heat exchanger with twisted tape

Figure 8.Reynolds number at out in heat exchanger with twisted tape

In the above figures we can observe that the Reynolds number is increasing from inlet of the heat exchanger to the outlet of the heat exchanger. This is because of the reason that, during the flow of fluid over the twisted tapes a disturbance is created in the flow, thus turbulence is created .This results in the increase of the Reynolds number.

Heat exchanger without twisted tape

Figure 9.Reynolds number at inlet in heat exchanger without twisted tape

Figure 10. Reynolds number at outlet in heat exchanger without twisted tape

Figs 9 & 10 shows the Reynolds number of the hot fluid at the inlet and outlet of the heat exchanger. We observe that there is not much difference in the values, they remain almost constant. This is due to no turbulence in the flow.

Velocity vector

Figure 11. velocity vector of heat exchanger with twisted tape

The above fig 11 shows the velocity & direction of the fluid elements during the flow in heat exchanger (with twisted tape). We can observe that there is a rise in velocity of the fluid elements when moving from inlet to the outlet. This is due to the swirl created by the twisted tape.

3. RESULTS AND DISCUSSION

The results showing for different velocities with different contours are plotted .The results obtained are tabulated as shown.

With twisted tape

At $V=33.63\text{m/s}$

Parameters	Hot fluid inlet	Hot fluid Outlet	Cold fluid inlet	Cold fluid outlet
Pressure(pas)	2.98e8	2.23e6	2.6e7	4.3e6
Reynolds no	3.61e4	6.28e5	9.12e4	1.17e6

Table 2. parameters at $V=33.63\text{m/s}$

$V=67.2\text{m/s}$

Parameter	Hot fluid inlet	Hot fluid outlet	cold fluid inlet	Cold fluid outlet
Pressure(pa)	1.17e9	1.35e7	2.8e9	9.79e7
Reynolds no	6.84e4	1.39e6	1.57e5	2.80e6

Table 3.parameters at $V=67.2\text{m/s}$

$V=100.8\text{m/s}$

Parameter	Hot fluid inlet	Hot fluid outlet	Cold fluid inlet	Cold fluid outlet
Pressure(pa)	3.15e9	3.1e8	6.3e9	6.2e8
Reynolds no	4.35e5	4.6e6	1.27e6	1.38e6

Table 4. Parameters at $V=100.8\text{m/s}$

Without twisted tape

At $V=33.63\text{m/s}$

Parameters	Hot fluid inlet	Hot fluid outlet	Cold fluid inlet	Cold fluid outlet
Pressure	1.02e5 pas	1.01e5 pas	1.01 e5 pas	1 e5 pas

Reynolds no	6.75 e4	6.76 e4	6.75e4	6.76e4
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Table 5. parameters at V=33.63m/s

At V=67.2m/s

Parameters	Hot fluid inlet	Hot fluid outlet	Cold fluid inlet	Cold fluid outlet
Pressure(pas)	1.03e5	1.01e5	1.06e5	1.01e5
Reynolds no	1.28e5	1.28e5	1.26e5	1.26e5

Table 6. parameters at V=67.2m/s

V =100.8m/s

Parameters	Hot fluid inlet	Hot fluid outlet	Cold fluid inlet	Cold fluid outlet
Pressure(pas)	1.05e5 pas	9.98e5	9.27e4	9.2e4
Reynolds no	2.01e5	2.03e5	1.92e5	1.94e5

Table 7. parameters at V=100.8m/s

After tabulating the results they are compared in both cases. It is observed that the Reynolds number varies largely between inlet and outlet of the heat exchanger in the case of heat exchanger with twisted tape, whereas in heat exchanger without twisted tape Reynolds number remains constant.

When we are concern about the pressure, pressure drop is larger in with twisted tape than without twisted tape. Our concern is about the enhancement of heat transfer so we can ignore the pressure drop.

3.1 Validation

By using the equation Dittus-Boelter Reynolds number is directly proportional to the nusselt number correlate the results

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

n = 0.4 for heating fluids
n = 0.3 for cooling liquids

Nu=Nusselt number
Re=Reynolds number
pr=prandtl number
h=heat transfer coefficient
 Δt =change in temperature

From the equation above we conclude that as Reynolds number increases Nusselt number also increases. We have the formula to validate

$$h = (Nu \cdot K) / l$$

$$Q = h \cdot a \cdot \Delta t$$

So, as Nusselt number increases the heat transfer coefficient also increases, as heat transfer coefficient increases the heat transfer enhancement is obtained.

4. CONCLUSIONS

CFD analysis is carried out by taking double pipe heat exchanger with cold and hot fluids with different boundary conditions by incorporating helical tape inserts. It can be concluded as follows: By using passive techniques that is by inserting helical tape inserts the heat transfer enhancement increased by 10-15% with the cost of reasonable allowable pressure drop. In this report we achieved enhancement of heat transfer effectively.

Future work may be extended to:

- Material should be changed to Aluminium to copper or which is having high thermal conductivity materials
- Combination of techniques may be used to enhancement of heat transfer coefficient by compound techniques.
- Reduce the width of helical tape inserts with low Reynolds number.
- By varying low Reynolds numbers check the Heat transfer enhancement coefficient

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