CFD Analysis of Heat Transfer Characteristics in Heat Exchanger Having Fins with Different Geometries - A Review

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Abstract— A heat exchanger is a device that transfers thermal energy between two or more fluids in thermal contact that are at different temperatures. They're employed in a variety of industries, including aerospace, chemical manufacturing, power plants, refineries, and HVAC refrigeration. In industry, the optimal design and efficient functioning of the heat exchanger and heat transfer network are critical for increasing efficiencies and lowering production costs and energy consumption. Heat transmission has long been a major factor in the design of electrical components, chemical reaction containers, apparatus, heat exchangers, and insulating materials, among other things. In some applications, it is critical to limit heat loss, while in others, it is critical to swiftly release excess heat into the surrounding atmosphere to avoid overheating. Finned surfaces give more support and so operate as efficient heat sinks by facilitating faster heat transmission. To better understand the elements affecting heat transfer over the length of the fin, we will use ANSYS Workbench® to simulate heat transfer processes via multiple finned surfaces of varying shapes and materials. The fins were created in the ANSYS Workbench environment while maintaining a consistent total exposed surface area. With different operating conditions and settings, the models were rendered and simulations were run. This study compiles and tabulates the results. Pin Fin, Plate Fin, and Elliptical Pin Fin geometries will be employed in this experiment.

Keywords: Computational Fluid Dynamics (CFD), Heat Sink, Heat Exchangers, Heat Transfer Analysis

I. INTRODUCTION

Industrial heat exchangers are pieces of machinery that transfer heat from one medium to another. The fundamental function of heat exchangers is to heat or cool the element [22]. Cooling is especially vital in the industrial sector because it prevents equipment from overheating. There are many different types of heat exchangers, each with its own set of benefits and downsides. Heat exchangers are used in a wide range of industries [24]. They're employed in a variety of cooling and heating systems as air conditioning components. Many industrial processes, in general, require a certain amount of heat to function properly. This necessitates extreme caution in maintaining these processes at optimal temperatures. Heat exchangers are essential in industrial plants to keep machinery, chemicals, water, gas, and other substances at a safe operating temperature. Heat exchangers are also used to catch the extra heat or steam that is emitted as a byproduct during the operation, so that the heat can be used more efficiently elsewhere.16].

Different types of heat exchangers have different flow arrangements, equipment, and design features, and thus work in different ways. All heat exchangers have one thing in common: they all work to expose a warmer media to a cooler medium, either directly or indirectly. Heat exchangers are usually made up of a series of tubes enclosed in a casing. Heat exchangers are generally classified by following ways,

- Nature of the heat exchange process.
- The physical state of the fluid.
- Heat exchangers flow arrangements.

The classification technique for heat exchangers is determined by whether the substances being exchanged come into direct touch with one another or are separated by a physical barrier such as the walls of their tubes. Instead than relying on radiant heat or convection, direct contact heat exchangers put the hot and cold fluids in direct contact within the tubes. Because direct contact is an exceptionally efficient method of transmitting heat, these direct contact heat exchangers must operate in a safe atmosphere. If the hot and cold fluids have a modest temperature difference, direct contact heat exchangers are ideal. The hot and cold fluids in an in-direct contact heat exchanger are physically isolated from one another. Instead of using radiant radiation and convection to exchange heat, an indirect con- tact heat exchanger will maintain hot and cold fluids in separate pipes. This is done to keep one fluid from contaminating the other.

Heat exchangers may also be classified based on the physical state of the hot and cold fluid such as,

Liquid → Gas.
Liquid → Solid.
Gas → Solid.

Immersible liquids that do not blend may also exist in specific circumstances. Oil with water, for example. Another major way of defining heat exchangers is the way fluids flow within the heat exchanger. Parallel flow, Counterflow, and Crossflow are the three major classifications. The hot and cold fluids enter the heat exchanger from the same end and flow parallel to each other in the same direction in a parallel flow heat exchanger. Although these configurations are less efficient than counterflow arrangements, they allow for greater temperature homogeneity across the heat exchanger's walls. The hot and cold fluids enter the heat exchanger from opposite directions and flow towards each other in a counterflow heat exchanger. Counterflow configurations are the most widely used flow configuration. This configuration is the most efficient because it allows for more heat transmission between fluids. Fluids flow perpendicular to one another in a cross-flow heat exchanger. The efficiency of a heat exchanger that uses this flow type is somewhere between counter-current and co-current [5] [25].

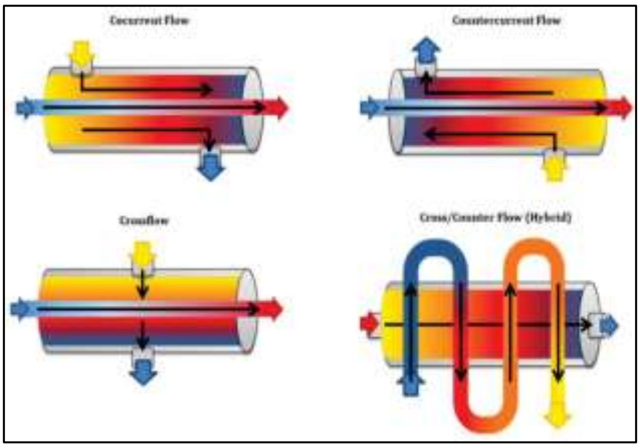

Figure 1.1.1: Heat exchanger flow configuration

A. Tubular Heat Exchanger

Depending on the purpose, tubular heat exchangers are typically constructed with circular, elliptical, rectangular, or other complicated shape twisted tubes. These heat exchangers have a flexible design and geometry, allowing them to modify the tube diameter, length, and flow arrangement with ease. Because of this, certain heat exchangers are preferred over others. Tubular heat exchangers are chosen for high-pressure

II. LITERATURE REVIEW

Applications when the pressure difference between the fluids is large. These tubular heat exchangers are commonly used for liquid-to-liquid and liquid-to-phase change heat transfer. These heat exchangers are popularly classified as shell and tube, finned and spiral tube exchangers. All primary surface of heat exchangers are same, but fins may be constructed outside or inside the tube.

Year	Name	Work	Outcomes
2021	Josua P. Meyer and Hilde van der vver	devised a new heat exchanger design based on fractals to significantly enhance heat transfer area. Analytical, numerical, and experimental methods are used to investigate the given results. In comparison to a conventional tube heat exchanger	the results from a fractal heat exchanger have a greater heat transfer to overall volume[15]
2020	Hesham G. Ibrahim [11]	employed imperial models to investigate forced convection with turbulent flow, as well as numerical solutions using CFD analysis to investigate turbulent flow pattern and heat transfer from air walls in a horizontal pipe. Despite the fact that we did not focus on turbulent flow.	this research assisted us in understanding the empirical correlation of the Nusselt number
2020	Mehrain Hashemian and Samad Jafarmadar	conducted research using conical tubes instead of cylindrical tubes to improve the geometry of finned heat exchangers. These conical tubes are tested in nine different layouts, each of which corresponds to a different flow direction. The effects of hydraulic, geometrical, and thermodynamic properties are investigated in this study.	. Finally, they concluded that there is a fifty-five percent improvement in effectiveness and a forty percent increase in heat transfer[9].
2019	Mohamad omidi and Mohamad jafari	conducted a complete review on finned heat exchangers. The role of change in geometry shapes in relation to heat transfer rate was investigated in this study, and various heat transfer enhancement methods were reviewed, as well as the importance of nano fluid in finned heat exchangers.	. Finally, a mathematical correlation of Nusselt's number in pressure drop coefficient was presented[17].
2018	Amit Rao and SV Dingare	did research on improving heat transfer rate by inserting dimples on the surface of the heat exchanger, as well as various heat transfer argumentation techniques[21].	Pressure drop in case of smooth tube is more compared to that of dimpled tube for low Reynolds number. The temperature of flue gases at the end of the heat exchanger is more in case of smooth tube when compared with the dimple tube
2017	Ganesh V.wafelkar and Dr.L V Kamble	did an experiment on a triple concentric heat exchanger using a finned heat exchanger. In comparison to finned heat exchangers, triple pipe heat exchangers provided a larger heat transfer area. Dimples have been added to the middle tube of the heat exchanger to improve its efficiency.	The link between Nusselt number, friction factor, and heat exchanger effectiveness was investigated using different flow rates of hot and cold fluid[7].

2017	Pooja Patil and Padmakar Deshmukh	conducted an experimental investigation on heat transfer coefficients in circular tubes produced with almond type dimples on the surface, with the final results compared to a basic plain tube.	And the results showed that a dimple in a circular tube has a 66% higher thermal performance factor than a regular tube[19]. Heat transfer and pressure drop are critical construction characteristics that have a significant impact on plate heat exchanger performance.
2016	Vinay Patel's	research on a plate heat exchanger, in which CFD (computational fluid dynamics) computational fluid dynamics applications were employed to develop the pasteurizer plant's optimization.	The results of CFD tests and analytical results are validated in this study. Temperature distribution, flow combination, and material thermal conductivity comparison are investigated using these data [18]. The design of shell and tube heat exchangers has a significant impact on their performance.
2016	Santosh K	did research using CFD analysis to investigate the numerical study of heat transfer enhancement in shell and tube heat exchangers. In this case, the CFD analysis is carried out with and without tabulators in the early phases, and then the design is combined with various baffle designs and semi-circular tabulators in the latter stages.	. Finally, theoretical results are used to validate the pressure drop, outlet temperatures, and heat transfer coefficients[10]. The finned heat exchanger is the most common type of heat exchanger, and it is widely used in industrial applications.
2015	Anton Gonez	In his research, the efficiency of heat exchangers is evaluated using enhancement approaches. Thermal performance is investigated using passive heat transfer improvement approaches. The heat exchanger's inner pipe is modified with a cross-section that follows the Koch snowflake fractal design.	. The fractal heat exchanger's performance is compared to that of a finned heat exchanger [8]. Because of its high efficiency, environmental conservation, and low maintenance cost, the borehole heat exchanger is used in a wide range of industrial applications, and many studies have been undertaken on it.
2015	Yong Li and Jinfeng Mao	explore the heat transfer between the pipe legs inside BHE (Bore- hole Heat Exchanger). The subsurface of two-leg pipes, namely DLP (Downward leg of pipe) and ULP (Upward leg of pipe) exhibited inside the vertical BHE, can either ex-retract or reject the transmitted heat.	The narrow borehole diameter (0.111 m to 0.22 m) may produce a temperature difference between DLP and ULP, which could lead to thermal short-circuiting. The 2-D model was used to study the produced short-circuit, and then a best-fit formulation of short-circuiting thermal resistance in dimensionless form was presented[14].
2014	Ping Cui and Hongxing Yang,	conducted a heat transfer analysis of ground heat exchangers made out of inclined boreholes. The author used many inclined bore-holes to investigate the heat exchange in this study. To begin, the authors built a transient three-dimensional heat conduction model that represents the heat exchange between the ground and the hole using a single inclined line source.	The authors investigated the heat exchange resulting from several boreholes by superimposing temperature changes from individual boreholes[3]. The design of heat exchangers plays a vital role in their smooth operation, therefore heat exchangers should be built using experimental analysis to determine the ideal size of parts such as coil pitch, coil diameter, and flow rate.
2014	N Jamshidi and M Farhadi	conducted research using experimental apparatus and the Taguchi method to investigate the fluid flow effect and changes in heat transfer due to geometrical parameters.	The overall heat transfer coefficient of the heat exchangers is found in ideal conditions. According to the Taguchi approach, the main design parameters in coil heat exchangers are the shell-side flow rate, coil diameter, tube side flow rate, and coil pitch. [12].

III. Aims and Objectives

The goal of this thesis is to look into heat transfer analysis and how it applies to various finned heat exchangers. Refrigeration, aerospace, the petrochemical industry, and a variety of other fields all use heat exchangers. During the operation of a finned heat exchanger with a constant volume of inner fluid, different shapes of inner pipe are investigated. Another feature of the finned heat exchanger that we looked into was a dent on the outer surface of the inner pipe. Temperature and pressure are measured with and without a dent in this experiment..

IV. STRATEGIES

The following is the master thesis's strategy:

– Data (objective outcomes) that haven't been analyzed or interpreted.
– Analysis/interpretation of the results that is objective and completely based on the data collected.
– Interpretation and analysis of the findings in the context of the corpus of knowledge (external to your thesis).

V. PROPOSED MATERIAL AND PROPERTIES:

Types of fins	Total Number	Material	Density	Thermal conductivity (k)	Specific heat (C)
pin fins:	4	Steel	8030 kg/m^3	16.27W/m K	502.48 J/kg K
Elliptical pin fins	2	Steel	8030 kg/m^3	16.27W/m K	502.48 J/kg K
Plate fins	3	Steel	8030 kg/m^3	16.27W/m K	502.48 J/kg K

VI. METHODOLOGY

Pre-Processing, Solver Execution, and Post-Processing are the three key processes in CFD computations. The modelling goals are specified and a computational grid is created during the pre-processing stage. The solver is started in the second phase by setting numerical models and boundary conditions. The solver continues to run until convergence is achieved. The findings are analysed once the solver has finished, which is the post-processing phase.

A. Procedure

1) Step 1: Draw the cylindrical pin fins, elliptical fins, plate fins in ANSYS Workbench or Space Claim 3D Modellers
2) Step 2: Using the created fins in ANSYS software for further simulations.
3) Step 3: Use the data for analysis and calculating efficiency and other parameters

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