Design of parallel flow heat Exchanger

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***Abstract* - Heat exchangers are integral part of engineering ecosystem. Their designing has been a challenging and most important task for the mechanical engineers. Parallel flow heat exchangers are commonly used in heating, cooling, refrigeration & air-conditioning, petrochemical refineries and other applications. It has been found by the literature survey that design parameters vary from one heat exchanger to another depending upon their applications. Their effectiveness can be increased by properly designing a heat exchanger. A review of the design of heat exchangers has been done in this research paper.**

***keywords* - Heat exchanger, Design, Effectiveness, Parallel flow, Heat Transfer**

1. INTRODUCTION

A heat exchanger is a device in which transfer of heat takes place between a hot fluid and cold fluid. These hot and cold fluids may be in direct contact or indirect contact. In other words, Heat exchangers are used for transfer of heat from one medium to another. A Gas, a liquid, or a combination of both can be used as a medium in heat exchanger. A solid wall can be used to prevent mixing of these media, sometimes media may come in direct contact. Heat exchangers are used both in heating process and cooling process. They are mainly used in power stations space heating, chemical plants, refrigeration & air conditioning, sewage treatment, natural gas processing, and petrochemical plants. Steam generator or boiler is a classic example of heat exchanger in which hot flue gases and water exchange heat without direct contact.

Waste exhaust heat from a gas turbine used for electricity generation can be transferred through a heat exchanger for boiling water, steam thus generated can be used to drive steam turbine for generation of electricity. This is the basis of Combined Cycle Gas Turbine technology. One such common use of heat exchanger is to pre-heat a cold fluid with the help of heat extracted from hot fluid exiting from a system. Some specific applications of heat exchangers can be stated as follows:

1. Heating a cold fluid using heat recovered from hot fluid.
2. Cooling a hot fluid by transferring its heat to a cold fluid.
3. Evaporation of a liquid by absorbing latent heat of vaporisation from a hotter fluid.
4. A gaseous fluid can be condensed by using a cold fluid.

Flow of hot and cold fluid takes place rapidly in a typical heat exchanger to facilitate transfer of heat from hot fluid to clod fluid through the process of forced convection. Due to rapid flow, there is pressure drops in the fluids. Mainly efficiency of heat exchangers can be estimated by knowing how well they can transfer heat with respect to the pressure losses incurred. Modern technology of heat exchanger focuses more and more on minimization of pressure losses and maximization of heat transfer rate along with fulfilment of other design objectives like how well it can withstand high pressures and temperatures, resisting corrosion and fouling losses and ease of cleaning, repair and inspection.

1.1 DESIGN OF HEAT EXCHANGERS

It is simply a process of finding the appropriate size of a heat exchanger which can satisfy predefined outputs fulfilling the needs of user under particular constraints imposed on the end user, the design engineer or both. In the first step of heat exchanger design various process parameters must be finalized, such as

1. Working pressure and temperatures.
2. Pressure and temperature to be designed
3. Total heat transfer rate to be obtained, it is also called heat duty.
4. Inlet and Outlet temperatures of hot fluid
5. Inlet and Outlet temperatures of cold fluid
6. Maximum permissible pressure drops on hot side
7. Maximum permissible pressure drops on cold side
8. Type of Heat exchanger to be used
9. Selection of fluid for shell side and tube side.

Design process of a heat exchanger can be understood with the help of following flow diagram

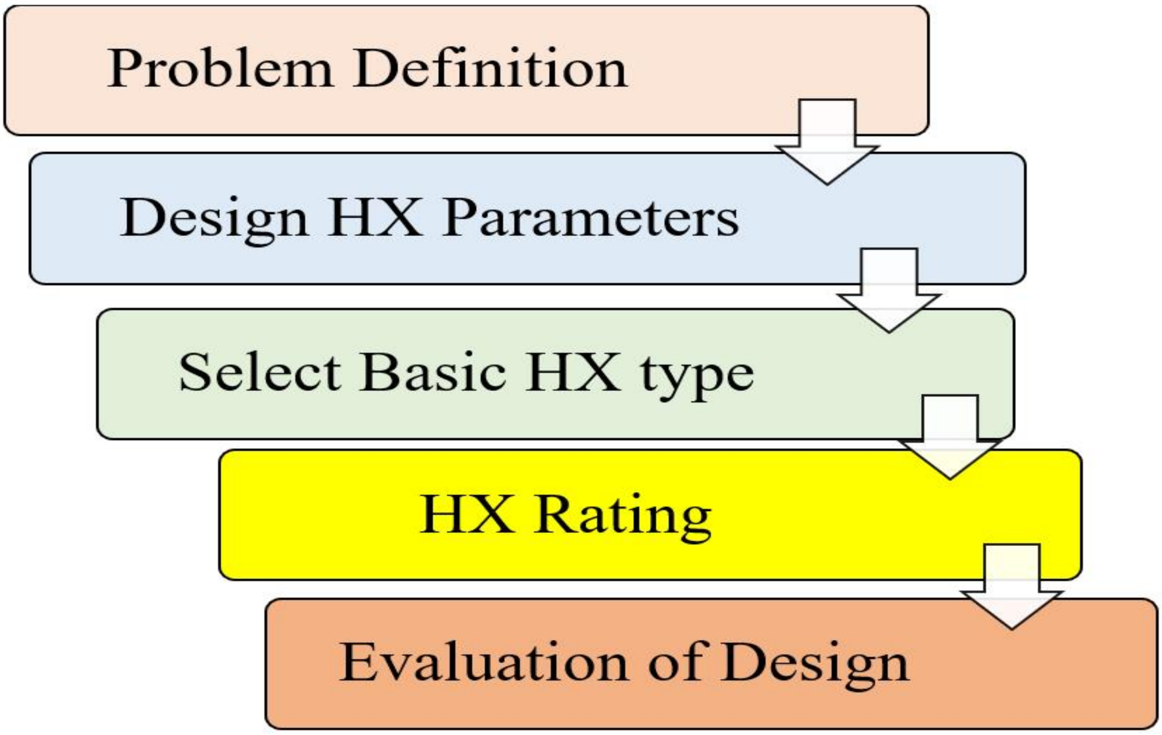

Figure 1: Design of Heat Exchanger

Engineering design can be defined as the process of devising a component, system or a process in order to meet desired objectives. It is a process of decision making (generally iterative), in which the concepts of Mathematics, basic sciences and the engineering are employed for optimal conversion of resources to fulfil these stated needs. Heat Exchanger can be considered as a component or system for the purpose of designing.

1.2 THERMAL DESIGN

Thermal design of a heat exchanger is a very important process. In this process, following three fundamental formulae are used:

Table 1: Formulae for thermal design of Heat Exchanger

S.N.	Formula	Symbols
1	Heat Rejected by hot fluid = Heat received by cold fluid $Q_{\text{Hot fluid}} = Q_{\text{Cold fluid}}$	Q = Heat Transfer rate
2	$Q_{\text{Hot fluid}} = m_h . C_{ph} \Delta T_h$	m_h = Mass flow rate of hot fluid C_{ph} = Specific heat of hot fluid ΔT_h = Temperature drop of hot fluid
3	$Q_{\text{cold fluid}} = m_c . C_{pc} \Delta T_c$	m_c = Mass flow rate of cold fluid C_{pc} = Specific heat of cold fluid ΔT_c = Temperature drop of cold fluid

To determine heating surface area, understanding of logarithmic mean temperature difference is matter of prime concern. The LMTD is a logarithmic average of the temperature difference between the hot and cold fluids at each end of the double pipe exchanger. Now surface area of heating surface can be determined by using the following relation

$$Q = U.A.\theta_m$$

Where Q = Heat transfer rate (in J/s) in heat exchanger
U = Overall heat transfer coefficient (Watt/m^2-K)
A = Surface area of heat exchanger (in square metre)
θ_m = Logarithmic mean temperature difference (LMTD

2. LITERATURE REVIEW

Literature review is an important part of any research. In this chapter researcher has reviewed a large number of research papers related to the domain of research. It helps a researcher to develop a proper understanding of the work done by the other researchers in the previous time. It provides a framework for the research to be done by the new researchers. Since no research is complete, it is a continuous process so by proper and sequential literature survey, a researcher becomes the part of flow of research in a particular direction. It is a process to be carried out with due care and full dedications because it uncovers so many dimensions of a particular research area. A literature review mainly highlights published information in a particular research area, and sometimes research done in a particular domain within a specified time period.

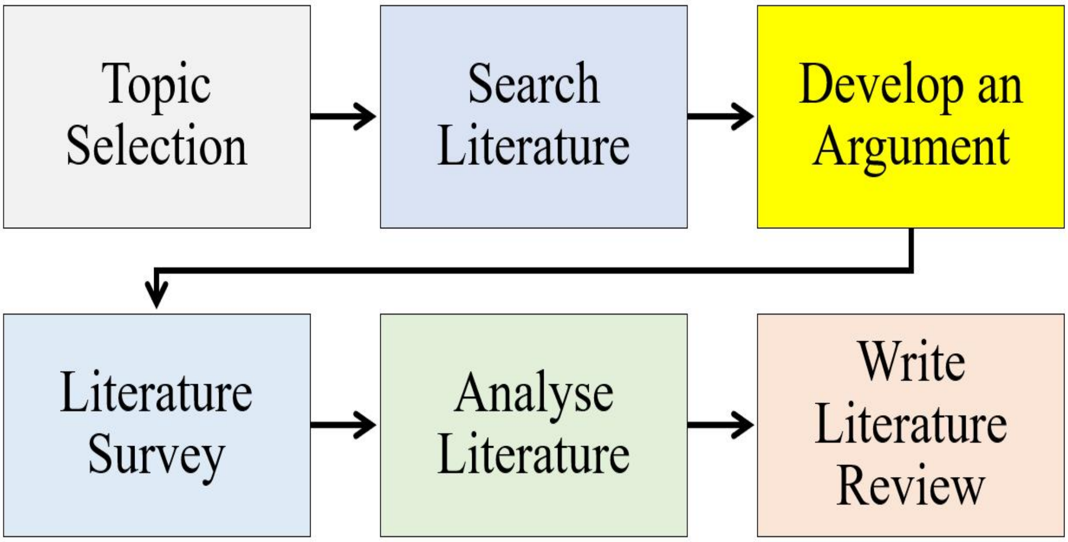

Figure 2: Steps of Literature Review

3. HEAT EXCHANGER

A heat exchanger can be defined as a device **(Sudhanshu Dogra, Nitin Chauhan, 2019)** which allows flow of heat from a hot fluid (a liquid or a gas) to flow to other fluid (another liquid or gas) with or without direct contact or direct mixing of two fluids. This paper has presented the contribution and research contributed by various researchers in this field and illustrates the various designing aspects of heat exchangers which can increase its effectiveness and efficiency.

Using multi-walled carbon nanotubes, **Marjan et al. 2015** conducted an experimental investigation on corrugated plate heat exchangers (MWCNT). investigating heat transfer and friction loss Nusselt number, convectional coefficient, and pumping power and pressure decrease in a heat-generating corrugated counterflow plate. various water-based nano-fluids, including gum multi-walled carbon nanotubes (MWCNTGA) with Arabic treatment and cysteine functionalization (FMWCNT-Cys) utilised as coolants were silver (FMWCNT-Ag). From Through testing, it was discovered that increasing Pecelet number, Reynolds number, or nonmaterial improvement portion changes in the heat transfer properties of the nanofluid increased.

This paper **(S. Bhuvaneswari, G. Elatharasan2019)** has given a detailed review of investigations of effectiveness of helical coil heat exchangers along with the other exchangers. Secondary flow of fluids inside the helical tubes takes place which results in higher heat transfer rates. friction factor also increases where effectiveness of heat exchanger varies linearly with it. Turbulent fluctuations of the tube are mainly caused by the curvature of the helical coil. The overall heat transfer coefficient is directly proportional with the values of Dean number, Nusselt number and Reynold number.

Elliptical Annular Fin (EAF) and Circular Annular Fin total heat transfer rates were given experimentally **(Nagrani et al. 2013)** and validated by CFD. Experimental study and EAF optimization were carried out using Genetic Algorithm (GA). According to the results of the experiment, the temperature of the annular fin surface continues to steadily decrease in the direction of the major axis, along with the projected surface area. The GA result demonstrated that, regardless of efficiency, EAF is more effective than circular fins for the same area of cross section. The smaller the radius of the circular tube, the lower the form factor, and the closer the minor axis is to the circumference of the tube, the more efficient the fins are.

Zheng et al [2002] used control-volume finite difference method to solve the three-dimensional governing equations with an accuracy of second order. In this paper the thermal radiation and laminar forced convection were investigated inside a helical pipe along with the effects of thermal radiation which could enhance the rate of heat transfer. Different researchers have studied the various parameters of the helical coil heat exchangers. **Yasuyuki et al. 2015** have studied a heat exchanger that can utilise the temperature difference between the ocean thermal energy system's source and sink (OTEC). OTEC's plate heat exchanger is inefficient. Herringbone heat exchangers were employed in experiments and numerical simulations in order to identify the heat exchanger that can deliver more efficiency while employing OTEC. The results showed that the herringbone heat exchanger had a superior rate of heat transfer than the plate heat exchanger.

Purandere et al. [2012] have discussed the Helical coil heat exchanger using parametric analysis. Range of Reynold number was found to be 100 to 6000 for laminar as well turbulent region. This research was is further studied and modified by **Kshirsagar et al. [2003]** by examining the variation in pitch to determine the overall heat transfer coefficient. Wilson pilot method was employed to calculate the inner heat transfer coefficient in the research of **Shirgire et al. [2014]** and it was proved by them that heat transfer coefficient is affected by the geometry of heat exchangers. **Jayakumar [2007]** conducted the numerical experiments in order to understand the influences of coil parameters on heat transfer. Finally, they concluded their research with the applications and advantages of helical coil heat exchangers. **Chen and Zhang [2003]** discussed the curvature (centrifugal force), cooling/ heating (buoyancy force) and rotation and their effects on the Nusselt number, temperature distribution, flow pattern and friction factor. **Lin Ebadian [1997]** have investigated three-dimensional turbulent heat transfer and employed the standard k-�� model with finite pitches in helical pipes. It was also discussed how curvature ratio, pitch and Reynolds number can affect local and average Nusselt numbers, temperature fields and thermal conductivity.

Gopu K et al. 2014 This study shows that as the baffle inclination angle was raised from 0 to 20, the outlet temperature on the shell side was significantly altered. This was brought on by a drop in shell side pressure. With 10 baffles inclined, the pressure reduction was observed to drop by 4%, and by 16% with 20 baffles inclined. With an increase in baffle tilt, the outlet velocity also rises, resulting in an even greater increase in heat transfer. It was discovered that the mode's forecast of pressure reduction and heat transfer had an average inaccuracy of 20%. In the entrance and outflow zone, there was rapid mixing and a change in flow direction, which was discovered to be the lone exception.

4.CONCLUSION

By examining the work done by many researchers, it can be determined that heat exchangers can become more effective and efficient by altering the design parameters and operating circumstances. Researchers have also demonstrated that the efficiency of heat exchangers can be increased by using expanded surfaces or fins. Additionally, utilising baffles with certain designs increases its suitability for various uses and applications.

In this research work, designing of heat exchangers has been reviewed. Research work carried out by various researcher was investigated. On the basis of the contributions of various researchers it was found that effectiveness and efficiency of heat exchangers can be increased by changing the operating conditions and design parameters of heat exchangers. Some researchers have also used of extended surfaces or fins over the heat exchangers to increases their effectiveness. Use of baffles in certain design can also make heat exchangers even more suitable for different applications.

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