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Experimental Investigation of External Inline Straight Fin Liner Enhanced Double Pipe Heat Exchanger

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Abstract : A Double-pipe heat exchanger carries hot and cold fluids wherein the hot fluid flows through the inner pipe and the cold fluid flows through the outer pipe thereby hot fluid giving away its heat to the colder one. Heat transfer augmentation techniques are used to increase rate of heat transfer without affecting much the overall performance of the system. In order to increase the rate of heat transfer, extended surfaces are incorporated which has proven results is compared in experiment and simulation with the thermodynamic analysis of heat transfer. A main design parameter for a double pipe heat exchanger will be the surface area of the inner pipe, which is the heat exchange area. In this investigation, extended surface has been achieved with external inline straight fin liner of the inner hot fluid pipe of the double pipe heat exchanger. The liners serve a dual purpose namely one to increase the surface area and other to improve the intermixing of particles and thereby increased heat transfer. The modeling of the set up was done using Unigraphix Nx-8 and the analysis was done using Ansys Workbench 16.0. The test and trial was done in the parallel flow and counter flow configuration. The comparative results are also displayed in the paper and recommendations are done accordingly.

IndexTerms **- Double pipe heat exchanger, augmentation techniques, extended surfaces, counter flow, parallel flow**

I. INTRODUCTION

Heat exchangers are mostly used devices in many areas of the industries, such as process industries, heating and cooling in evaporators, thermal power plants, refrigeration and air-conditioning equipment's, radiators for space vehicles, automobiles, etc. Increase in heat exchangers performance can lead to more economical design of the heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. The need to increase the thermal performance of heat exchangers, there by effecting energy, material & cost savings have led to development & use of many techniques termed as Heat transfer augmentation. These methodologies are also called as Enhancement techniques for heat transfer. It is a method of Intensification of rate of heat transfer. By decreasing the thermal resistance, these techniques improve the convective heat transfer.

1.1 Double Pipe Heat Exchanger Design

In order to determine the surface area of heat transfer for a double pipe heat exchanger design, following heat exchanger equation can be used: $Q = UA\,\Delta T_{lm}$, where:

Q = heat transfer rate between the hot and cold fluids in Watts,

U = overall heat transfer coefficient in W/m^2K,

A = Surface area of heat transfer in m^2, and

ΔT_{lm} = log mean temperature difference between both fluids temperature at inlet and outlet in K.

1.2 Enhanced Surfaces

There are various kinds of Enhanced surfaces of heat exchanger enhancements. Usually the some crucial data related to the heat transfer enhancement may not be released by the manufacturers. But it does not mean that these fundamental calculations cannot be performed by the engineers handling their projects for new technologies. Below are few types of heat exchanger enhancements. The prime goal of Heat exchanger enhancement is to provide cost effectiveness in comparison to the conventional heat exchangers. The potential for fouling, factors related to safety and reliability must also be considered. Heat exchanger enhancement can be divided into both passive and active methods. The passive techniques are widely used which involves some sorts of modifications done mechanically to the baffles or tubes or both. Following figures represents different kinds heat exchanger enhancements such as twist, inserts, fins etc.

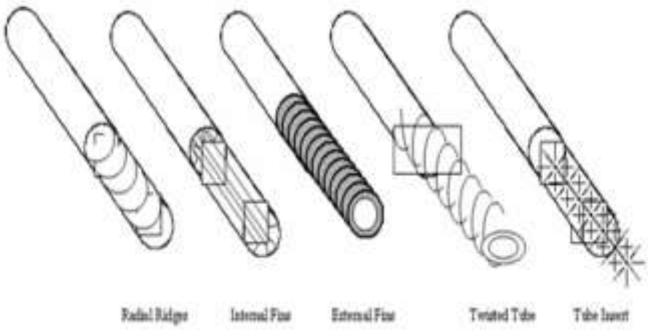

Figure 1: Examples of tubes with heat transfer enhancement

1.3 Heat Transfer Enhancement Using Extended Surfaces (Fins)

Fins are widely used in industry, much more extensively used in heat exchanger industry for double-pipe type, shell-and-tube type and compact type of heat exchangers. For example, in air cooled systems like automobile radiators and other heat dissipation devices, fins are employed. They are also used in refrigeration and heating systems. The fins are also vast application in the field of electronic and are also used in gas turbine blades for cooling of blades. Fins are also used in thermal storage heat exchanger systems including phase change materials. Fins are passive techniques of augmentation for heat transfer rate and various parameters are to be considered while designing it to suit for required application.

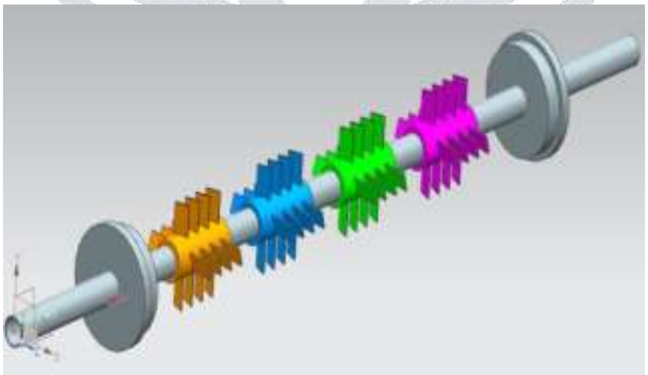

Figure 2: Arrangement of Inline straight fin liner

II. LITERATURE REVIEW

1. C. K. Pardhi et.al the results generated by this research work in relation to various heat transfer augmentation techniques are as: In comparison to conventional system of heat exchange, the enhancement method has showed better performance in heat transfer coefficient by 61 % and 78% for twisted tape I and II respectively. The twisted tape is better than smooth tube when only heat

transfer capacity is considered and the effect of pumping power is excluded (1.6 to 1.8 times). Whereas smooth tube is much better than twisted tapes when equal pumping power and pressure drop is considered (1.3 to 1.7 times). Keeping the flow rate of water constant and increasing the oil flow rate results in slight decrease in thermal performance for each other, also lower ratio of twisted tape (p/d =3.5) results in higher value of coefficient of heat transfer (1.39 times) than greater twist ratio of p/d = 7.

2. Gamit Sandip D et al. concludes that by conducting experiment as well as simulation result shows that heat transfer rate of double pipe heat exchanger with outer twisted tap and hot fluid flowing outside of inner tube has maximum and log mean temperature difference is linearly with respect to different mass flow rate and also increase heat transfer coefficient at interchanging domain Results obtained from CFD are validating with experimental values and % deviation from it is also very small.

3. Ranjith, Shaji K. investigated that Insertion of twisted tape in double pipe heat exchanger improved the heat transfer coefficient on both tube side and annulus side of heat exchanger. Secondary flows induced by the twisted tape, enhanced cross stream mixing of the fluids, increase in the effective flow length and the fin effect of the twisted tape were the reasons behind improved performance of the heat exchanger. When the heat transfer and pressure drop characteristics were compared on the basis of “Overall Enhancement Ratio” (OER) criteria, results show that the twisted tape insert performed reasonably well both in tube and annulus, with OER around unity the attempt to study the fin effect produced by the twisted tape in the modified heat exchanger revealed that the twisted tape exhibit significant fin effect which is an advantage not covered by the OER criterion.

4. S. Perumal et al.studied that heat transfer, friction factor and thermal performance of concentric tube heat exchanger using different enhancement techniques. The CFD modeling and experimental results showed from different study’s that an increase in turbulence intensity could be one of the reasons for higher performance augmentation methods with the plain tubes heat exchanger. The numerical and analytical investigation for plain tube treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices is carried out for review study. Also enhancements techniques are present a better performance than the smooth concentric tube heat exchanger in given study.

5. Sanjay P. Govindani et al. concludes that by using Rotor inserted tube we get highly turbulent flow compare to plain tube. Double pipe type of counter flow heat exchanger was employed. Reynolds number range for fully develop flow is from Re 3000 to 1.26 ×106 covering turbulent range. It also shows overall heat transfer coefficient of Rotor inserted tube heat exchanger increases compare to plain tube.

6. Akshay kumar et al. discussed about performance of Parallel and Counter Flow Heat Exchanger considering temperature changes in water and lubricating oil (Synthetic oil) are to be studied. Also knows that heat exchanger performance varies from fluid to fluid and temperature to temperature. By varying the values of mass flow rate and temperature, LMTD is calculated. Comparison of Parallel and Counter flow configurations is done to evaluate performance. The performance of such heat exchangers under different operating conditions is calculated in this paper.

III. OBJECTIVES

1. Design and development of single element fin holder with 6 fins in one row and 6-rows along length of holder.
2. Design and development of double pipe heat exchanger for thermal and strength analysis of components
3. Test and trial on heat exchanger in parallel and counter flow condition with Inline configuration.
4. To evaluate and compare performance on heat exchanger in parallel and counter flow conditions with Inline arrangement of fins.

IV. EXPERIMENTAL SETUP

The testing setup is shown in below figures. Which shows schematic layout of experiment and the actual fabricated double pipe heat exchanger and fig.5 shows the external inline straight fin liner. The setup consists of water tank, pump, control valves, heating coils and thermocouples.

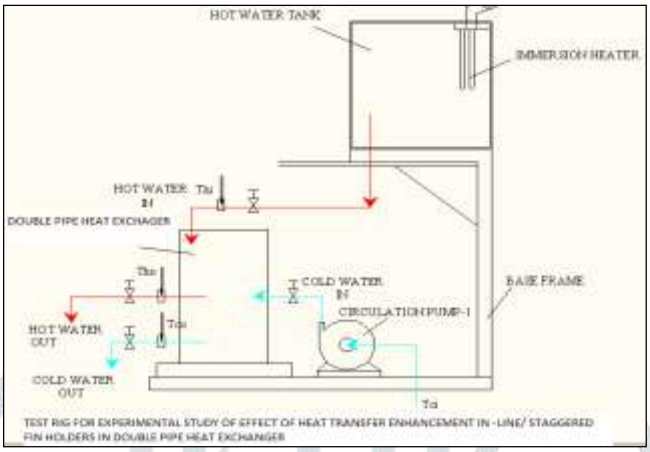

Figure 3: Schematic test rig for experimental study of heat transfer enhancement.

The water tank is mounted at the uppermost position in the setup. The four control valves are mounted on the inlet end and outlet end of pipe which is operated according to parallel and counter flow configuration. The immersion heater of 300 W is inserted in the tank as a heat source for heating the water.

Figure 4: Actual experimental setup

Figure 5. Fin holder with inline configuration

The two concentric pipes are attached to the wooden plate. Hot water flows through inner pipe made up of copper and cold water flows through outer pipe which is made up of aluminum. The outer pipe is insulated with asbestos rope and cera wool to minimize the heat loss to the surrounding. The inline straight fin liner is fitted at the external surface of the inner pipe which is made of ABS material and fins are made from aluminum. The liner is fitted at the outer surface of the inner pipe which is made of ABS material and fins are made from aluminum.

V. DESIGN METHODOLOGY

1. To carry out comparative study of theoretical and experimental analysis results to decide the double pipe heat exchanger parameter optimization in parallel flow configuration.
2. To carry out comparative study of theoretical and experimental analysis results to decide the double pipe heat exchanger parameter optimization in counter flow configuration
3. Interpretation of results will be done to suggest the modifications to improve the design of double pipe heat exchanger for enhanced performance for any given design considerations .
4. In experimental analysis the testing of double pipe heat exchanger with external straight fin liner by parallel and counter flow configuration following parameters are to be consider
    - LMTD
    - Capacity ratio
    - Effectiveness
    - Overall heat transfer coefficient

The study is embodied as,

$Q = UA\ \Delta T_{lm}$, where:

Q is the rate of heat transfer between the two fluids in the heat exchanger

U is the overall heat transfer coefficient

A is the heat transfer surface area

ΔT_{lm} is the log means temperature difference in cold and hot fluid

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A. Input Data

To check the validity of experimental results with theoretical results.

1. To carry out comparative study of theoretical and experimental analysis results to decide the double pipe heat exchanger parameter optimization in parallel flow configuration.

2. To carry out comparative study of theoretical and experimental analysis results to decide the double pipe heat exchanger parameter optimization in counter flow configuration

3. Interpretation of results will be done to suggest the modifications to improve the design of double pipe heat exchanger for enhanced performance for any given design considerations .

- Specific heat of water at (25 to 30 ^{0} C) = 4187 kJ/kg-k
- Density of water at 80 ^{0} C = 985 kg/ m^3
- Density of water at 30 ^{0} C = 1000 kg/ m^3

B. Test and Trail Procedure

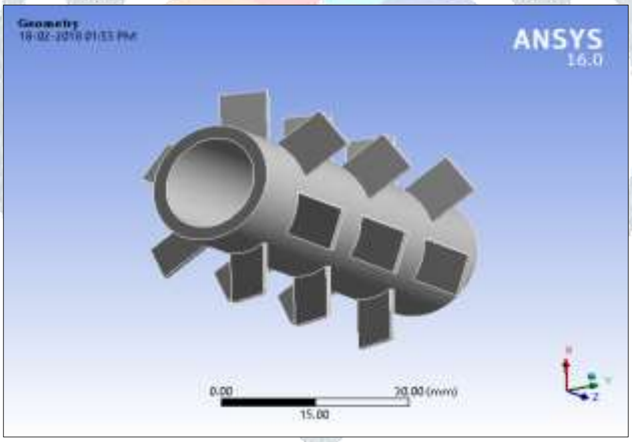
Procedure of trial:

1. Heat water in the top tank up to desired temperature
2. Start flow of hot water in downward direction for parallel/counter flow configuration
3. Start cooling water pump, and send water top to bottom for parallel/counter flow.
4. Take mass flow readings for hot water and also note temperature gradient
5. Take mass flow readings for cold water and also note temperature gradient.

VI. RESULTS AND DISCUSSION

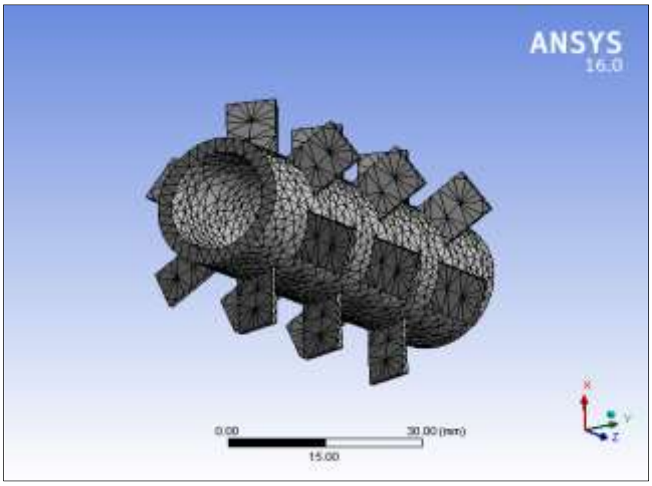
A. ANALYSIS OF INLINE STRAIGHT FIN LINER

(1) Geometry:



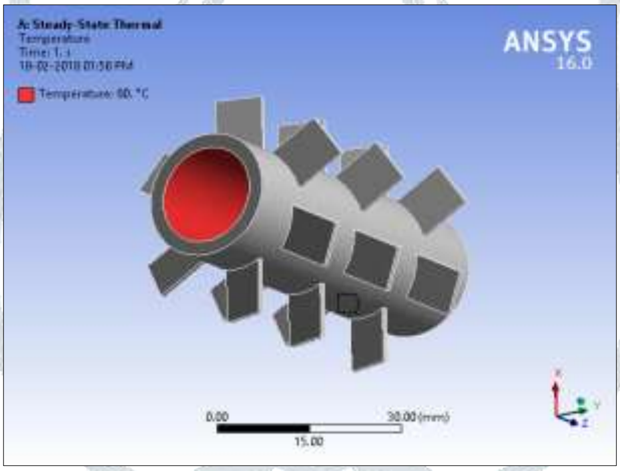
Above figure shows the geometry in which the part was developed using UG –Nx and the step file was used as input to Ansys work bench.

(2) Meshing:

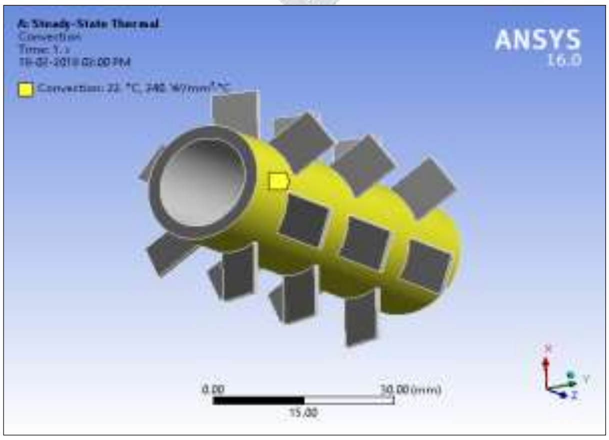


Statistics	
Nodes	18349
Elements	9637
Mesh Metric	None

(3) <u>Boundary Conditions:</u>



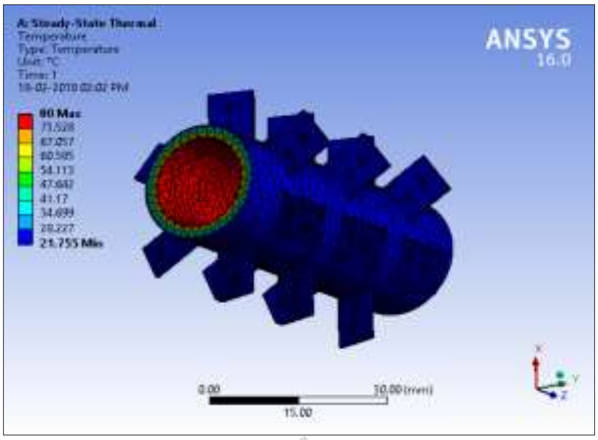
Above figure shows the boundary conditions the water in contact with the inner tube is at 80^{0}C and hence the inner surface of the tube is subjected to given temperature load.



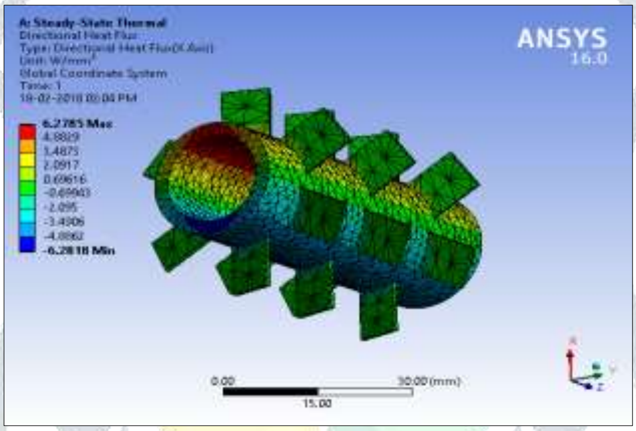
Above figure shows the boundary conditions .The convection takes place at the outer surface of pipe. The convection takes place at 22^{0}C, the convective film coefficient is 240 W/m^{2}k applied to the outside surface.

Results:

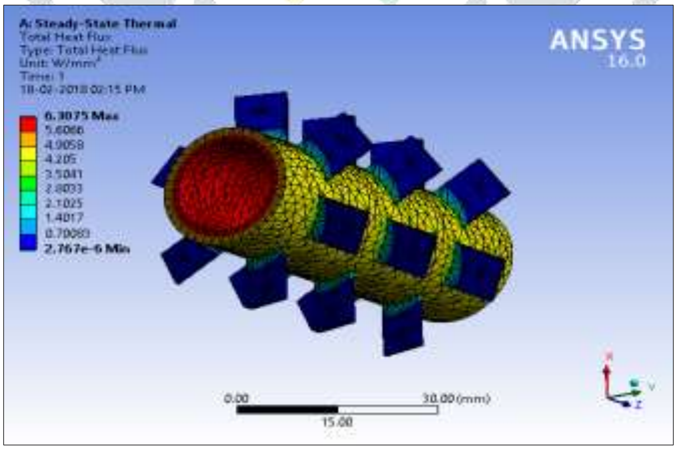
Temperature distribution:



The figure above shows the temperature distribution in the fin structure showing the maximum temperature at the center of the tube and then lightly reducing to room temperature at the fin tips.



The figure above shows that the maximum directional heat flux is 6.27 watt



The figure above shows that the maximum heat flux through the liner system is 6.3 watt.

B. RESULT TABLE FOR INLINE PARALLEL FLOW CONFIGURATION

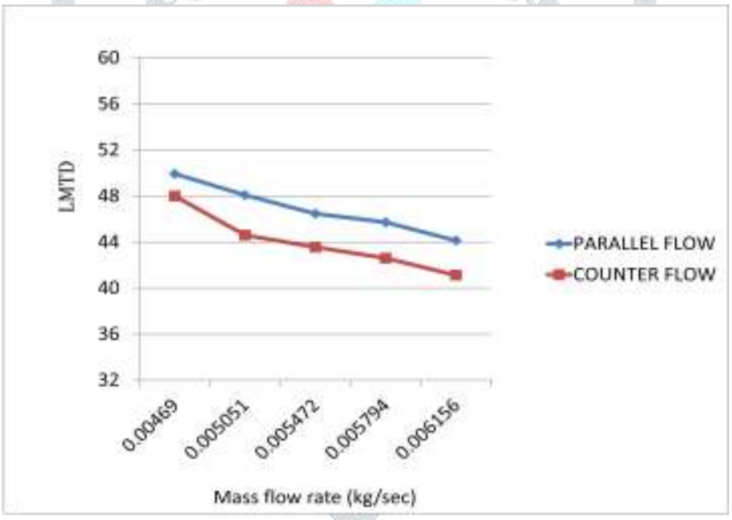
Sr.no.	Thi	Tho	Tci	Tco	M(hot) Kg/sec	Q(watts)	LMTD	Effectiveness	U (W/ m^{2}k)
1	80	77	28	29	0.00469	58.91109	49.92194268	0.057692308	1.180064053
2	78	76	28	30	0.005051	42.29707	48.07497226	0.04	0.879814839
3	78	74	28	31	0.005472	91.64506	46.46464386	0.08	1.972361098
4	79	73	28	32	0.005794	145.5569	45.7104852	0.117647059	3.18432122
5	80	71	29	33	0.006156	231.9765	44.12638704	0.176470588	5.257093625

C.RESULT TABLE FOR INLINE COUNTER FLOW CONFIGURATION

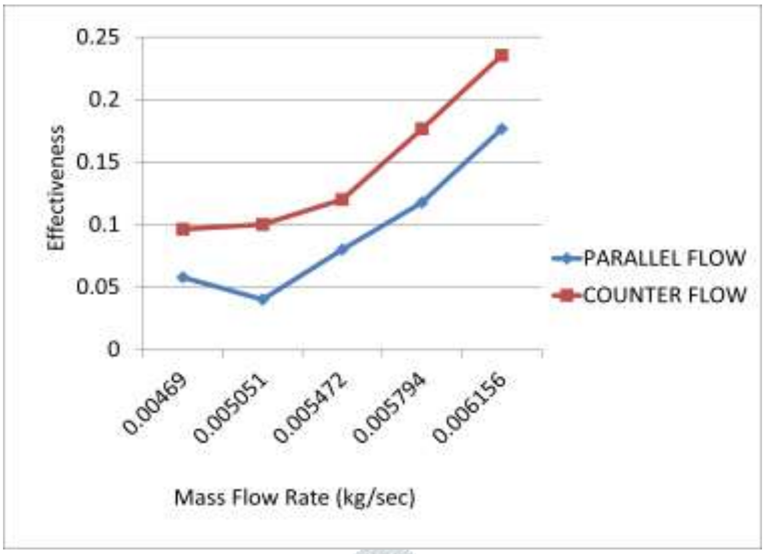
Sr.no.	Thi	Tho	Tci	Tco	M(hot) Kg/sec	Q(watts)	LMTD	Effectiveness	U (W/ m^{2}k)
1	80	75	28	31	0.00469	98.18515	47.99305475	0.096153846	2.045819973
2	78	73	28	34	0.005051	105.7427	44.59880416	0.1	2.370975792
3	78	72	28	35	0.005472	137.4676	43.54845001	0.12	3.156658479
4	79	70	28	36	0.005794	218.3353	42.59718295	0.176470588	5.125580775
5	80	68	29	37	0.006156	309.3021	41.11252839	0.235294118	7.523304357

D. COMPARATIVE RESULTS GRAPHS

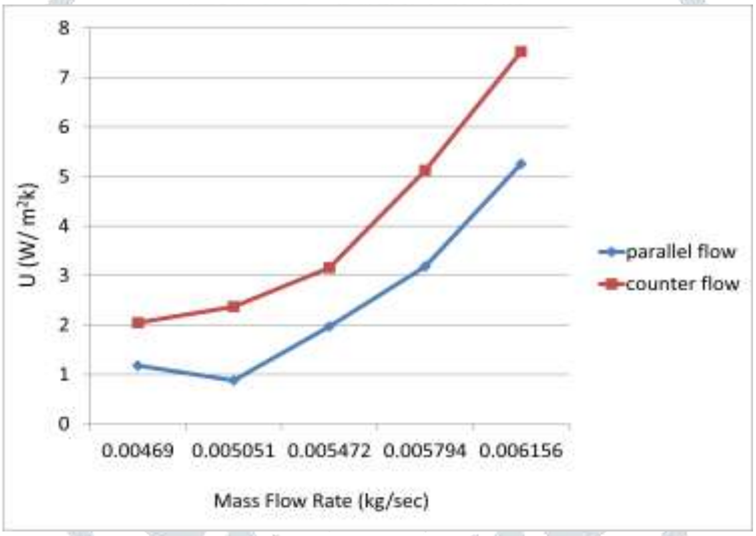
1. Mass flow rate Vs LMTD



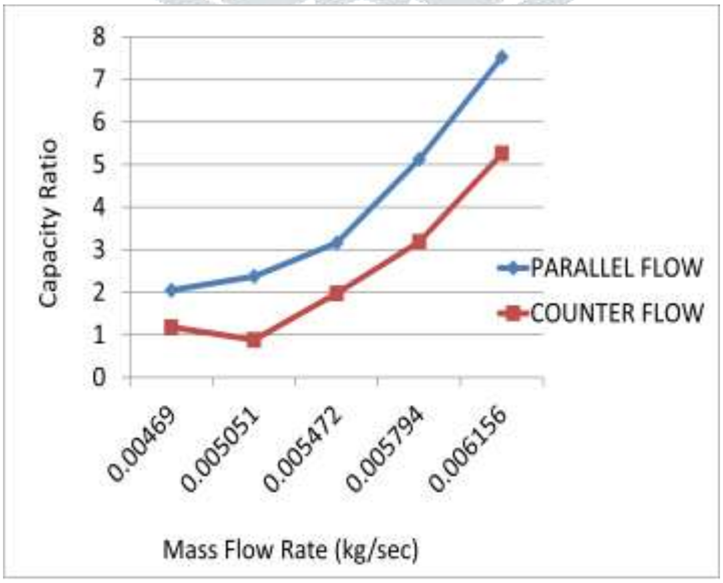
2. Mass flow rate Vs Effectiveness



3. Mass flow rate Vs Overall heat transfer coefficient



4. Mass flow rate Vs Capacity Ratio



VII. CONCLUSION

- From the experimental result as shown in graphs LMTD and Capacity ratio decreases with increase in mass flow rate.
- Similarly Overall heat transfer Coefficient and effectiveness increases with increase in mass flow rate.
- Therefore from the experimental results for the inline configuration the heat transfer parameters like LMTD, effectiveness, capacity ratio and overall heat transfer coefficient in case of parallel and counter flow, the counter flow arrangement gives more effective result.
- By comparing the overall parameters in both configurations the inline with counter flow is the most effective and efficient method for obtaining more heat transfer rate.

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