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Experimental Investigations to Augment The Heat Transfer Rate In a Double Pipe Heat Exchanger Using Tube Inserts

P. Keshav
Jawaharlal Nehru Technological University,
Hyderabad, India.

***Abstract*— Heat transfer augmentation or enhancement refers to the process of increasing the heat transfer co-efficient which leads to the improvement in the performance of the system. Heat transfer enhancement is very important in many engineering applications to increase the performance of heat exchangers. Heat transfer enhancement techniques are broadly classified into two types. They are: Active Techniques and Passive Techniques. The active techniques require external power like surface vibrations, electrical fields etc. The passive techniques are those which do not require any external power like different types of inserts which are used to disturb the flow thereby creating turbulence for the enhancement of heat transfer. Previously most of the researchers had conducted experiments for the enhancement of heat transfer using different inserts.**

Keywords*— Enhancement, heat transfer, counter flow heat exchanger, CFD Analysis, passive technique, Inserts

I. 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 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. 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. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, sometimes there is a need for miniaturization of a heat exchanger in specific applications, such as space application, through an augmentation of heat transfer. For example, a heat exchanger for an ocean thermal energy conversion(OTEC) plant requires a heat transfer surface area of the order of 10000 m2/MW. Therefore an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost. Furthermore as heat exchanger becomes older, the resistance to heat transfer increases owing to scaling or fouling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow thereby breaking the viscous and thermal boundary layer. However, in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years.

II. HEAT EXCHANGER MATERIAL:

The exchanger material used in this experiment is MILD STEEL. Mild steel is a very popular metal and one of the cheapest types of steel available. It's found in almost every metal product. This type of steel contains less than 2 percent carbon, which makes it magnetize well. Since it's relatively inexpensive, mild steel is useful for most projects requiring huge amounts of steel.

Because it is a soft material, mild steel is easy to weld, whereas high-carbon steels, such as stainless steel, require the use of specialized welding techniques. Also, electricity can flow through mild steel easily without impacting its structural integrity. Mild steel is a variant of hard steels, which makes it much less brittle and enhances its flexibility.

Inserts are also made up of Aluminum, the properties of aluminium include: low density and therefore low weight, high strength, superior malleability, easy machining, an excellent corrosion resistor and good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while 30% of copper's density, also a non-toxic compound. Aluminium is also very easy to recycle.

III. EXPERIMENTAL PROCEDURE:

1. Switch on the geyser and allow the hot fluid (water) to flow in the inner tube.
2. Open the valve so that cold fluid (water) to flow through the annulus and run the exchanger as a counter flow unit.
3. See that the pipes run full of water.
4. Record the inlet and exit temperatures of hot and cold fluid after steady state is attained.
5. The experiment is done for plain tube with cold fluid (water) mass flow rate constant at full valve opening and hot

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fluid (water) mass flow rate is varied at three valve openings (90, 60 and 30 degrees of the valve openings) respectively.
6. Repeat the same process for inserts namely trapezoidal strip, wedge shaped strip and cylindrical strip inserts.

A. Nomenclature

A Wetted Area, (m^2)
A_h Area of hotter section, (m^2)
A_c Area of colder section, (m^2)
C Specific Heat, (J / kg K)
D_h Hydraulic Diameter, (mm)
D_i Inner Diameter of Outer tube, (mm)
d_o Outer Diameter of Inner tube, (mm)
d_i Inner Diameter of inner tube, (mm)
D_a Diameter of Annulus, (mm)
h_o Heat transfer coefficient of outer fluid(W / m^2 K)
h_i Heat transfer coefficient of inner fluid, (W / m^2 K)
k Thermal Conductivity,(W / m K)
L Length of heat exchanger, (m)
$\dot{m}$ mass flow rate of water, (kg / s)
Nu Nusselt Number
Pr Prandtl Number
ΔP Pressure drop, (Pa)
Q Total Heat Energy, (W)
Re Reynolds Number
T_1 Inlet temperature of hot water, (°C)
T_2 Outlet temperature of hot water, (°C)
T_3 Inlet temperature of cold water, (°C)
T_4 Outlet temperature of cold water, (°C)
U Overall Heat transfer coefficient, (W / m^2 K)
V Velocity of fluid in heat exchanger, (m / s)
Vol Free volume of fluid flow, (m^3)
ρ Density of water(kg / m^3),
ν Kinematic viscosity of water,(m^2/ s)
μ Dynamic viscosity, (kg / m.s)
α Thermal Diffusivity(m^2/ s)
A_s Surface area of the heat exchanger
ρ_{Hg} Density of mercury column

B. Experimental Specifications

DOUBLE PIPE HEAT EXCHANGER:
1. INNER DIAMETER OF INNER PIPE = 28.64 mm
2. OUTER DIAMETER OF INNER PIPE = 42.66 mm
3. INNER DIAMETER OF OUTER PIPE = 74.74 mm
4. LENGTH OF HEAT EXCHANGER = 2080 mm

TRAPEZOIDAL STRIP INSERT:
1. LENGTH OF THE INSERT = 2100 mm
2. NO. OF TRAPEZOIDAL STRIPS = 30 mm
3. HEIGHT OF THE TRAPEZOIDAL STRIP = 25 mm
4. THICKNESS OF THE STRIP = 12 mm
5. DIAMETER OF THE CORE ROD = 6 mm
6. LARGER LENGTH OF THE STRIP = 40 mm
7. SMALLER LENGTH OF THE STRIP = 20 mm
8. PITCH DISTANCE BETWEEN THE STRIPS = 70 mm

WEDGE SHAPED INSERT:
1. LENGTH OF THE INSERT=2100 mm
2. LARGER HEIGHT OF WEDGE STRIP=9 mm
3. SMALLER HEIGHT OF WEDGE STRIP=4 mm
4. LARGER LENGTH OF WEDGE STRIP=30 mm
5. SMALLER LENGTH OF WEDGE STRIP=20 mm
6. NO. OF WEDGE STRIPS=29
7. PITCH DISTANCE BETWEEN THE STRIPS=70 mm
8. RECTANGULAR ROD OF 6*6 mm DIMENSIONS IS TAKEN.
9. THICKNESS OF THE STRIP=6 mm
10. CHAMFER EDGE INCLINATION=135^0

CYLINDRICAL STRIP INSERT:

1. LENGTH OF THE INSERT=2100 mm
2. NO. OF PROFILES=51
3. PITCH DISTANCE BETWEEN THE PROFILES=40 mm
4. DIAMETER OF THE CYINDRICAL PROFILE=6 mm
5. HEIGHT OF THE CYLINDRICAL PROFILE=9 mm
6. RECTANGULAR ROD OF 6*6 mm DIMENSIONS IS TAKEN.
7. THICKNESS OF THE PROFILE=6 mm

C. Equations

(a) APPROACH 1:EXPERIMENTAL CALCULATIONS

$$T_{h\,avg} = \frac{T_1+T_2}{2}$$

$$T_{c\,avg} = \frac{T_3+T_4}{2}$$

$$Q_h = \dot{m}_h \times C_{ph} \times \Delta T_h$$
$$Q_c = \dot{m}_c \times C_{pc} \times \Delta T_c$$

$$Q_{avg} = \frac{Q_h+Q_c}{2}$$

$$Q_{avg} = U \times A_s \times \Delta T_m$$

$$A_s = \pi d_o L$$

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{ln\frac{\Delta T_1}{\Delta T_2}}$$

(b) APPROACH 2:THEORITICAL CALCULATIONS:

$$Re_h = \frac{\rho_h V_h d_i}{\mu_h}$$
$$Re_c = \frac{\rho_c V_c D_a}{\mu_c}$$
$$D_a = \frac{D_i^2 - d_o^2}{d_o}$$

$$Nu = 0.023\ Re^{0.8}\ Pr^n$$

$n = 0.4$ For heating of fluids
$n = 0.3$ For cooling of fluids

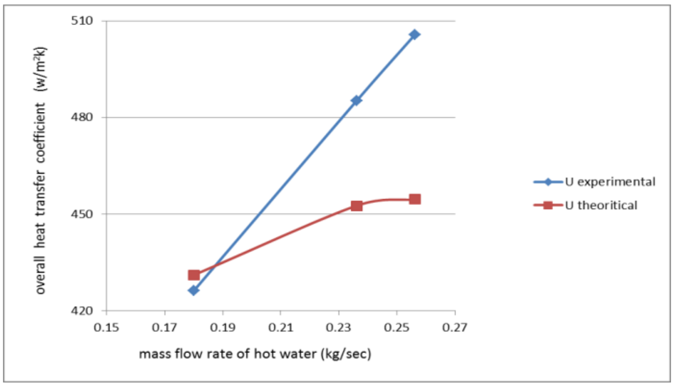
$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_0}$$
$$Nu_h = \frac{h_i d_i}{k_h}$$
$$Nu_c = \frac{h_o D_a}{k_c}$$

(c) Pressure drop calculations:

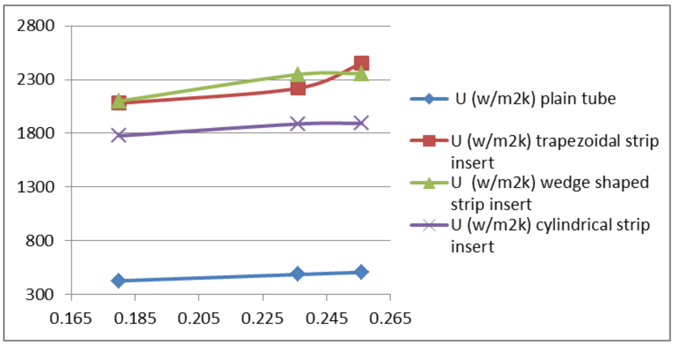
$$h_{water} = (\rho_{Hg} . h_{Hg}) / \rho_{water}$$

$$\Delta P = \rho_{water}\, g\, h_{water}$$

(d) Graphs:



Overall heat transfer coefficient (Experimental and Theoretical) (w/m^{2}k) vs Mass flow rate of hot water (kg/sec) for plain tube



Overall heat transfer coefficient (w/m^{2}k) vs Mass flow rate of hot water (kg/sec) for plain tube and inserts

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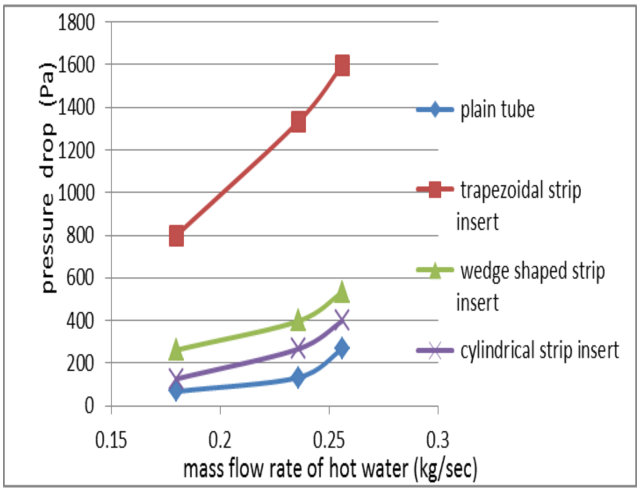

Pressure drop (Pa) vs Mass flow rate of hot water (kg/sec) for plain tube and inserts

IV. CONCLUSIONS

THREE INSERTS NAMELY TRAPEZOIDAL STRIP, WEDGE SHAPED STRIP, CYLINDRICAL STRIP ARE USED FOR EXPERIMENTAL INVESTIGATIONS TO AUGMENT THE HEAT TRANSFER RATE.

The following conclusions are drawn from the experimentation:

Insert-1: Trapezoidal strip insert:-

A maximum heat transfer enhancement of 388% is obtained compared to plain tube. The increase in pressure drop is 950% as compared to plain tube.

Insert-2: Wedge shaped insert:-

A maximum heat transfer enhancement of 392% is obtained as compared to plain tube. The increase in pressure drop is 293% as compared to plain tube.

Insert-3: Cylindrical strip insert:-

A maximum heat transfer enhancement of 316% is obtained as compared to plain tube. The increase in pressure drop is 88.7% as compared to plain tube.

Among all the inserts heat transfer enhancement is highest for wedge shaped insert followed by trapezoidal strip insert but the pressure drop is also maximum for both the inserts. In this context, cylindrical strip insert is recommended as an optimum insert since for the increase in heat transfer rate corresponding increase in pressure drop is minimum.

V. FUTURE SCOPE

The same procedure is done by rotating the inserts with a motor and operational rotating speed of the motor depends upon the weight of the insert.

The inserts can be wounded by wire coils and both these methods could be investigated to create more turbulence so that heat transfer enhancement can be further improved.

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