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Heat Transfer Analysis in Heat Exchanger using Helical Baffles

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ABSTRACT

Heat exchanger is the device used to transfer the heat from the hot fluid to the cold fluid directly in contact with each other. In heat exchanger, the heat transfer rate depends on the surface area of metal are in contact with hot and cold fluid. It also depends on the type of flow of fluid in the heat exchanger. The baffle plate is to control the flow of the fluid and reduce the turbulence of flow. It guides the water flow around the hot fluid pipe and rejects the heat from the pipe. The helical plate is attached to the hot fluid pipe and guides the flow of the cold fluid. The helical baffle plates are used to increase the surface area of fluid contact and enhance the effectiveness of the heat exchanger. From the helical baffle plate the size of the heat exchanger is reduced due to increased area to transfer the heat. It is simple in construction and the plate is also act as a fin and improves the heat exchanger process. The parallel flow and counter flow characteristics are enhanced by the helical baffles in the heat exchanger. It is economical by the usage of material for heat exchanger preparation and reduces the complexity of design of heat exchanger.

Keywords: Heat exchanger, Hot fluid, Helical baffle and Complexity.

1. INTRODUCTION

Heat exchanger is used to exchange the heat from the fluid to the cold fluid without the fluid directly in contact with each other. The hot fluid that runs in the inner pipe and the cold fluid that runs on the outer pipe.

The heat is transferred from the hot fluid to the inner pipe by convection process. Again heat from the inner pipe flows to the cold pipe by convection process. The baffles plates are uses it support the pipes or tubes and also to direct the fluid flow and to increase the turbulence of the shell fluid.

The shell and tube baffle plates are also designed according to their spacing, geometry depends on the flow rate, allowable shell – side pressure drop, and tube support requirement used the flow induced vibration.

1. Plate heat exchanger

Plate heat exchangers usually are constructed of thin plates. The plates may be smooth or may have some form of corrugation. Since the plate geometry cannot accommodate as high pressure differentials as a circular tube, they are generally designed for moderate temperature or pressure.

2. Plate fin heat exchangers

Louvered or corrugated fins are separated by flat plates, Cross flow, counter flow, or parallel flow arrangement can be obtained readily by properly arranging the fins on each side of the plates. Plate fin heat exchangers are generally used for the gas-to-gas application.

3. Tube fin heat exchangers

When a high operating pressure or an extended surface is needed on one side, tube fin exchangers are used. It is of two configurations, one with round tube and the other with flat tubes. Tube fin exchangers can be used for a wide range of tube fluid operating pressure not exceeding about 30 atm and operating temperatures from low cryogenic applications to about 1113K. The tube-fin heat exchangers are used in gas turbine, nuclear, fuel cell, auto-mobile, airplane, heat pump, refrigeration, electronics, cryogenics, air-conditioning and may other applications.

4. Regenerative heat exchangers

Regenerative heat exchangers can be static or dynamic. The static type has no moving parts and consists of a porous mass through which hot and cold fluids pass alternatively. A flow-switching device regulates the periodic flowing of the two fluids. In dynamic type regenerators, the matrix is arranged in the form of a drum which rotates about an axis so that a given portion of the matrix passes periodically through the hot stream and then through the cold stream. The heat stored in the matrix during its contact with the hot gas is transferred to the cold gas during its contact with the cold stream.

Fluid flow type

In the tube fin heat exchanger, the shell and tube are to be used to transfer the heat the based on the classification of flow. The flows of fluid in heat exchanger are of mainly divided in three types namely

1. Parallel flow
2. Counter flow

2. DEVELOPMENT OF THE SYSTEM

The heat exchanger is designed to increase the heat transfer by altering the baffle plate design. The Design calculation is required to increase the heat transfer rate of the heat exchanger. The baffle plates are to be helically designed to increase the surface area. The baffle plates are attached to the hot fluid pipe to increase the heat transfer rate.

Calculation of helical angle
The helical angle is in between the plate and the perpendicular plane to the flow of pipe.
Total length of inner pipe = 1000 mm
Number of helical turns required = 21

Helix angle determination
tanϴ = (Length of helical distance per turn) / (length of helical plate)
Requirement of voltage for welding the helical plate:
1. The welding voltage that is depends on the material thickness needs to be welded.

2.1. Components required in heat exchanger
The components used in the heat exchanger that are namely

1. Casing
2. Inner pipe with helical baffles
3. Hose connection for fluid inlet and outlet
4. Clamp
5. Thermometer
6. Water heater

1. Casing
The casing is the outer part of the heat exchanger. It is used to reduce the leakage of the cold fluid. The casing contains the inlet and outlet hole for fluid flow. The outer casing cannot be in contact with the inner pipe. The casing is a cylindrical component and the centre of the casing.

2. Inner pipe with helical baffles
The inner pipes are in the centre of the heat exchanger, the baffles plates are welded with the inner pipe at certain helical angle. The inner pipe flow the hot fluid and transfer the heat from the hot fluid to the cold fluid by the helical plates.

3. Hose connection
The hose pipe are used of normal plastic pipe for the cold pipe, the metal or thermal withstand plastic are to be used for the hot fluid. In connects the inlets and the outlets of the heat exchanger

4. Clamp
The clamp is used to fit the hose pipe with the inlet and outlet of the heat exchanger; it connects the hose and the metal pipe at the proper position and holds them tightly.

5. Thermometer
Thermometer is an instrument used to measure the temperature, the thermometer is used to measure the fluid temperature and determine the mean temperature value in the inlet and the outlet of the hot and cold fluid.

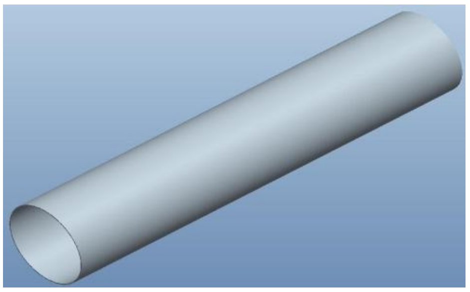
The temperature is determined and tabulated to calculate the effectiveness of the heat exchanger.

6. Water heater
Water heater is a device is used to heat the water and feed into the hot fluid the hot fluid to the heat exchanger. The hot fluid are connected by the hose and fed into the heat exchanger.

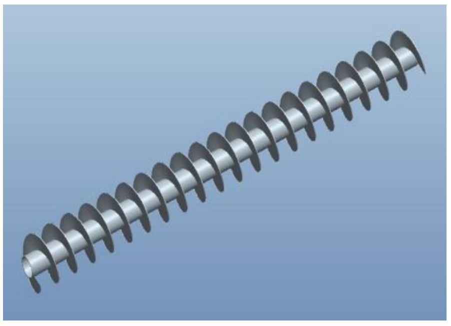
2.2. Procedure
Design needs
The designing of heat exchanger require the ANSYS software for solid work. The designing measurement of the heat exchanger is required for 2D draw.

Design procedure
The ANSYS software is opened and the new file is opened for drawing.

Casing
In that sketch the drawing of the outer pipe or casing and the 2D is extruded according to the length. The diagram of casing is saved.



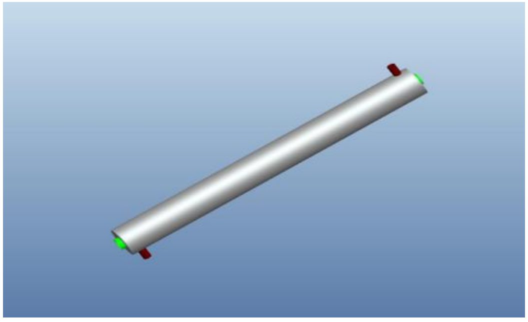
Inner pipe
In the new page the inner pipe is to be drawn according to the design requirement diameter and thickness. The 2D of inner pipe is extruded according to the length. The sketch option is selected and the helical sweep is clicked. From the surface option is selected in it. The surface required to produce the helical surface is also selected. The length of helical surface generation are produced by a line on the surface is drawn. The centre axis is also drawn at the centre of the inner pipe. The pitch value is given and the length of helical surface is drawn the preview is selected and click the ok button to generate the helical surface and it is saved.



Side casing
The circular plate is drawn in a new file and it contains a hole to procedure the fluid is comes in and goes out from the heat exchanger and saved. The additional pipe connection are drawn and saved in new file. The saved data are to be named together the diagram in the assembly of the parts.

Assembly
In ANSYS the new page is opened and the assembly option is clicked .The new page is opened. The assembly parts are inserted one after another by the assembly part option. And

the parts are opened from the file saved page the parts are inserted and the parts are aligned by the options in the assembly.



The parts are inserted and the heat exchanger design is prepared and the design is saved on the file.

Material selection

The material to be selected based on the heat transfer rate. The heat transfer rate is higher for copper, aluminum material. But the material are of having low melting point and higher thermal expansion and it affects the design of the heat exchanger. The welding of copper and aluminum material is also difficult and that will affect the design so the sheet plate of is used to weld on the inner pipe. The hose is made up of plastic to reduce the heat transfer with the atmosphere from the heater to the heat exchanger. The inner pipe thickness is to be of having higher thermal conductivity by critical radius.

Design requirement Inner pipe

In the inner pipe, the thickness of the pipe depends on the critical radius to transfer the heat from fluid to the cold fluid. The heat transfer increases at the critical radius of the pipe and transfer more heat to the fluids.

Outer pipe

The outer casing thickness is also designed to reduce the heat transfer from the cold fluid to the atmosphere. The sheet plate thickness is reduced as much as possible to increase the heat transfer rate.

Sheet thickness

The sheet thickness of the baffle plates is to be smaller to enhance the heat transfer from the inner pipe.

Fabrication process

In the fabrication process the heat exchanger is designed and the data are to be fabricated as to be same as the design of heat exchanger. From the design work, the fabrication is started and the product is developed as per the design parameter. The heat exchanger design that is based on the ANSYS design diagram the fabrication process is started.

Lathe operation

In the fabrication process, the diameter of the pipe is to be varied according to the requirement to increase the heat transfer. In this the diameter incremented by the heat transfer rate, increasing the rate by the critical radius. The critical radius of heat transfer that conduct more heat from one end to another in the pipe. If the diameter thickness is reduced to increase the heat transfer of the inner pipe, the length of the inner pipe is need to fix to the casing

Inner pipe

So the inner pie is cut by the pipe cutter using metal hacksaw to the required size measurement value of inner diameter pipe
Outer diameter of pipe = 43 mm
Inner diameter of pipe = 38 mm
Thickness = 2.5 mm

Outer diameter casing

In this the outer diameter pipe is used as casing of the heat exchanger. The casing that are need to reduce the heat transfer rate and they are need to be isolated from the surrounding. The diameter is determined and the thickness of the outer diameter pipe is determined based on the requirement and that reduce the heat transfer rate with the surrounding.

The length of the casing is to be cut slightly greater than the inner pipe. The inner pipes are needed to be fixed with the outer pipe after the helical baffle is welded.

The outer diameter is then surface finished after the fabrication is completed.

The measurement value of outer diameter is pipe:
Outer diameter of pipe = 108 mm
Inner diameter of pipe = 105 mm
Thickness = 1.5 mm

Sheet metal

In this process the sheet metal is used as baffle plates. The helical designs are produced by bending the sheets. The sheets are selected for welding the sheet with the pipe .the sheet that is to be cut to the spherical shape. The plates that are cut off from the sheets and the diameter of the sheet have the diameter of the outer casing inner diameter.

The circular sheets are cut and they are to be again cut at the centre of having the diameter of the inner pipe. The cut pipe is removed from the circular plate. The plates are again cut at the one side from the outer diameter to the inner diameter. The cut sheets are then inserted into the inner pipe diameter. The sheets are to be placed in the inner diameter and made the heat in the helical form. The helical sections are drawn on the inner pipe by a chalk piece. The marked place is to be welded with the inner pipe. The sheets are placed at the marked chalk mark and bended according to the helical section. The each sheet plate is welded and the sheet and the sheets are connected by the welding process.

Calculation of helical angle

Helical angle => $\sin\theta = 3.7272/31$
$\sin\theta = 0.120232$
$\theta = 6.85^\circ = 7^\circ$

Measurement of sheet cutting

Outer diameter of sheet = 105 mm
Inner diameter of sheet = 43 mm

2.3. Welding process

The welding process is fused to attach the sheet with the inner pipe. It is also used to connect the casing and the pipe connection with the casing. The welding voltage is determined to connect the plates with the pipe. The plates are welded by using the gas welding process to reduce the plate damage so the gas welding is performed for attaching the sheet with the inner pipe. The gas arc is regulated by using the acetylene and oxygen cylinder. The oxygen gas is regulated by the knob at the arc value. The neutral flame is used to fix the plate. The filler material is selected with the parent metal of the sheet. The sheet is bended in the helical from the circulated form. The each plate is to be welded at the arc end it is to be cut and they are joined to create the helical structure. The each plate is welded with the filler material and they are attached. The gas arc that are used to heat the sheet and the filler rod that melted and it is to be connected with the plates. The heat that also melts the sheet so the sheet and filler rod that are melted and they connected to form a joint. The joint that connects the each circular plate and they are formed in helical structure, the plates are connected and it is inserted in the inner pipe to create a helical structure in the pipe at the marked place.

The circular plates are stretched to produce a helical form and the distance is to be aligned according to the distance need for the helix angle. The marked sketch on the inner pipe is to be based on the helix angle on the pipe. The plates are clamped or fixed at the particular marked portion and then it is to be welded with the inner pipe. The plates are melted and the inner pipe surface metal melts this melted zone are connected with the filler rod. The filler rod that molten and they are connected with the inner pipe and plate. This way the plate is connected with the inner pipe. The inner pipe accurately connected with the pates without any gap with the plates.

So it reduces the leakage of flow of water through the gap. So the welding area is surrounding the inner pipe in the helical shape. This way the inner pipe and the plates are connected. The chips of the filler material are removed with the help of tool. The excess welded zone is to be removed with the grinding too to reduce the defect in the heat transfer of the plate and the inner pipe.

The casing pipe is to be already reducing the thickness and to insulate the heat transfer with the surrounding. This casing is then drilled at the sides of the pipe to produce a hole to insert a pipe for inlet and outlet pipe of cold fluid. The diameter of drilled material is of having the diameter of pipe need to be inlet into the heat exchanger casing. The outer diameter of the pipe is need to b drilled to fix the pipe is need to be drilled to fix the pipe on the casing.

The one side of the casing is drilled at the top of the casing to put a pipe and fix it in the top for the inlet of cod fluid into the heat exchanger. Another drill is required at the other end and it is opposite to the inlet pipe. So the outer drill of same size is removed on the surface of casing for fixing the pipe at the other end. So the material is removed and they are to be fixed and the drill hole is to be reduced to produce good end to connect the pipe of outlet for the cold pipe. The surface of drilled end is cleaned and the removed aerial are cleaned from the pipe. The welding is to be done to connect the small pipe with the casing pipe. The end of the pipe is connected with the casing drilled hole. And the outer sides are to be drilled to create a connection with the casing. The smaller pipe connects the hosing and the heater. The hose is to be selected to fit with the smaller pipe. The smaller pipe is fixed and he casing is used for providing the cold water into the heat exchanger.

Side casing

The side casing is he metal that are used to close the sides of the casing pipe .It is also used to hold the inner pipe at the proper position. The side casing that are of having the material that covers and reduce the leakage of cold fluid and also it reduce the contact of the inner pipe with the casing to reduce heat loss through casing. The side casing thickness is similar to the thickness of casing. The casings have the hole at the centre of one circular hole. The diameter of the side plate is of having the diameter of casing. The centre of the plate is of having a hole to insert the pipe of the hot fluid.

Inner pipe

The inner pipe is based on the size of the design calculation and it is to transfer the heat from the hot water to the cold water. The thickness of the inner pipe is based on the critical radius. And the heat transfer is enhanced by the thickness selection of the pipe. The inner pipe thickness is reduced by the lathe process and the inner pipe is used for the heat transfer purpose. The inner pipe is used for welding the plates to produce the helical baffles.

2.4. Working procedure

The heat exchanger is placed in a surface and the heat fluid is allowed in the centre of the pipe. The hot water enters into the pipe and transfers the heat from the fluid to the hot pipe. The heat transfer from the moving fluid to the stagnation fluid. The stagnated fluid is called as boundary layer thickness of the fluid. The fluid heat transferred from the moving fluid to the boundary layer thickness. This transfer of heat is in convection process.

The heat transfer from the thermal boundary layer thickness to the material is by conduction process because the boundary layer acts as a material to conduct the heat transfer. The hot fluid that transfer the heat to the material by convection and conduction process. The material is of having the baffles plates attached to the hot pipe and the heat transfer from the pipe to the baffles by acting as a fin transfer of heat.

The heat transfer from the hot pipe to the baffles plate to transfer the heat to the cold fluid. The cold fluid is allowed into the connecting pipe through the casing. The cold water that flows through the casing and travels around the hot pipe. The baffles plate that transfer the heat from the plate to the cold fluid by conduction and convection process. The heat transfer from the helical plates to the boundary layer by conduction process and the heat from the layer to the cold fluid by convection process.

So the heat transfer rate is enhanced by increasing the surface area of the inner pipe. The heat transfer from the hot fluid to the cold fluid depends on the material to the thermal conductivity.

The higher thermal conductivity of material conducts the heat easier from the hot fluid to the cold fluid. The concept of helical baffle heat exchangers was developed for the first time in Czechoslovakia. The Helical baffle heat exchanger, also known as 'Helix changer', is a superior shell and tube exchanger solution that removes many of the inherent deficiencies of conventional segmental baffle exchangers. Helical baffle heat exchangers have shown very effective performance especially for the cases in which the heat transfer coefficient in shell side is controlled; or less pressure drop and less fouling are expected.

3. TABULATION AND CALCULATION

Parallel flow

1.) $\Delta T_{LMTD} = \dfrac{(T1-t1)-(T2-t2)}{ln\left\{\frac{T1-t1}{T2-t2}\right\}}$

$= \dfrac{(91.6-29.5)-(70.4-38.3)}{ln\left\{\frac{91.6-29.5}{70.4-38.3}\right\}}$

$= \dfrac{62.1-32.1}{ln\left\{\frac{62.1}{32.1}\right\}}$

Formula used

Parallel flow (ΔT_{LMTD}) = $\dfrac{(T1-t1)-(T2-t2)}{ln\left\{\frac{T1-t1}{T2-t2}\right\}}$

Counter flow (ΔT_{LMTD}) = $\dfrac{(T1-t2)-(T2-t1)}{ln\left\{\frac{T1-t2}{T2-t1}\right\}}$

T_1 = Entry temperature of hot fluid
T_2 = Exit temperature of hot fluid
t_1= Entry temperature of cold fluid
t_2 = exit temperature of cold fluid
(ΔT_{LMTD}) = logarithmic mean temperature difference

ΔT_{LMTD} = 45.46˚C

2.) $\Delta T_{LMTD} = \dfrac{(90-29.4)-(67.8-39.2)}{ln\left\{\frac{90-29.4}{67.8-39.2}\right\}}$

$= \dfrac{60.6-28.6}{ln\left\{\frac{60.6}{28.6}\right\}}$

= 42.61˚C

3.) $\Delta T_{LMTD} = \dfrac{(91-29.5)-(69.7-41.8)}{ln\left\{\frac{91-29.5}{69.7-41.8}\right\}}$

$= \dfrac{61.5-27.9}{ln\left\{\frac{61.5}{27.9}\right\}}$

=42.5˚C

SI. No	HOT WATER		COLD WATER		ΔT_{LMTD} ˚C	HEAT TRANSFER KW
	INLET ˚C	OUTLET ˚C	INLET ˚C	OUTLET ˚C		
1.	91.6	70.4	29.5	38.3	45.46	22.636
2.	90	67.8	29.4	39.2	42.61	21.217
3.	91	69.7	29.5	41.8	42.51	21.162

SI. No.	HOT WATER		COLD WATER		ΔT_{LMTD} ˚C	HEAT TRANSFER W
	INLET ˚C	OUTLET ˚C	INLET ˚C	OUTLET ˚C		
1.	91.6	66.7	29.5	36.1	44.41	22.113
2.	90.8	64.3	29.4	40.2	42.26	21.043
3.	91.4	66.2	29.4	39.8	43.78	21.80

Counter flow

Counter flow (ΔT_{LMTD}) = $\dfrac{(T1-t2)-(T2-t1)}{ln\left\{\frac{T1-t2}{T2-t1}\right\}}$

1.) $\Delta T_{LMTD} = \dfrac{(91.6-39.1)-(66.7-29.5)}{ln\left\{\frac{91.6-39.1}{66.7-29.5}\right\}}$

$= \dfrac{52.5-37.2}{ln\left\{\frac{52.5}{37.2}\right\}}$

= 44.41˚C

2.) $\Delta T_{LMTD} = \dfrac{(90.8-40.2)-(64.3-29.4)}{ln\left\{\frac{90.8-40.2}{64.3-29.4}\right\}}$

$= \dfrac{50.6-34.9}{ln\left\{\frac{50.6}{34.9}\right\}}$

= 42.26˚C

3.) $\Delta T_{LMTD} = \frac{(91.4-39.8)-(66.2-29.4)}{ln\left\{\frac{91.4-39.8}{66.2-29.4}\right\}}$

$= \frac{51.6-36.8}{ln\left\{\frac{51.6}{36.8}\right\}}$

= 43.78˚C

Heat transfer

Heat transfer 'Q' = $U \times A \times (\Delta T_{LMTD})$

U = Overall heat transfer coefficient

A = area of the surface

(ΔT_{LMTD}) = logarithmic mean temperature difference

Calculation

Surface area of the inner pipe (A):

Area = Area of the inner pipe + Area of the helical plates

$= \{\pi DL + 2N[\pi(R^2 - r^2]]\}$[N = number of turns]

$= \{\pi \times 0.043 \times 1\} + \{21 \times 2[\pi(0.105^2) - (0.043^2)]\}$

$= 0.1351 + (0.605372 \times 2)$

= 0.1351+1.210744

$= 1.345844 m^2$

2. Overall heat transfer coefficient

Heat transfer coefficient

U = 370 W/m^2

Calculation:

Heat transfer 'Q' = $U \times A \times (\Delta T_{LMTD})$

Parallel flow:

1.) $Q = 370 \times 1.3458 \times 45.46$
= 22.636 KW

2.) $Q = 370 \times 1.3458 \times 42.61$
= 21.217 KW

3.) $Q = 370 \times 1.3458 \times 42.5$
= 21.162 KW

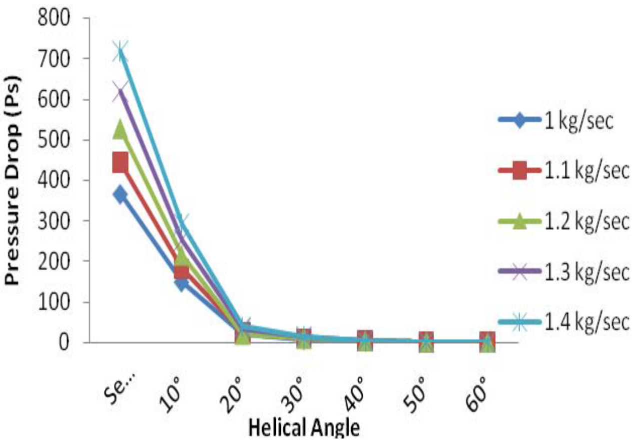
Counter flow:

1.) $Q = 370 \times 1.3458 \times 44.41$
= 22.113 KW

2.) $Q = 370 \times 1.3458 \times 42.26$
= 21.043 KW

3.) $Q = 370 \times 1.3458 \times 43.78$
= 21.80 KW

Graph variations



Graph plot between pressure drop and helical angle

Advantages:

- Increased heat transfer rate/ pressure drop ratio.
- Reduced bypass effects.
- Reduced shell side fouling.
- Prevention of flow induced vibration.
- Reduced maintenance
- The baffles are of primary importance in improving mixing levels and consequently enhancing heat transfer of shell-and-tube heat exchangers.
- the segmental baffles have some adverse effects such as large back mixing, fouling, high leakage flow, and large cross flow, but the main shortcomings of segmental baffle design remain

4. CONCLUSION

From the helical baffle the heat transfer rate is enhanced. The size of the heat exchanger is reduced. The flow speed of the water is not affected by the spiral flow. The effectiveness of helix changers is proved on test units and in industry applications, The heat exchanger concept enables the designer to meet a relatively wide range of process requirements, The flexibility offered by this design is determining optimum helix angles and using reverse lapping baffles or a double helix arrangement can be used to design a helix exchanger suitable for specific process applications, The history of the development of helix exchangers as presented here will be supplemented by further publications in this series discussing design techniques and industry applications

REFERENCES

[1] Lutcha J, Nemcansky J. Performance improvement of tubular heat exchangers.

[2] Wang SL. Hydrodynamic studies on heat exchangers with helical baffles.

[3] Nemati Taher F, Zeyninejad Movassag S, Razmi K, Tasouji Azar R. Baffle space Impact on the performance of helical baffle shell and tube heat exchangers.

[4] Stehlik P, Wadekar V. Different strategies to improve industrial heat exchange.

[5] Thundil Karuppa Raj R, Ganne S. Shell side numerical analysis of a shell and Tube heat exchanger considering the effects of baffle inclination angle on fluid Flow.

[6] M. Saffar-Avval, E. Damangir, A general correlation for determining optimum baffle spacing for all types of shell and tube exchangers, *Int. J. Heat Mass Transfer.*

[7] K.J. Bell, Heat exchanger design for the process Industries, *ASME J. Heat Transfer.*

[8] S.L.Wang, Hydrodynamic studies on heat exchangers with helical baffles, *Heat Transfer.*