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EXPERIMENTAL INVESTIGATION OF TUBE IN TUBE EXCHANGER IN ORDER TO INCREASE HEAT TRANSFER

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Abstract

In recent years, researchers have conducted multiple studies on heat transfer increase in tubes by inserting various tapes. The need to improve the thermal performance of heat exchangers, resulting in smaller heat exchangers and material savings, as well as energy and cost savings, prompted the invention and usage of heat transfer augmentation techniques. The purpose of this study is to see how washer inserts of various designs affect the heat transfer rate in a twin pipe heat exchanger. The experiment was carried out with washers with 2, 3, and 4 slots for hot water temperatures up to 70°C. The experimental results show that the pipe with washer inserts improves the heat transfer rate significantly over the pipe without washer inserts.

Keywords: Double pipe heat exchanger; washer; heat transfer rate

1. Introduction

A heat exchanger is a device that uses an impermeable wall to transfer heat from a hot fluid to a cool fluid. The basic premise of a heat exchanger is to allow for efficient heat transmission from a hot fluid to a cold fluid. Heating, ventilation, and air conditioning (HVAC) systems, radiators on internal combustion engines, boilers, condensers, and as pre-heaters or coolers in fluid systems are some of the most typical applications. Heat must be moved from one place to another or from one fluid to another in most industrial systems. The following are some of the reasons for heat transfer:

1. Using a hotter fluid to heat a colder fluid
2. Using a cooler fluid to lower the temperature of a hot fluid
3. Using a hotter fluid to bring a liquid to a boil
4. Using a colder fluid to condense a gaseous fluid
5. To condense a hotter gaseous fluid while boiling a liquid.

The temperature differential between the two fluids, the area where heat is transmitted, and the fluid's conductive/convective properties, as well as the flow state, all influence the heat flow. This relationship was formulated by Newton and is known as Newton's law of cooling (Equation).

$$Q = hA\Delta TLMTD \qquad (1)$$

2. Methodology

ISSN No.: 2455-6130
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The purpose of the current work is to determine the heat transfer rate in double pipe heat exchanger fitted with washer as inserts having different slots. The parameters of interest are Reynolds number (Re) and Prandtl number (Pr) are given by,

$$Re = \rho\, v\, D/ \mu \qquad (2)$$

Where, ρ= water density = 1000 (kg/m3),
D= ID of outer pipe (mm),
μ= viscosity of water (Kg/m-s),
v= velocity of water (m/s).
Velocity can be obtain from discharge equation,
$Q = Ac \times v$
Where, Ac = cold water flow area
Prandtl number can be given by,

$$Pr = \mu\, Cp/K \qquad (3)$$

From above nature of flow is laminar or turbulent by looking at the Reynolds number.
If Reynolds number below 2000, flow will be laminar.
If Reynolds number lies between 2000-4000, flow will be transitional. For this Nusselt can be given by Gnielinski correlation,
$Nu= (f/2)(Re-1000)Pr/1+12.7(Pr2/3-1)(f/2)^{0.5}$
If Reynolds number greater than 4000, flow will be turbulent. For this Nusselt number can be given by,
$Nu = 0.023 Re^{0.8} Pr^{0.4}$
Also Nu = hD/K
From this h= convective heat transfer coefficient can be obtained. Now, Heat transfer coefficient can be obtained from equation,
$Q = hA_w \Delta TLMTD$
Where, A_w= washer surface area

3. Experimentation and Evaluation

a) In this double pipe heat exchanger, the inner pipe flows through the outer pipe
b) Spot weld 30 washers at a 45° angle at 5 cm intervals on the inner pipe across a 1.5 m length.
c) Each of these groupings contains three different washer forms.
d) In the reservoir, there is a heater. This heater is connected to a thermostatic valve that controls the temperature of the water.

Figure 1 : Experimental Setup

<u>Experimental Procedure</u>: -

ISSN No.: 2455-6130
Special Issue: I, 2022, pp. 01-09

1. Water is filled in reservoir and then heater switched on.
2. Temperature of reservoir water increased up to 50°C and controlled by thermostatic valve.
3. Pump priming is to be done.
4. Hot water is circulated through inner pipe by water pump in counter and parallel flow direction.
5. Tap water (at ambient temperature) is circulated through outer pipe.
6. Using four temperature sensors temperature of hot and cold water inlet and outlet are to be measured.
7. These readings taken over 2 min. span with 30 sec interval.
8. Same procedure is repeated for all four arrangements and temperatures obtain for that arrangement.
9. Time required for filling the container of 1.25 litre capacity is measured by using stopwatch. By using this, discharge of the flow can be calculated. It will be same for all four.

Table 1: Components And Specifications

SR.NO.	COMPONENT	SPECIFICATIONS
1	OUTER PIPE	ID-32.5mm, length-1.7m, Thickness-3.5mm, (Mild steel)
2	INNER PIPE	OD-12.5 mm, length-1.7 m, Thickness-1mm, (Mild steel)
3	WASHER WITH SLOTS	OD-27.5 mm,ID-14 mm (Mild Steel) SLOT DIMENSIONS- DIAGRAMME a 4mm b10mm
4	THERMOSTATE	30-110 °C
5	HEATER	HEATING CAPACITY UPTO 95°C
6	TEMPERATURE SENSOR	Digital Senor, -30 to 110 °C
7	RESERVOIR	36 litre

<u>Common Parameters</u>: -

1. Discharge of cold water
2. Time required for 1.25 litre=25 sec
3. Time required for 1 litre= 20 sec
4. $Q = \frac{(1\times10^{-3})}{20} = 5\times10^{-5}\ \frac{m^3}{sec}$
5. $x = a \times b = 10 \times 4 = 40mm^2$ = area of slot
6. D = ID of outer pipe = 32mm
7. dw = OD of washer=27mm
8. d = OD of inner pipe=12mm
9. Ac = cold water flow area
10. μ = dynamic viscosity of water, (Pa-sec)
11. ρ = density of water = 1000 kg/m3
12. k = thermal conductivity water, (W/m-K)
13. f = friction factor = 0.008 (from Darcy-Weisbatch equation)

ISSN No.: 2455-6130
Special Issue: I, 2022, pp. 01-09

14. Pr = Prandtl number

5. Observations

1. Parallel flow

Table 2: Temperature readings for no slot Grey Pipe (without washer, no slot)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.2	34.1	51.3	48.7
2	62	30.1	33	51	47.7
3	92	30.1	34.4	50.5	48.2
4	121	30.3	33.8	50	47.2
Avg	-----	30.1	33.9	50.7	48

Table 3: Temperature readings for 2-slot Violet Pipe (with washer, two slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30	34.5	49.2	43.4
2	62	29.8	34.6	49.1	43.1
3	92	29.8	34.4	48.8	43
4	121	29.8	34.8	48.4	43.1
Average	-----	29.9	34.6	48.9	43.1

Table 4: Temperature readings for 3-slot washer Red Pipe (with washer, three slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.1	34.5	50.0	43.3
2	62	29.9	34.9	49.5	43.2
3	92	29.8	34.1	49.0	43.3
4	121	29.8	34.3	47.8	42.2
Average	-----	29.9	34.45	49.075	43.0

Table 5: Temperature readings for 4-slot washer Pine Pipe (with washer, four slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.1	34.5	50.0	43.3
2	62	29.9	34.9	49.5	43.2
3	92	29.8	34.1	49.0	43.3
4	121	29.8	34.3	47.8	42.2
Average	-----	29.9	34.45	49.075	43.0

2. Counter Flow

Table 6: Temperature readings for no slot Grey Pipe (without washer, no slot)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.8	33.2	51.1	48
2	62	30.6	33.2	51	47.7
3	92	30.4	33.3	51	47.6
4	121	30.2	33	51	47.5
Average	-----	30.5	33.1	51.1	47.7

Table 7: Temperature readings for 2-slot Violet Pipe (with washer, two slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.8	33.2	51.1	48
2	62	30.6	33.2	51	47.7
3	92	30.4	33.3	51	47.6
4	121	30.2	33	51	47.5
Average	-----	30.5	33.2	51	47.7

Table 8: Temperature readings for 3-slot washer Red Pipe (with washer, three slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	31	30.3	34.1	52.6	44.2
2	62	30.6	35.1	52.3	44
3	92	31	35.7	52.1	45
4	121	31.4	36.1	51.8	44.4
Average	-----	31	35.3	52.2	44.4

Table 9: Temperature readings for 4-slot washer Pine Pipe (with washer, four slots)

Sr. No.	Time (S)	T_{ci} °C	T_{co}°C	T_{hi}°C	T_{ho}°C
1	30	30.8	33.9	50.0	43.0
2	60	30.0	35.4	51.0	44.0
3	90	30.2	36.9	51.7	45.7
4	120	30.2	36.8	51.6	45.8
Average	-----	30.3	35.75	51.0	44.45

6. Result and Discussion

An experimental examination was conducted primarily for the purpose of determining heat transfer rate under various conditions as described above. In addition, at certain temperatures, Reynolds number, Prandtl number, Nusselt number, LMTD, and convective heat transfer coefficient must be calculated. The average of the intake and outlet temperatures of the respective pipes is used in the calculations. The findings can be summarized as follows:

Table 10: Obtained parameters for Parallel Flow arrangement

ISSN No.: 2455-6130
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No. of slot	Re	Pr	Nu	h(W/m^2°C)	$\Delta TLMTD$(°C)	Q (W)
0 Grey	3031	4.8	5.6	110.9	17.14	1.2
2 Blue	6751	5.0	50.7	985.7	13.11	4.8
3 Brown	5954	4.7	45.2	882	13.1	3.8
4 Pine	5330	4.7	41.4	800	12.7	3

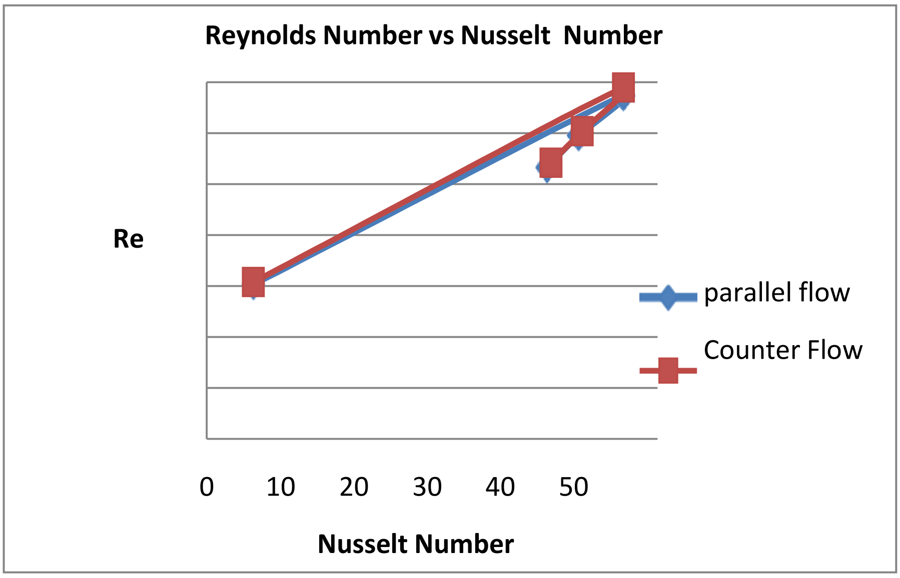
Table 11: Obtained parameters for Counter Flow arrangement

No. of slot	Re	Pr	Nu	h(W/m^2°C)	$\Delta TLMTD$(°C)	Q (W)
0 Grey	3077	5.0	5.7	111.0	17.4	1.4
2 Blue	6897	4.7	50.8	986.1	14.1	5.2
3 Brown	6044	4.7	45.7	892.6	13.5	4.4
4 Pine	5426	4.8	42	805.1	14.7	3.4

After completion of experimentation all the reading are noted down and comparative graphs can be plotted to find optimum arrangement.

Reynolds Number vs. Nusselt Number for all four arrangements:

Graph no. 1: Re. no. vs. Nu. no. for all four arrangements for both parallel flow and counter flow arrangement

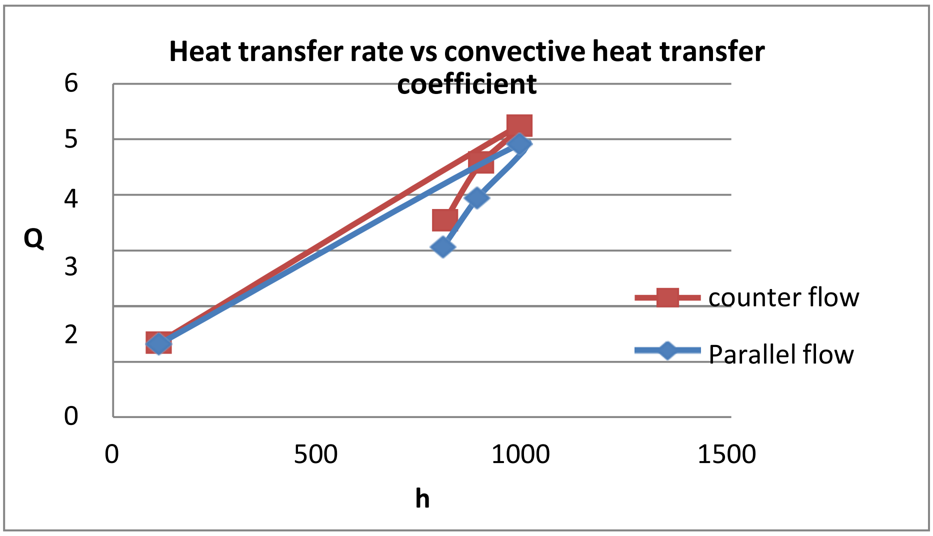


- From the above graph conclusion can be drawn that; the washer inserted arrangement yields considerable heat transfer compared with the without washer arrangement.
- The Nu shows the uptrend with raising the Re. The Nu of the washer insert is much higher than that of the without washer pipe.
- From graph it can be concluded that Re and Nu is more for counter flow than the parallel flow arrangement for two slotted washer.

Type of heat exchanger	Re	Pr

1)Parallel flow	6752	50.8
2)counter flow	6898	50.8

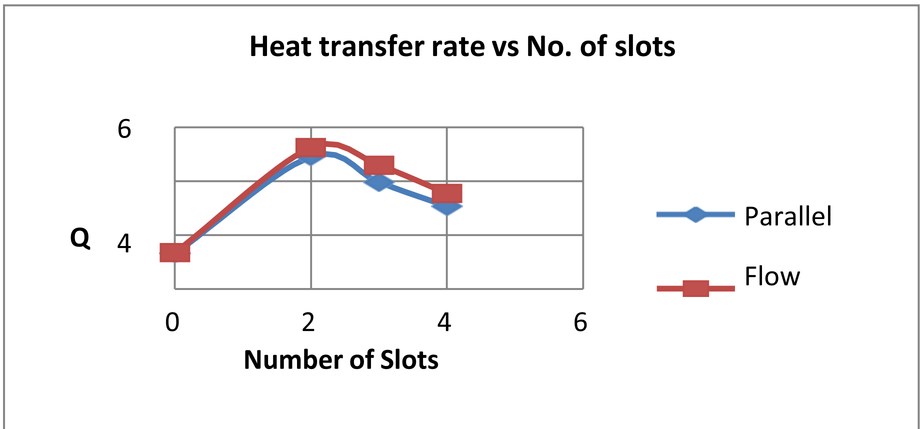
Graph no. 2: Heat transfer rate vs. convective heat transfer coefficient for all four arrangements for both parallel flow and counter flow arrangement



- As the convective heat transfer coefficient (h) is directly proportional to area; it implies that there is improvement in „h" with increase in area.
- Hence from above graph it can be concluded that there is increase in heat transfer rate with respect to the convective heat transfer coefficient
- Further it can be estimated that, both heat transfer coefficient and heat transfer rate is slightly more for counter flow heat exchanger compared parallel flow heat exchanger for two slot washer. And their values are as follow,

Type of heat exchanger	**Q (W)**	***h*(W/m^{2}°C)**
1)Parallel flow	4.90	985
2)counter flow	5.24	986

Graph no. 3: Heat transfer rate vs. Number of slots for all four arrangements:



- Heat transfer rate is depends on convective heat transfer coefficient, washer's area and logarithmic mean temperature difference.

- As per observation from above graph, it can be concluded that heat transfer rate is maximum for both parallel flow and counter flow heat exchanger; having the washer of two slots.
- This happens, because the surface area for two slot washer is maximum as compared to other washers.
- As the LMTD of counter flow heat exchanger is always more than parallel flow heat exchanger; our graph shows optimum heat transfer rate for counter flow heat exchanger having two slot washer which is 5.248 W.

4. Conclusions

This experiment was carried out on a twin pipe heat exchanger with washer layouts of 2-slot, 3-slot, 4-slot, and no washer. According to the results of the aforesaid experiment, the application of a heat transfer enhancement approach resulted in an increase in heat transfer rate as the Reynolds number and Nusselt number increased. For each arrangement with counter and parallel flow, the heat transfer rate, Reynolds number, and Nusselt number are determined. As can be seen, the Nusselt number grows as the Reynolds number increases, and it reaches its maximum for the counter flow 2-slot arrangement.

Heat transfer rates for three arrangements (with washers) are compared to those without washers, and it can be stated that in a parallel flow arrangement, the 2-slot washer arrangement will have the highest heat transfer rate. This is up by 265 percent compared to before the washer arrangement. The highest heat transfer rate in a counter flow arrangement is for a 2-slot washer system, which is boosted by 290 percent when compared to no washer arrangement.
When the maximum heat transfer rate of a parallel flow configuration is compared to the maximum heat transfer rate of a counter flow arrangement, it can be shown that the latter is 6.90 percent greater.

References

[1] [1] Bodius Salam, Sumana Biswas, Shuvra Saha and Muhammad Mostafa K Bhuiya, “Heat transfer enhancement in a tube using rectangular-cut twisted tape insert,” Procedia Engineering , vol- 56, pp. 96 – 103, 2013.

[2] P.V. Durga Prasad, A.V.S.S.K.S. Gupta and K. Deepak, “Investigation of Trapezoidal-Cut Twisted Tape Insert in a Double Pipe U-Tube Heat Exchanger using Al2O3/Water Nanofluid,” Procedia Materials Science, vol. 10, pp.50 – 63,2015.

[3] Zhang-Jing Zheng, Ming-Jia Li and Ya-Ling He, “Optimization of Porous Insert Configuration in a central Receiver Tube for Heat Transfer Enhancement,” Energy Procedia, vol. 75,pp. 502 – 507,2015.

[4] Sombat Tamna, Yingyong Kaewkohkiat, Sompol Skullong and Pongjet Promvonge, “Heat transfer enhancement in tubular heat exchanger with double V-ribbed twisted-tapes,” case Studies in Thermal Engineering, vol. 7, pp.14–24,2016.

[5] Alok Kumar, Manoj Kumar, Sunil Chamoli, “Comparative study for thermal-hydraulic performance of circular tube with inserts,” Alexandria Engineering Journal, vol. 55, pp. 343–349, January 2016.

[6] Kumbhar D.G., Sane N.K., “Exploring heat transfer and friction factor performance of dimpled tube equipped with regularly spaced twisted tape inserts,” Procedia Engineering, vol. 127, pp.1142 – 1149,2015.

[7] Muley, A., and R. M. Manglik. "Experimental study of turbulent flow heat transfer and pressure drop in a plate heat exchanger with chevron plates." Journal of heat transfer 121.1 (1999): 110-117.
[8] Leu, Jin-Sheng, Ying-Hao Wu, and Jiin-Yuh Jang. "Heat transfer and fluid flow analysis in plate-fin and tube heat exchangers with a pair of block shape vortex generators." International Journal of Heat and Mass Transfer 47.19-20 (2004): 4327-4338.
[9] Hwang, Seong Won, et al. "CFD analysis of fin tube heat exchanger with a pair of delta winglet vortex generators." Journal of Mechanical Science and Technology 26.9 (2012): 2949-2958.
[10] Jayakumar, J. S., et al. "Experimental and CFD estimation of heat transfer in helically coiled heat exchangers." Chemical engineering research and design 86.3 (2008): 221-232.
[11] Mandal, Monisha Mridha, and Krishna DP Nigam. "Experimental study on pressure drop and heat transfer of turbulent flow in tube in tube helical heat exchanger." Industrial & Engineering Chemistry Research 48.20 (2009): 9318-9324.
[12] Mohammed, H. A., et al. "Heat transfer and fluid flow characteristics in microchannels heat exchanger using nanofluids: a review." Renewable and Sustainable Energy Reviews 15.3 (2011): 1502-1512.
[13] Das, Prasanta Kumar, and Indranil Ghosh. "Thermal design of multistream plate fin heat exchangers—a state-of-the-art review." Heat Transfer Engineering 33.4-5 (2012): 284-300.
[14] Nagarsheth, Shaival H., Dhruvi S. Bhatt, and Jayesh J. Barve. "Temperature profile modelling, simulation and validation for a counter flow water tube in tube heat exchanger." Control Conference (ICC), 2017 Indian. IEEE, 2017.
[15] Ackerman, R. A., 1997, Cryogenic Regenerative Heat Exchangers, International Cryogenics Monograph Series, Plenum Publishing, New York.
[16] Afgan, N., M. Carvalho, A. Bar-Cohen, D. Butterworth, and W. Roetzel, eds., 1994, New Developments in Heat Exchangers, Gordon & Breach, New York.
[17] Apblett, W. R., Jr., ed., 1982, Shell and Tube Heat Exchangers, American Society for Metals, Metals Park, OH.
[18] Au-Yang, M. K., 2001, Flow-Induced Vibrations of Power Plants Components: A Practical Workbook, ASME Press, New York.
[19] Bar-Cohen, A., M. Carvalho, and R. Berryman, eds., 1998, Heat exchangers for sustainable development, Proc. Heat Exchangers for Sustainable Development, Lisbon, Portugal.
[20] Bhatia, M. V., and P. N. Cheremisinoff, 1980, Heat Transfer Equipment, Process Equipment Series, Vol. 2, Technomic Publishing, Westport, CT.