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ANALYSIS OF UNIDIRECTIONAL AND BI-DIRECTIONAL FLOW HEAT EXCHANGERS

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Abstract- The flow pattern through a heat exchanger affects the required heat exchanger surface. A counter flow heat exchanger needs the lowest heat transfer surface area. A heat exchanger can have several different flow patterns. Counter flow, parallel flow and cross flow are common heat exchanger types. In this thesis, analysis is done to compare the heat transfer rates between the two basic flow arrangements: (i) the unidirectional flow and (ii) bidirectional flow. CFD analysis and thermal analysis is done on the heat exchanger for different fluids, by taking hot water and refrigerants R134A, R22, R600A and different materials of heat exchangers. 3D models are done in Pro/Engineer and analysis is done in Ansys.

Key words-Aluminium, copper, R134A, R22, R600.

I. INTRODUCTION

The technology of heating and cooling of systems is one of the most basic areas of mechanical engineering. Wherever steam is used or wherever hot or cold fluids are required we will find a heat exchanger. They are used to heat and cool homes, offices, markets, shopping malls, cars, trucks, trailers, aero planes, and other transportation systems. They are used to process foods, paper, Petroleum and in many other industrial processes. They are found in superconductors, fusion power labs, spacecrafts, and advanced computer systems. The list of applications, in both low and high tech industries is practically endless.

Heat exchangers are typically classified according to flow arrangement and type of construction. In this introductory treatment, we will consider three types that are representative of a wide variety of exchangers used in industrial practice. The simplest heat exchanger is one for which the hot and cold fluids flow in the same or opposite directions in a concentric-tube (or double-pipe) construction. In the parallel-flow arrangement, the hot and cold fluids enter at the same end, flow in the same direction and leave at the same end. In the counter flow arrangement, the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends. A common configuration for power plant and large industrial applications is the shell-and tube heat exchanger. This exchanger has one shell with multiple tubes, but the flow makes one pass through the shell. Baffles are usually installed to increase the convection coefficient of the shell side by inducing turbulence and a cross flow velocity component. The cross-flow heat exchanger is constructed with a stack of thin plates bonded to a series of parallel tubes. The plates function as fins to enhance convection heat transfer and to ensure cross-flow over the tubes. Usually it is a gas that flows over the fin surfaces and the tubes, while a liquid fluid flows in the tube. Such exchangers are used for air-conditioner and refrigeration heat rejection applications.

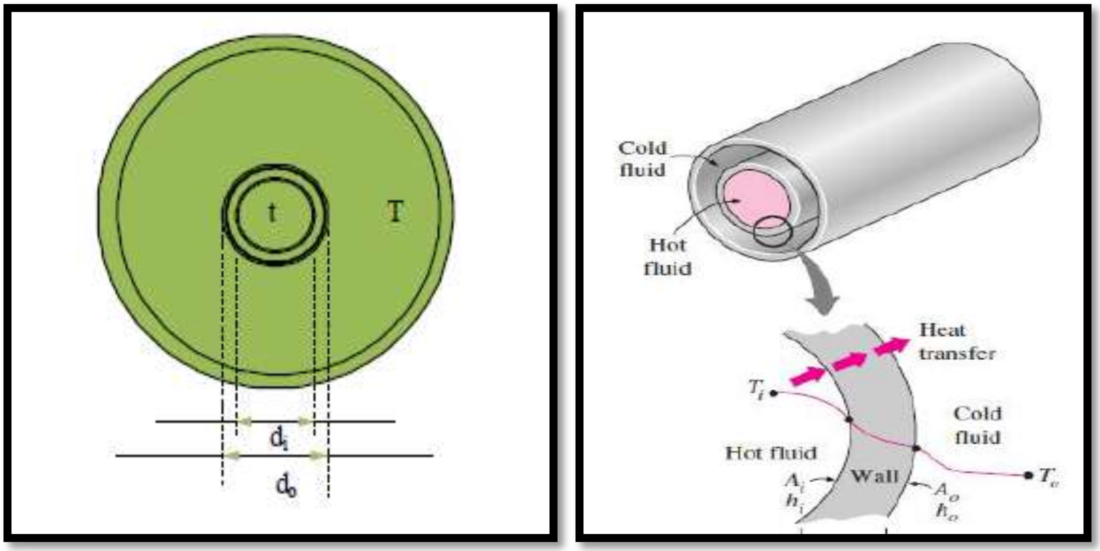

Figure: 1.End view of a tubular heat exchanger

II. LITERATURE SURVEY

The development of fluid flow and temperature profiles of a fluid after undergoing a sudden change in wall temperature is dependent on the fluid properties as well as the temperature of the wall. This thermal entrance problem is well known as the Graetz Problem. From reference [1] for incompressible Newtonian fluid flow with constant ρ and k,

The velocity profile can also be developing and can be used for any Prandtl number material assuming the velocity and temperature profiles are starting at the same point [2]. For the original Graetz problem, Poiseuille flow was assumed and equation was used to describe the fully developed velocity field of the fluid flowing through the constant wall temperature tubing. Analyzing the paper from Sellars et al [3] where he extends the Graetz problem, this equation for velocity is also used. For the purposes of this paper and the use of the finite element program, a constant value for the inlet velocity was used. This means a modified Graetz problem was introduced and analyzed.

In the cases studied, engine oil was assumed to be flowing through the inner pipe which was made of copper and cooled by the outer concentric pipe in which water was flowing. Material properties such as dynamic viscosity, density, Prandtl number, and thermal conductivity were obtained from reference [4]. Graetz found a solution in the form of an infinite series in which the eigenvalues and functions satisfied the Sturm-Louiville system. While Graetz himself only determined the first two terms, Sellars, Tribus, and Klein et al [5] were able to extend the problem and determine the first ten eigenvalues . Even though this further developed the original solution, at the entrance of the tubing the series solution had extremely poor convergence where up to 121 terms would Mnot make the series converge.

Schmidt and Zeldin et al [6] extended the Graetz problem to include axial heat conduction and found that for very high Peclet numbers (Reynolds number multiplied by the Prandtl number) the problem solution is essentially the original Graetz problem.

Hwang et al [7] measured pressure drop and heat transfer coefficient in fully developed laminar pipe flow using constant HEAT FLUX conditions. Based on the experimental results they showed that the experimental friction factor was in good agreement with the theoretical predictions using the Darcy equation. Bianco et al [8] observed only amaximum of 11% difference between single and two phase results for the laminar regime.

Akbari et al [9] for the first time compared three different two phase models and the single phase model in the laminar regime. Single and two phase models were found to be predicting identical hydrodynamic fields but very different thermal ones. The expression defining the velocity distribution in a pipe flow across turbulent flow is derived and demonstrated in Bejan, “Convective heat transfer coefficient”,1994 .

Hydro dynamically developed flow is achieved in a pipe after a certain length i.e. entrance length Le, where the effect of viscosity reaches the centre of pipe. At this point the velocity assumes some average profile across the pipe which is no longer influenced by any edge effects arising from the entrance region. The flow of real fluids exhibit viscous effects in pipe flow. Here this effect is identified for turbulent flow conditions.

A closer look at all the experimental and numerical works reveals that most of the forced convective heat transfer studies in pipe flow have been done with constant wall flux boundary condition. So in this work, a systematic computational fluid dynamic investigation with constant wall temperature Boundary condition has been carried out adopting the single phase approach in the turbulent regime and the results are compared with the analytical and numerical results available in the literature.

III. RESULTS

A) CFD ANALYSIS

In this CFD analysis, the heat transfer rate was found by using the different flow arrangements parallel flow and counter flow.

Table: 1. PARALLEL FLOW

Refrigerants	Pressure (Pa)	Velocity (m/s)	HT Coefficient (W/m^2 K)	Heat transfer rate (W)	Mass flow rate(kg/s)
R22	0.04	0.0170	20.9	0.406	$3.169e^{-6}$
R134A	0.03	0.0173	22.9	0.5	$1.24e^{-6}$
R600A	0.053	0.0184	27.32	0.66	$0.545e^{-6}$

Table: 2. COUNTER FLOW

Refrigerants	Pressure (Pa)	Velocity (m/s)	H.T Coefficient (W/m^2 K)	Heat transfer rate (W)	Mass flow rate(kg/s)
R22	0.0145	0.0112	21.3	0.306	$0.953e^{-6}$
R134A	0.0393	0.0134	23.2	0.192	$0.916e^{-6}$
R600A	0.0612	0.0348	28.1	0.43	$0.125e^{-6}$

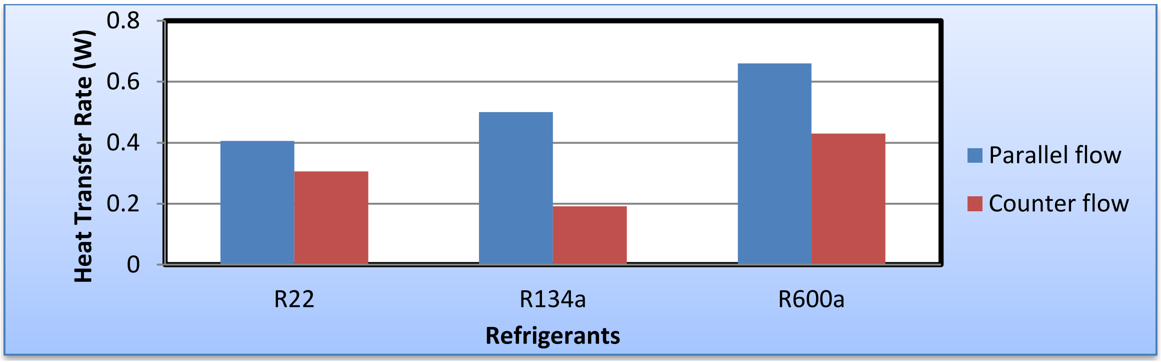

Figure.2. Comparison of heat transfer rate values for parallel and counter flow for different refrigerants

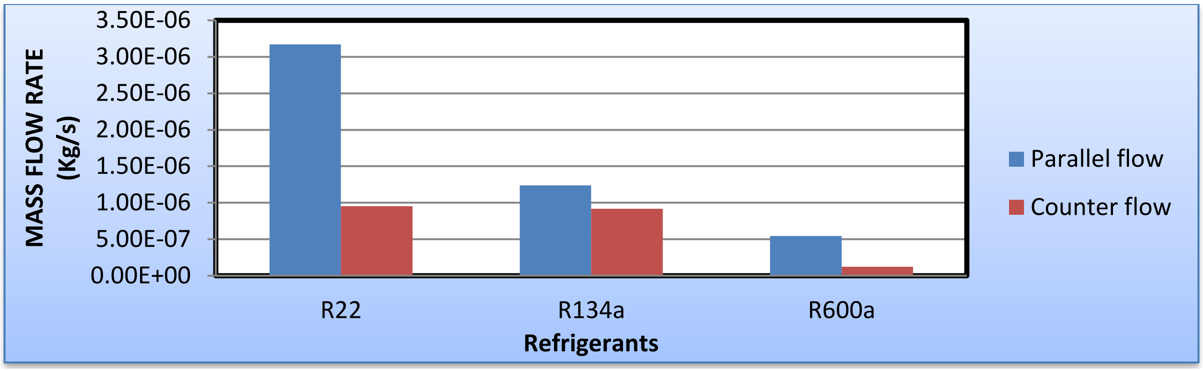

Figure.3.Comparision of mass flow rate values for parallel and counter flow for different refrigerants

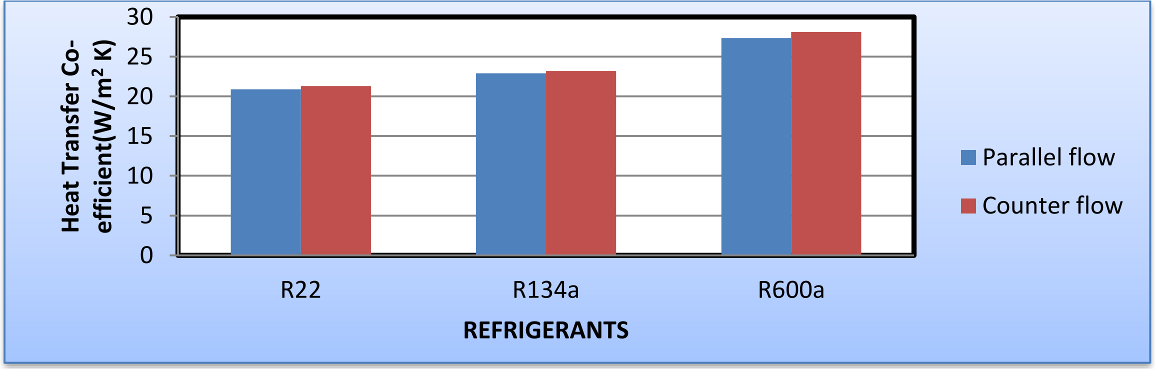

Fig.4.Comparision of heat transfer coefficient values for parallel and counter flow for different refrigerants

By observing CFD analysis results, the heat transfer coefficient is more for counter flow and less for parallel flow heat exchanger.

B) Thermal analysis

In this thermal analysis the heat transfer rate find out at the parallel flow and counter flow and different materials are used, the results is shown in below.

Table: 3. Heat transfer rate for parallel flow& counter flow for different materials

Refrigerants	**Materials name**	**PARALLEL FLOW**	**COUNTER FLOW**
		Heat flux (W/m^2)	**Heat flux(W/m^2)**
R22	**Aluminium**	577.18	588.19
	Copper	605.38	700.75
R134A	**Aluminium**	632.24	640.49
	Copper	753.31	763.16
R600A	**Aluminium**	753.81	773.87
	Copper	790.99	922.41

Comparison of heat flux values for parallel and counter flow for different refrigerants with different materials shown in figures 4,5,6 &7.

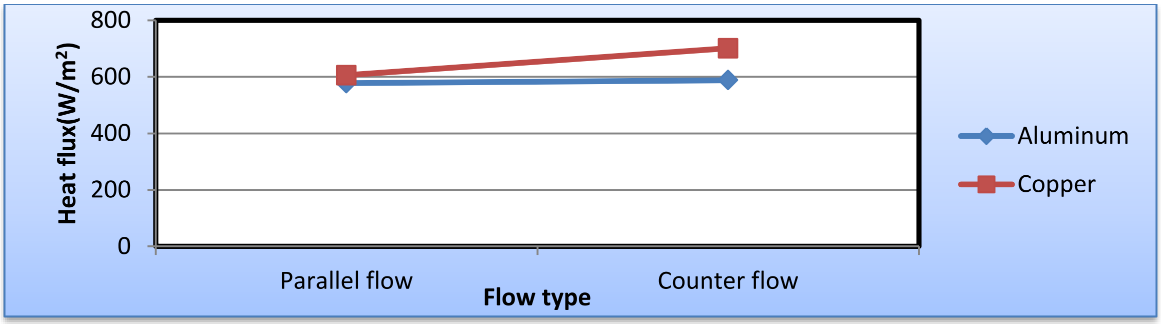

Figure: 4.Comparison of heat flux values for parallel and counter flow for R22 refrigerant with different materials.

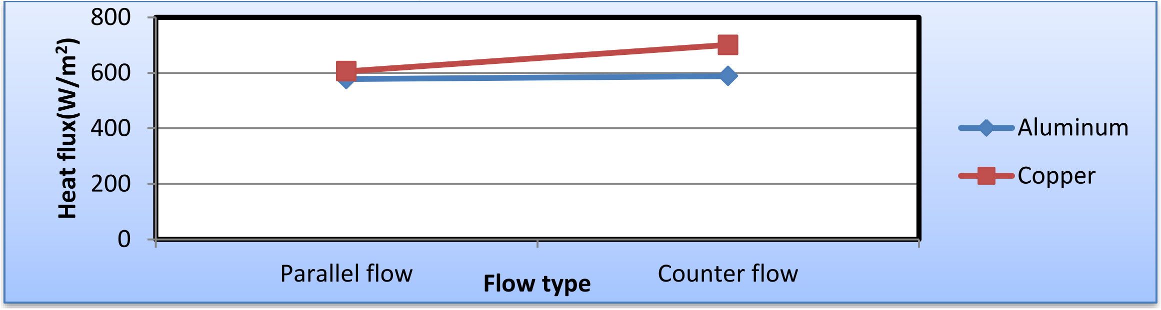

Figure: 5.Comparison of heat flux values for parallel and counter flow for R134A refrigerant with different materials.

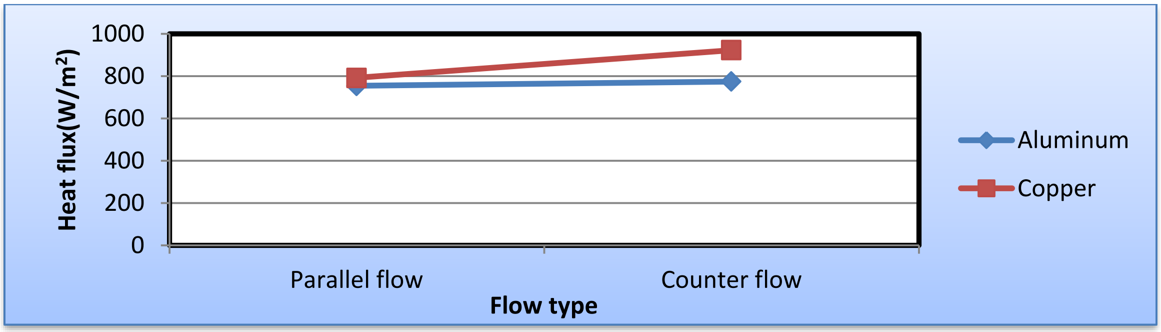

Figure: 6.Comparison of heat flux values for parallel and counter flow for fluid-R600A refrigerant with different materials.

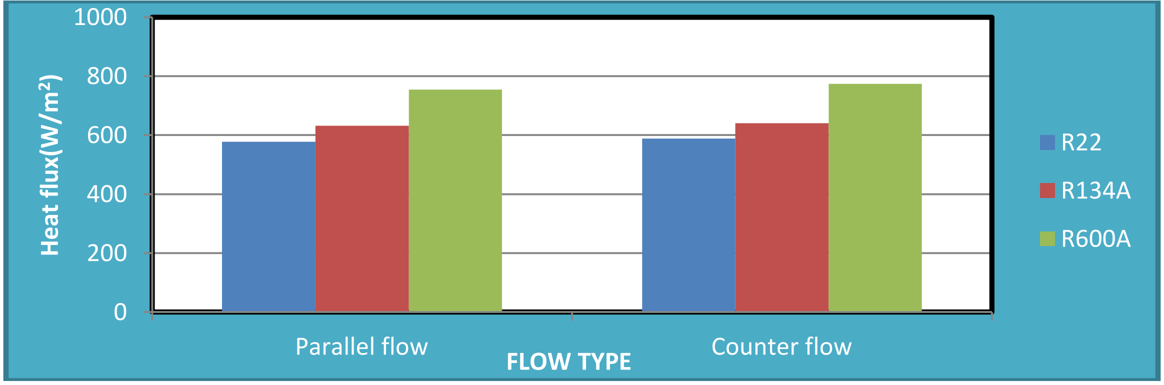

Figure: 7. Comparison of heat flux values for Parallel and counter flow for aluminium material and different refrigerants.

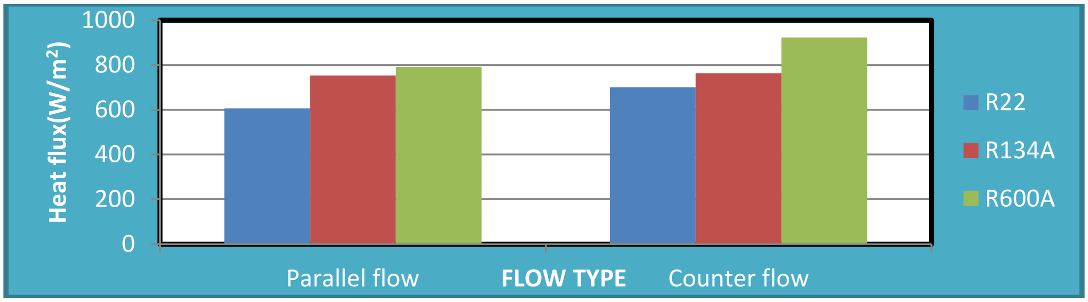

Figure: 8.Comparison of heat flux values for Parallel and counter flow for copper material and different refrigerants.

By observing the above results, the heat flux is more for counter flow heat exchanger than parallel flow heat exchanger.

V. CONCLUSION

In this present work, analysis is done to compare the heat transfer rates between the two basic flow arrangements (i) the unidirectional flow (parallel flow or co-current flow) and (ii) bidirectional flow (counter flow or counter-current flow).

CFD analysis is done on two types of heat exchangers by taking hot water and R134A, R22, R600A as refrigerants. By observing CFD analysis results, the heat transfer coefficient is more and heat transfer rate is less for counter flow heat exchanger due to more area than parallel flow heat exchanger. By comparing the results between fluids, the heat transfer coefficient and heat transfer rate are more for R600A.

Thermal analysis is done on the heat exchanger for different fluids, R134A, R22, R600A and different materials Aluminum and Copper. By observing the results, the heat flux is more for counter flow heat exchanger than parallel flow heat exchanger. The maximum heat flux value is obtained for counter flow heat exchanger when R600A is used as refrigerant and Copper is used as material.

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