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Experimental Study of Heat Transfer Enhancement Using TShaped Baffles in Double Tube Heat Exchanger

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ABSTRACT-

Double pipe heat exchangers are used in many industrial processes, cooling technology, refrigeration device, sustainable energy applications and another field. The purpose of this article is to observe the effects of baffles design in double pipe heat exchanger on effectiveness at various mass flow rates. The effectiveness depend on the baffles design so here different baffles are simulated to evaluate the performance and find the best and suitable baffle at mass flow rate in double pipe heat exchanger. For diverse mass flow rates ranging from 0.01 kg/s to 0.05kg/s and varying hot fluid temperatures, an experimental analysis is carried out. The addition of baffles to the tube has been shown to increase the turbulent flow and behaviour of hot fluid. Baffles improve heat transfer performance by increasing heat transfer rate. Simulated results have shown that the without baffles have less heat transmission rate but after placing a baffles have more heat transfer rate even at high mass flow rate than that of a conventional tube.

Keypoints:DPHE, T- shaped baffles, Mass flow rate, Effectiveness.

1. INDROTUCTION

The heat exchanger is a device used to transfer the heat from the hot fluid to cold fluid with maximum rate and minimum investment.The T-shaped baffles on the inner tube increase the area available for the heat transfer and the rotation of inner tube increases the turbulence. With T-shaped baffles at larger pitch, the efficiency of the heat transfer enhancement however is rather low when the total length of heat exchanger is fixed. At high Reynolds number, pressure drop will increase sharply if the T-shaped baffles decreases. Due to this reason the heat transfer enhancement with T-shaped baffles is more suitable at high Reynolds number.

2.LITERATURE REVIEW

ShaileshDewangan et al., (2018) studies made helical ribs on the tube surface by machining the surface on the lathe so that artificial roughness can be created. The artificial roughness that results in an undesirable increase in the pressure drop due to the increased friction; thus the design of the tubes surface of heat exchanger should be executed with the objectives of high heat transfer.

Asghar Ali Ghoto et al., (2019) a CFD model is used to compare and compute effects of baffles' designs on the performance shell and tube heat exchanger. These four baffle including, 1. single segmental baffle, 2. double segmental baffle, 3. helical baffle and 4. single + helical segmental baffle were simulated to see the effects of baffles' design on the pressure drop and thermal performance. Pressure drop effects if the number of baffles are increased. Due to change of the baffles' design and keeping the other parameters same It is found that single segmental baffle gives high pressure drop however, new design single segmental+ helical baffle gives very less pressure drop comparatively all these baffle was simulated in this study.

Ali Akbar AbbasianArani et al., (2019) study the thermos hydraulic behaviour of STHE with the new baffles and ribbed tube in a 3D geometry. The pressure drop decreases due to the directional movement of the fluid along the axis of the tubes. The outputs of this study show that the DB-STHE and CSDB-STHE significantly reduce the pressure drop of the shell side rather than common SB-STHE. With new tubes, heat transfer is also increased due to the promoting area of heat exchanging with this ribbed tube. To show the thermos hydraulic behaviour of presented baffles and ribbed tubes combinations, the ratio of net heat transfers to pressure drop of all proposed types are compered. Based on obtained results, among the proposed combinations the DB-TR show the best performance among the other combinations. This type of baffle and tube configuration can be a good choice instead of current SB STHE, because of its application in energy optimization and increase the lifetime of the device.

Maakoul et al., (2020) designed the double pipe heat exchanger with helical baffles in the annulus side and investigated numerically. A numerical analysis is conducted for different values of Reynolds number and baffle spacing (0.025–0.1m). Shows that helical baffles also provide enhanced thermal performances in double pipe heat exchangers. The results obtained for a helically baffled annulus side provide enhanced heat transfer performance and high-pressure drop compared to the simple double-pipe exchangers.

AvitaAyuPermanasari et al., (2020) analysed heat exchanger with baffle was more efficient in reducing heat in hot water compared to heat exchanger without baffle. The more significant difference in heat transfer in exchangers with and without baffle was because of the longer distance travelled by the fluid on single segmental baffle with the same flow. Thus, the heat transfer process that occurred was greater by using a single segmental baffle.

Abdul Aziz Faisal et al., (2021) studied Helical fins result in a higher heat transfer surface area than longitudinal fins. Overall, the thermo hydraulic performance of double-pipe heat exchangers is better with helical fins than with longitudinal fins, which indicates that the pressure loss of helical fins is offset by the improvement in the heat transfer rate.

3. OBSERVATION & PROPOSED SYSTEM

3.1 PROBLEM STATEMENT:

The double heat pipe heat exchanger is already developed technology
for quick response of heat transfer. This method of heat transfer provides better results and suitable for few applications in large scale industries. The advantageous technology should be applicable for all sectors to reduce the investment. So, the present work has been processed under this area to improve heat transfer efficiency.

3.2 OBJECTIVE:

Heat transfer enhancement in a heat exchanger is getting industrial
Importance because it gives the opportunity to reduce the heat transfer area for the heat exchanger. Increase in the heat exchanger performance can help to make energy, material and cost saving related to a heat exchange process.

- To improve the heat transfer performance in double pipe heat exchanger by implementing T-shaped baffles inside the inner pipe.
- The T-shaped baffles should be arranged in a uniform manner.

4. MATERIAL SELECTION

In present work, the material of steel and copper has been selected for heat pipe. The inner pipe is made of copper and external pipe is steel. The T shaped baffles mount over inner pipe is also copper material.

4.1 GALVANISED STEEL:

Galvanised Steel is an alloy of iron and carbon, and sometimes other elements. Because of its high tensile strength and low cost, it is a major component used in buildings, infrastructure, tools, ships, automobiles, machines, appliances, and weapons.

MODULUS OF ELASTICITY (GPa)	**THERMAL CONDUCTIVITY (W/m-K)**	**POISIONS RATIO**	**DENSITY (Kg/m^3)**
205	19.3	0.3	7600

Table 4.1Properties of standard steel

4.2 COPPER:

Copper is a chemical element with the symbol Cu (from Latin: *cuprum*) and atomic number 29. It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a pinkish orange colour.

Table 4.2Properties of copper

MODULUS OF ELASTICITY (GPa)	**THERMAL CONDUCTIVITY (W/m-K)**	**POISIONS RATIO**	**DENSITY (g/m^3)**
110-128	670	0.34	8.96

5. EXPERIMENTAL SETUP:

Heat exchangers may be extremely different in design and construction and may be of the single or two-phase type, their modes of operation and effectiveness are largely determined by the direction of the fluid flow within the exchanger.

The most common arrangements for flow paths within a heat exchanger are counter-flow and parallel flow. A counter-flow heat exchanger is one in which the direction of the flow of one of the working fluids is opposite to the direction to the flow of the other fluid. In a parallel flow exchanger, both fluids in the heat exchanger flow in the same direction. Figure 5.4 represents the directions of fluid flow in the parallel and counter-flow exchangers. Under comparable conditions, more heat is transferred in a counter-flow arrangement than in a parallel flow heat exchanger.

Fig 5.1 EXPERIMENTAL SETUP

The flow rate of the hot water is controlled by rotating valve with a range of 0.01–0.05 kg/s. The hot water is the working medium in the copper tube as well as cold water is the cooling medium in the outer pipe of mild steel. Initially the experiment was conducted by without T-shaped baffles and note the reading, then the Baffles are kept in the inner tube, which is made up of steel material. Experiments were conducted at different inlet temperatures of hot water. Flow rate of hot water and cold water entering the test section was varied.

6. READINGS AND CALCULATION

Table 6.1 Readings with corresponding MFR

WITHOUT BAFFLES					***WITH BAFFLES***				
FLOW RATE Kg/S	***HOT WATER INLET (°C)***	***HOT WATER OUTLET (°C)***	***COLD WATER INLET (°C)***	***COLD WATER OUTLET (°C)***	***FLOW RATE Kg/S***	***HOT WATER INLET (°C)***	***HOT WATER OUT (°C)***	***COLD WATER INLET (°C)***	***COLD WATER OUTLET (°C)***
0.01	**50**	47.6	30.2	34	**0.01**	**50**	45.5	30.2	37.6
	55	52.4	30.4	34.2		**55**	49.4	30.2	38.4
0.02	**50**	47	30.2	34	**0.02**	**50**	45	30.2	36.4
	55	51.7	30.2	36.1		**55**	48.6	30.1	38.2
0.03	**50**	46.6	30.2	35.2	**0.03**	**50**	44.6	30.1	34.3
	55	49.5	30.2	37.1		**55**	47.6	30.1	37.4
0.04	**50**	46.2	30.1	35.1	**0.04**	**50**	43.8	30.1	39.2
	55	49.2	30.1	39.1		**55**	46.2	30.1	40.6
0.05	**50**	45.4	30.2	35.2	**0.05**	**50**	42.9	30.1	37.6
	55	48.8	30.1	39.1		**55**	45.3	30.2	41.4

6.1 WITH T-SHAPED BAFFLES READING

Table 6.1.1 Flow rate = 0.01 Kg/s

HOT IN (°C)	HOT OUT (°C)	COLD IN (°C)	COLD OUT (°C)
50	45.5	30.2	37.6
55	49.4	30.2	38.4

Flow rate = 0.01 Kg/s

Heat power emitted

Q_{act} **or** Q_e $= m_h c_{p\,h} (T_{hi} - T_{ho})$

= 0.01 x 4187 (50 – 45.5)

= 188.415 W

Heat power maximum

$Q_{max} = m_h c_{p\,h} (T_{hi} - T_{ci})$

= 0.01 x 4187 (50 – 30.2)

= 829.026 W

Effectiveness

$£ = \frac{Q_{act}}{Q_{max}}$

= 188.415 / 829.026

= 0.25

Heat power emitted

Q_{act} **or** Q_e $= m_h c_{p\,h} (T_{hi} - T_{ho})$

= 0.01 x 4187(55 – 49.4)

= 234.472 W

Heat power maximum

$Q_{max} = m_h c_{p\,h} (T_{hi} - T_{ci})$

= 0.01 x 4187 (55 – 30.2)

= 1038.376 W

Effectiveness

$£ = \frac{Q_{act}}{Q_{max}}$

= 234.472 / 1038.376

= 0.226

6.2 WITHOUT T-SHAPED BAFFLES READING

Flow rate = 0.01 Kg/s

Table 5.3.1 Flow rate = 0.01 Kg/s

HOT IN (°C)	HOT OUT (°C)	COLD IN (°C)	COLD OUT (°C)
50	47.6	30.2	34
55	52.4	30.4	34.2

Heat power emitted

Q_{act} **or** Q_e $= m_h c_{p\,h} (T_{hi} - T_{ho})$

= 0.01x 4187 (50 – 47.6)

= 100.488 W

Heat power maximum

$Q_{max} = m_h c_{p\,h} (T_{hi} - T_{ci})$

= 0.01 x 4187 (50 – 30.2)

= 829.026 W

Effectiveness

$£ = \frac{Q_{act}}{Q_{max}}$

= 100.488 / 829.026

= 0.1212

Heat power emitted

Q_{act} or Q_e $= m_h c_{p\,h} (T_{hi} - T_{ho})$

= 0.01 x 4187 (55 – 52.4)

= 108.862 W

Heat power maximum

$Q_{max} = m_h c_{p\,h} (T_{hi} - T_{ci})$

= 0.01 x 4187 (55 – 30.4)

= 1030.002 W

Effectiveness

$£ = \frac{Q_{act}}{Q_{max}}$

= 108.862 / 1030.002

= 0.105

7. RESULT AND DISCUSSION

The experiment is made out with four different mass flow rates ranges from 0.01 to 0.05 kg/s, while the hot water inlet temperature conditions ranges from 50°C to 55°C and the inlet fluid temperature is kept as atmospheric temperature. This inlet conditions are used for both readings (without and with Baffles).

MASS FLOW RATE Vs EFFECTIVENESS

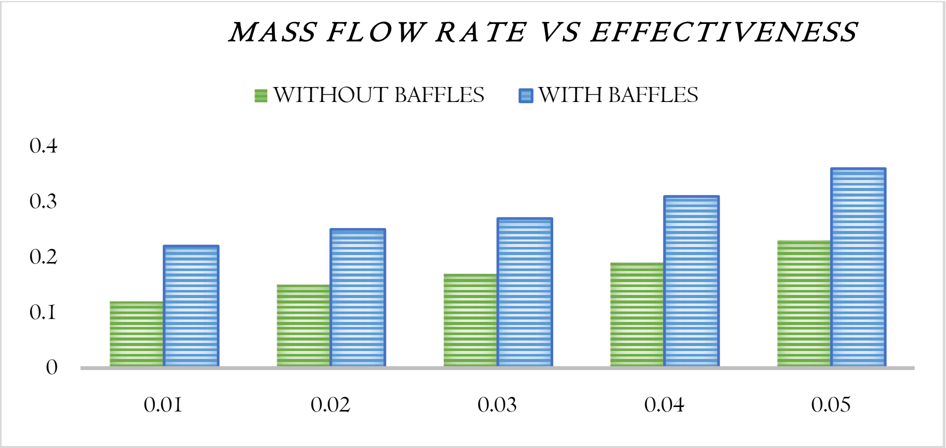

Fig 6.1 Mass flow rate vs effectiveness for 50ºC

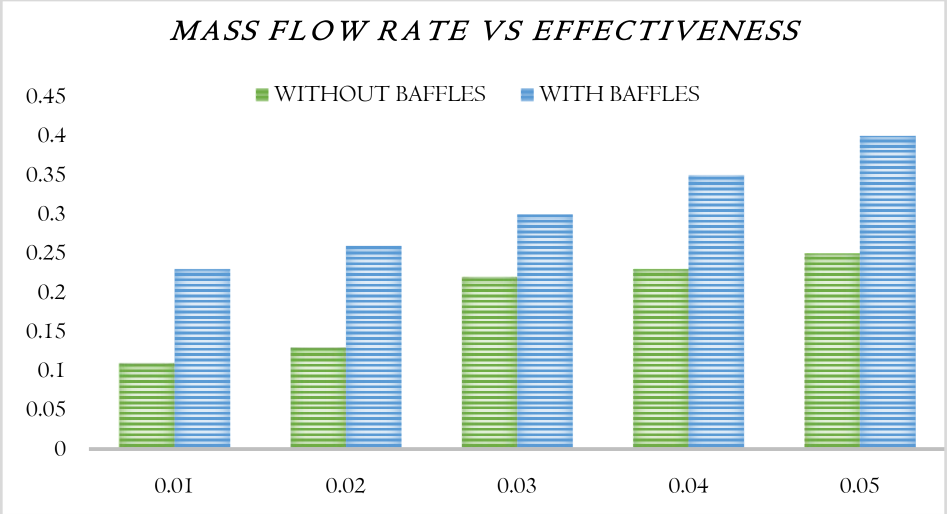

Fig 6.2 Mass flow rate vs effectiveness for 55°c

Table6.1.Effectiveness at mass flow rates

WITHOUT BAFFLES			***WITH BAFFLES***		
FLOW RATE Kg/S	***HOT WATER INLET (°C)***	***EFFECTIVENESS***	***FLOW RATE Kg/S***	***HOT WATER INLET (°C)***	***EFFECTIVENESS***
0.01	**50**	0.121	**0.01**	**50**	0.227
	55	0.105		**55**	0.226
0.02	**50**	0.152	**0.02**	**50**	0.253
	55	0.133		**55**	0.258
0.03	**50**	0.172	**0.03**	**50**	0.271
	55	0.221		**55**	0.296
0.04	**50**	0.192	**0.04**	**50**	0.311
	55	0.233		**55**	0.353
0.05	**50**	0.232	**0.05**	**50**	0.357
	55	0.248		**55**	0.391

1.Effectiveness at mass flow rates

The effectiveness value and heat transferred from the hot water to the cold water is low for the conventional double pipe heat exchanger whereas the effectiveness value and heat transferred from the hot water to the cold water is high for baffles when compared to conventional double pipe heat exchanger.

The effectiveness of double pipe heat exchanger for without baffles is 0.105 whereas the effectiveness of double pipe heat exchanger for with baffles is 0.226. The overall percentage increase attained is 43.5%.

Table.6.2.Maximum effectiveness attained

Flow Rate Kg/s	*Effectiveness*		
	Without Baffles	*With Baffles*	*Percentage Attained (%)*
0.01	**0.105**	**0.226**	**43.5**

7. CONCLUSION

In the present work, the double pipe heat exchanger equipped with and without T-shaped baffles has been analysed. In this study of the T-shaped baffles on the effectiveness for a various mass flow rate have been examined. Here, the T-shaped baffles have been implemented into the inner pipe. The highest heat transfer rate has been achieved when the mass flow rate is 0.01 kg/s at the inlet hot fluid temperature at 55^0 C. This work determines with better enhancements in heat transfer rate and effectiveness using T shaped baffles. When compared with the absence of T shaped baffles in the double pipe heat exchanger the results show that the use of T-shaped baffles significantly enhances the heat transfer rate by 43.5 % when compared to the plain tube.

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