

A Review on Design and Optimization of Shell and Tube Heat Exchanger by Varying Parameters

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Abstract: In recent years, thermal control systems performance has improved in numerous ways due to developments in control theory and information technology. Efforts have been made to produce more efficient heat exchangers by employing various methods of heat transfer enhancement. An increase in heat exchanger performance can lead to a more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. Compact heat exchangers (CHEs) technologies are expected to be one of the solutions for the new generation heat exchanger. In this paper are presented of the compact heat exchanger, Plate-fin heat exchanger, and Printed Circuit Heat Exchanger. And computation fluid dynamic is used which offers an alternative to the quick and inexpensive solution for the design and optimization of compact heat exchangers.

Keywords: control system, heat exchanger, heat transfer, enhancement, heat exchanger configuration.

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Ghaziabad, India Heat exchangers are one of the mostly used equipment in the process industries. Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop

[1]. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements.

I. LITERATURE REVIEW

Chamil Abeykoon et al. [1] this study aims to investigate the design procedure of a heat exchanger theoretically and then its performance will be analyzed and optimized using computational fluid dynamics. For the design purposes, a counter flow heat exchanger was considered and its length was theoretically calculated with the LMTD method while the pressure drop and energy consumption were also calculated with the Kern method.

Devvrat Verma et al. [2] the project is design of shell and tube heat exchanger with helical baffle and study the flow and temperature field inside the shell using ANSYS software tools. The heat exchanger contains 7 tubes and 800 mm length shell diameter 90 mm. The helix angle of helical baffle will be varied from 00 to 20°. In CFD will show how the temperature varies in shell due to different helix angle and flow rate. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger.

Mohammed Irshad et al. [3] in this paper presented are the Shell and tube heat exchangers are the most common type

of heat exchangers used in present scenario. Heat exchangers are widely used equipment in various industries such as power generation and transportation, refrigeration industry and chemical process industries because it suits high pressure application. Presented in this project is comparison for several shell- and- tube heat exchangers with segmental baffles. In simulation we will show how the temperature, pressure, velocity varies in shell due to different baffles orientation.

Gurbir Singh et al. [4] In this paper, the shell and tube heat exchanger is considered in which hot water is flowing inside one tube and cold water runs over that tube. Computational fluid dynamics technique which is a computer based analysis is used to simulate the heat exchanger involving fluid flow, heat transfer. CFD resolve the entire heat exchanger in discrete elements to find the temperature gradients, pressure distribution and velocity vectors. The turbulence model $k-\epsilon$ is used for accurate results from CFD. The temperature variations are calculated from experiment for parallel and counter flow by varying the mass flow rate of fluid of 2L/min and 3L/min which is controlled by Rota meter and the temperature variations are noted by the sensors attached at the inlets and outlets of tube.

II. COMPACT HEAT EXCHANGERS

A compact heat exchanger is generally defined as one which incorporates a heat transfer surface having a high "area density". In other words, having a surface area density greater its volume (greater than $700 \text{ m}^2/\text{m}^3$). Or a hydraulic diameter $D_h \leq 6 \text{ mm}$ if at least one fluid is gas, and in excess of $400 \text{ m}^2/\text{m}^3$ when operating in liquid or multi-phase streams. A typical shell and tube heat exchanger has an area density of less than $100 \text{ m}^2/\text{m}^3$ on one fluid side with plain tubes, and 2–3 times greater than that with high-fin-density low-finned tubing. Some micro scale heat exchangers under development, having an area density greater than about $15000 \text{ m}^2/\text{m}^3$, are as compact as the human lung and even more compact. As easily understandable, small flow passages have two effects, a tendency to laminar flow in the channels and a high pressure drop. Laminar flow is associated with low heat transfer coefficients, and therefore, the efficiency is necessarily improved by various heat transfer enhancement techniques, which have brought in a variety of CHEs [5]-[6]. Some types of CHEs have been in routine use for many decades. Others have recently been introduced into the market, while a number of types are

still being tested in the laboratory. The usage of compact heat exchangers for multi-phase flow is another area in which a lot of attention has been paid in the recent years. To discuss different types of compact heat exchangers, their new usages, and future directions in research and development.

III. PLATE HEAT EXCHANGER (PHE)

A large number of plate fin geometries have been used in compact CHEs and more are still being developed (Fig. 1). It consists of a series of corrugated plates supported by a rigid frame forming highly interrupted and tortuous channels. Multi-pass can be accommodated by blanking plates within the stack. Basic advantages of the plate heat exchangers are compactness, large heat transfer areas and high heat transfer coefficients [7]. To better understand the heat transfer characteristics and flow mechanism of the PHEs, Many works have been including flow visualization, heat transfer and pressure drop measurement; numerical simulation. The main weakness is that the plate-and frame heat exchangers are restricted to low or moderate temperature and pressure applications due to the use of gaskets. Beside this, for equivalent flow velocities, pressure drop in a PHE is relatively high due to its narrow passages which can be blocked by particulate contaminants in the fluid, and ineffective transversely vortices and zigzag flow patterns.

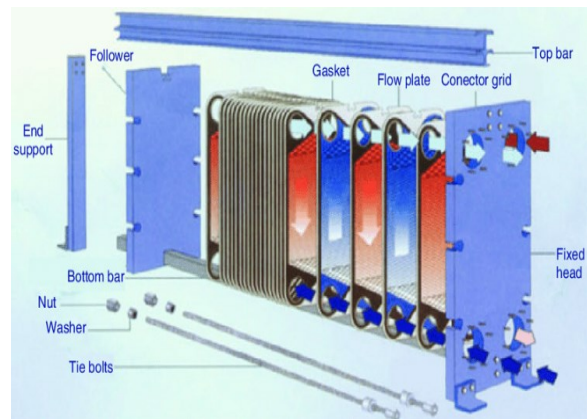


Fig. 1 Plate heat exchanger (PHE).

The advantages of PHEs are: high efficiency, compact design, can operate at high temperatures and pressure and easily cleaned. The surface area required for a PHE is 30–50% that of a shell-and-tube heat exchanger for a given heat duty, thus in turn reducing the cost. For the same effective heat transfer area, the weight and volume of

PHEs are approximately only 30% and 20%, respectively, of those of shell-and-tube heat exchangers.

IV. PLATE-FIN HEAT EXCHANGER (PFHE)

PFHE operated in cross-flow, counter-flow, cross-counter flow or co-current flow. It consists of fins which are bound by side bars and separated by flat parting sheets (Fig. 2). Various types of fin geometry are developed to increase heat transfer coefficient depending on the application (plain fins, wavy and corrugated channels, offset strip fins, louvered fins, and vortex generator). The information obtained is divided into three parts: offset fins, wavy fins and non-uniformity of inlet fluid flow. This review helps the researchers to carry out their further research in this field and also gives awareness for the designers to select the accurate design data for the optimum design [8]. Most PFHEs still use brazing to assemble the core.

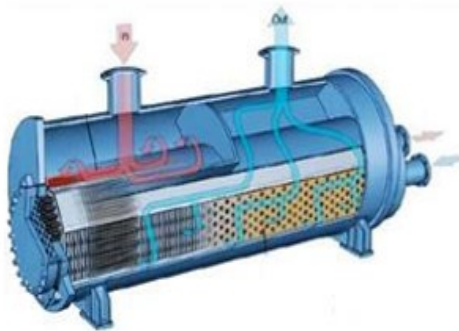


Fig. 2 Plate-fin heat exchanger (PFHE).

V. PRINTED CIRCUIT HEAT EXCHANGER (PCHE)

The name PCHE implies, the same technique is applied as the one used for manufacturing printed circuit boards in the electronics industry. In the first step of the manufacturing process, fine grooves are photo-chemically etched into one side of a flat metal plate forming the fluid passages. The etched-out plates are thereafter alternately joined by diffusion bonding, which is the second step and results in compact, extremely strong, all-metal heat exchanger cores [9]. The diffusion bonding process includes a thermal soaking period to allow grain growth, thereby essentially eliminating the interface at the joints, which in turn gives base-material strength and very high pressure containment capability throughout the entire exchanger, in addition to the avoidance of corrosion cells.

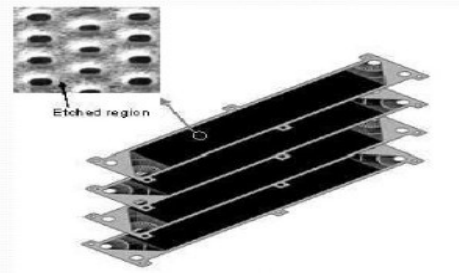


Fig. 3. Printed circuit heat exchanger (PCHE).

Because of diffusion bonding, its expected lifetime exceeds that of any other heat exchanger, based on a brazed structure. The complete heat exchanger core is composed by welding together as many of these blocks as the thermal duty (flow capacity) of the heat exchanger requires.

VI. SPIRAL HEAT EXCHANGER

Most of SHEs are not compact (some recent developments are compact). They are often used in the heating of high viscosity and dirty fluids [10]. A SHE refers to a helical tube configuration; more generally, the term refers to a circular heat exchanger with two long metal strips of plate rolled together to form a pair of concentric spiral channels of rectangular cross-section, one for each fluid.

The passages can be either smooth or corrugated, in some cases studs are welded onto one side of each strip to fix the spacing between the plates, provide mechanical strength and induce turbulence that increases heat transfer. Alternate passage edges are sealed either by welding at each side of the channel or by providing a gasket at each end cover to obtain the following arrangements of the two fluids: (1) both in spiral counter-flow; (2) one in spiral flow, the other in cross-flow across the spiral; or (3) one in spiral flow, the other in a combination of cross-flow and spiral flow. The internal void volume is lower (less than 60%) than in a shell-and-tube heat exchanger, and this yields a compact and space saving construction that can be readily integrated in any plant and reduces installation costs. Recently the newly designed Swiss-roll recuperator based on a spiral concept is proposed as a heat exchanger to recover the exhaust heat for future higher efficiency micro-turbines.

VII. COMPUTATIONAL FLUID DYNAMICS

CFD is useful for studying fluid flow and heat transfer chemical reactions, etc. solving mathematical equations

using numerical analysis. CFD solves the entire system in small cells and applies relevant equations to these discrete elements to find numerical solutions relating to pressure distribution and temperature gradients. This software can also create a virtual prototype of the system or device before it can be applied to the actual physics of the model and the software provides images and data that predict the performance of this project [11].

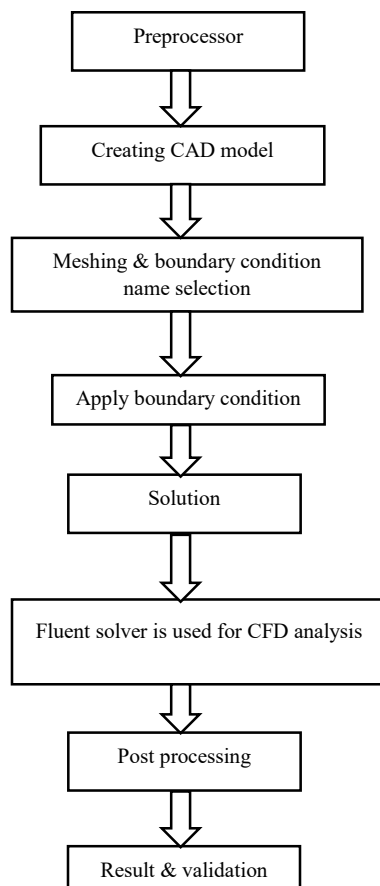


Fig. 4. Algorithm used for CFD analysis

More recently, methods have been applied for the construction of internal combustion engines, combustion chambers of gas turbines and furnaces, as well as for fluid flows and heat transfer in heat exchangers. Development in the CFD domain offers a capacity comparable to other CAE (Computer Aided Engineering) tools such as stress analysis codes [12].

VIII. CONCLUSION

Conventional methods of designing and developing heat exchangers are expensive. CFD offers an alternative to the quick and inexpensive solution for the design and optimization of heat exchangers. CFD outcomes are an essential part of the design process and make prototypes superfluous. Due to the development of CFD models, the use of CFDs is no longer a particular activity. In this paper are presented of the compact heat exchanger, Plate-fin heat exchanger, and Printed Circuit Heat Exchanger is described. CFD is still a developing art in the prediction of erosion/corrosion due to a lack of suitable mathematical models to represent the physical process. New flow modeling strategies can be developed for flow simulation in the compact heat exchanger.

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