ISSN: 2581-9674
Article ID: IJDCSE07202004
International Journal for Development of Computer Science and Engineering (IJDCSE)
Volume-2, Issue-4, July-2020, PP.20-30
www.ijdcse.org
Received: 08-03-2020, Accepted: 07-04-2020, Published: 08-05-2020

Cfd Analysis Of Louvered Fin Heat Exchangers Used In Hvac Application In Engineering

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Abstract

The Fin and tube heat exchangers are commonly used in the process and HVAC industries. The louver fin pattern is one of the common enhanced surfaces because it can provide periodical renewal of boundary layer. For HVAC application, the fin and tube heat exchangers include a group of fins arranged parallel to one another at predetermined spacing. The heat exchanger tubes were arranged in one or more rows that are perpendicular to the direction of air. For such applications the airside resistance generally comprises over 90% of the total thermal resistance. Therefore finned surfaces were often employed to effectively improve the overall performance of the heat exchangers. Further the design of finned surfaces has to be optimized. CFD is considered an effective tool for such analysis. The objective of the project is to investigate the airside performance of fin and tube heat exchangers having circular tube configuration. The heat transfer and pressure drop characteristics of the louvered fin geometry have to be analyzed using CFD. The geometrical parameters of louver angle, louver pitch sand louver length are analyzed during the study. Due to difficulties induced by the finned geometry an approach through a simplified model is to be followed initially. This simple model comprises of simple plates having circular configuration is to be simulated. The results of simplified model in terms of heat transfer and pressure drop would be used to analyze the finned tube plates.

Introduction

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Heat exchangers are used in a wide variety of application. Typical among them are the district hear stations, HVAC (heating, ventilating, air-conditioning, and refrigeration) systems, food and chemical process systems, and heat recovery systems. Fin and tube heat exchangers are frequently used in vehicular air- conditioning systems in the automotive industry. An advantage of decreasing the size of heat exchangers in vehicles is weight savings, as well as a reduction in the required frontal area of the vehicles that must be dedicated to the heat exchanger. Therefore, enhanced surfaces are often employed to effectively improve the overall performance of the fin and tube heat exchanger.

Typical applications involve heating or cooling of a fluid steam of concern and evaporation or condensation of single-or multi component fluid streams. In other application, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact.

In most heat exchangers, heat transfer between fluids place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply re cooperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface are referred to as indirect transfer type, or simply regenerators.

Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/ valve switching. Common examples of heat exchangers are shell-and tube exchangers. Automobile radiators, condensers, evaporators, air pre heaters, and cooling towers.

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In contrast exchangers in which is intermittent heat exchanger between the hot and cold fluids-via thermal energy storage and release through the exchanger surface or matrix – are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching. Common examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air repeaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger.

There could be internal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place with in the exchanger, such as in boilers, fired heaters, and fluidized – bed exchangers. Mechanical devices mat be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperate generally takes place by conduction. However, in a heat pipe heat exchanger, the heat pipe not only acts as a separating wall, but also facilitates the transfer of heat by condensation, evaporation, and conduction of the working fluid inside the heat pipe. In general, if the fluids are immiscible a heat transfer surface, as in a direct – contact heat exchanger.

A heat exchanger consists of heat transfer elements such as a core or matrix containing the heat transfer surface, and fluid distribution elements such as headers, manifolds, tanks, inlet and outlet nozzles or pipes, or seals. Usually, there are no moving parts in a heat exchanger: however, there are exceptions, such as a rotary regenerative exchanger (in which the matrix is mechanically driven to rotate at some design speed) or a scraped surface heat exchanger.

The heat transfer surface is a surface of the exchanger core that is in direct contact with fluids and through which heat is transferred by conduction. That portion of the surface that is in direct contact with both the hot and cold fluids and transfers heat between them is referred to as the primary or direct surface.

To increase the heat transfer area, appendages may be intimately connected to the primary surface to provide an extended, secondary, or indirect surface. These extended surface elements are referred to as fins. Thus heat is conducted through the fin and convicted (and/or radiated) from the fin (through the surface area) to the surrounding fluid, or vice versa, depending on whether the fin is being cooled or heated.

As a result, the addition of fins to the primary surface reduces the thermal resistance on that side and thereby increases the total heat transfer from the surface for the same temperature difference. Fins may form flow passages for the individual fluids but do not separate the two (or more) fluids of the exchanger.

These secondary surfaces or fins may also be in traduced primarily for structural strength purposes or to provide thorough mixing of a highly viscous liquid. Not only are hear exchangers often used in the process, power petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, alternative fuel, and manufacturing industries, they also serve as key components of many industrial products available in the marketplace.

These exchangers can be classified in many different ways. We will classify them according to transfer processes, number of fluids, and heat transfer mechanisms. Conventional heat exchangers are further classified according to construction type and flow arrangements. Another arbitrary classification can be made, based on the heat transfer surface area/ volume ratio, into compact and non compact heat exchangers.

This classification is made because the type of equipment, fields of applications, and design techniques generally differ. All these classification are summarized and discussed further in this chapter. Heat exchangers can also be classified according to the process function, as outlined. However, they are not discussed here and there adder may refer to shah and Mueller (1988). Additional ways to classify hear exchangers are by fluid type (gas-gas, gas-liquid, and liquid-liquid, gas two – phase, liquid two-phase, etc). Industry, and so on, but we do not cover such classifications.

Classification According To Transfer Processes

Heat exchangers are classified according to transfer processes into indirect- and direct contact types.

Indirect-Contact Heat Exchangers

In an indirect-contact heat exchanger, the fluid streams remain separate and the heat transfers continuously through an impervious dividing wall or into and out of a wall in a transient manner. Thus, ideally, there is no direct contact between thermally interacting fluids. This type of heat exchanger also referred to as a surface heat exchanger, can be further classified into direct-transfer type, storage type, and fluidized-bed exchangers.

Direct transfer type exchangers.

In this type, heat transfers continuously from the hot fluid to the cold fluid through a dividing wall. Although a simultaneous of two (or more) fluids is required in the exchanger, there is no direct mixing of the two (or more) fluids because each fluid flows in separate fluid passages. In general, there are no moving parts in most such heat exchangers. This type of exchanger is designated as a recuperative heat exchanger or simply as a remunerator. Some examples of direct transfer type heat exchangers are tubular. Plate – type and extended surface exchangers. Note that term remunerator is not commonly used in the process industry for shell- and tube and plate heat exchangers although they are also considered as remunerators. Remunerators are further sub classified as prime surface exchangers and extended- surface exchangers.

Prime surface exchangers do not employ fins or extended surfaces on any fluid side. Plain tubular exchangers, shell and tube exchangers with plain tubes, and plate exchangers are good examples of prime surface exchangers. Recuperates constitute a vast majority of all heat exchangers.

Storage type exchangers.

In storage type exchanger, both fluids flow alternatively through the same flow passages, and hence heat transfer is intermittent. The heat transfer surface (or flow passages) is generally cellular in structure and is referred to as a matrix, or it is a permeable (porous) solid material, referred to as a packed bed. When hot gas flows over the heat transfer surface (through flow passages), the thermal energy from the hot gas is stored in the matrix wall, and thus the hot gas is being cooled during the matrix heating period.

As cold gas flows through the same passages later (i.e., during the matrix cooling period), the matrix wall gives up thermal energy, which is absorbed by the cold fluid. Thus heat is not transferred continuously through the wall as in a direct – transfer type exchanger (remunerator), but the corresponding thermal energy is alternately stored and released by the matrix wall.

This storage type heat exchanger is also referred to as a regenerative heat exchanger, or simply as a regenerator. {To operate continuously and within a desired temperature rang, the gases, headers, or matrices are switched periodically (i.e., rotated), so that the same passage is occupied periodically by hot and cold gases. The actual time that hot gas takes to flow through a cold regenerator matrix is called the hot period or hot blow, and the time that cold gas flows through the hot regenerator matrix is called the cold period or cold blow. For successful operation, it is not necessary to have hot and cold gas flow periods of equal duration.

There is some unavoidable carryover of a small fraction of the fluid trapped in the passage to the other fluid stream just after switching of the fluids; this is referred to as carryover. In addition, if the hot and cold fluids are at different pressures, there will be leakage. In addition, if the hot and cold fluids are at different pressures, there will be leakage from the high – pressure fluid to the low – pressure fluid past the radial, peripheral, and axial seals, or across the valves. This leakage is referred to as pressure leakage. Since the seleaks are unavoidable, regenerators are used exclusively in gas -to-gas heat (and mass) transfer applications with sensible heat transfer: in some applications, regenerators may transfer moisture from humid air to dry air up to about 5%.

For heat transfer analysis of regenerators, the E- NTU method of remunerators needs to be modified to take into account the thermal energy storing capacity of the matrix. We discuss the design theory of regenerators. Fluidized-bed heat exchangers. In a fluidized- bed heat exchanger, one side of a two-fluid exchanger is immersed in a bed of finely divided solid material, such as a tube bundle immersed in a bed of sand or coal particles as show in fig 1.

If the upward fluid velocity on the bed side is low, the solid particles will remain fixed in position in the bed and the fluid will flow through the interstices of the bed. If the upward fluid velocity is high, the solid particles will be carried away with the fluid. At a proper value of the fluid velocity, the upward drag force is slightly higher than the weight of the bed particles.

As a result, the solid particles will float with an increase in bed volume, and the bed behaves as a liquid. This characteristic of the bed is referred to as a fluidized condition. Under this condition, the fluid pressure drop through the bed remains almost constant, independent of the flow rate, and a strong mixing of the solid particles occurs.

This results in a uniform temperature for the total bed (gas and particles) with an apparent thermal conductivity of the solid particles as infinity. Very high heat transfer coefficients are achieved on the fluidized on the fluidized side compared to particle-free or dilute – phase particle gas flows. Chemical reaction is common on the fluidized side in many process applications and combustion take place in coal combustion fluidized beds. The common application of the fluidized bed heat exchanger is drying mixing, adsorption, reactor engineering, coal combustion, and waste heat recovery. Since the initial temperature difference (Th;i _ Tf ;i)is reduced due to fluidization, the exchanger effectiveness is lower, and hence e-NTU theory for a fluidized-bed exchanger needs to be modified (suo1976).

Direct-Contact Heat Exchangers

In a direct-contact exchanger, two fluid streams come in to direct contact, exchange heat, and are then separated. Common applications of a direct-contact exchanger involve mass transfer in addition to heat transfer, such as in evaporative cooling and rectification;
Applications involving only sensible heat transfer are rare. The enthalpy of phase change in such an exchanger generally represents a significant portion of the total energy transfer.

The phase change generally enhances the heat transfer rate. Compared to indirect contact remunerators and regenerators, in direct-contact heat exchangers,
(1) Very high heat transfer rates are achievable,
(2) The exchanger construction is relatively inexpensive,
(3) The fouling problem is generally nonexistent, due to the absence of a heat transfer
Surface (wall) between the two fluids. However, the applications are limited to those cases
Where a direct contact of two fluid streams is permissible.
These exchangers may be further classified as follows.

Immiscible Fluid Exchangers.

In this type, two immiscible fluid streams are brought into direct contact. These fluids may be single-phase fluids, or they may involve Condensation or vaporization. Condensation of organic vapors and oil vapors with Water or air are typical examples.

Gas–Liquid Exchangers.

In this type, one fluid is a gas (more commonly, air) and the other a low-pressure liquid (more commonly, water) and is readily separable After the energy exchange. In either cooling of liquid (water) or humidification of gas(Air) applications, liquid partially evaporates and the vapor is carried away with the gas. In these exchangers, more than 90% of the energy transfer is by virtue of mass transfer (Due to the evaporation of the liquid), and convective heat transfer is a minor mechanism. A ‘‘wet’’ (water) cooling tower with forced- or natural-draft air. Flow is the most Common application. Other applications are the air-conditioning spray chamber, spray drier, spray tower, and spray pond.

Liquid–Vapor Exchangers.

In this type, typically steam is partially or fully Condensed using cooling water, or water is heated with waste steam through direct Contact in the exchanger. Noncondensables and residual steam and hot water are the Outlet streams. Common examples are desuperheaters and open feed water heaters (also Known as deserters) in power plants.

Classification According to Number of Fluids

Most processes of heating, cooling, heat recovery and heat rejection involve transfer of Heat between two fluids. Hence, two-fluid heat exchangers are the most common. Three-fluid heat exchangers are widely used in cryogenics and some chemical processes (e.g., air Separation systems, a helium–air separation unit, purification and liquefaction of hydrogen, Ammonia gas synthesis). Heat exchangers with as many as 12 fluid streams have been used in some chemical process applications. The design theory of three- and multiplied heat exchangers is algebraically very complex and is not covered.

Classification According To Surface Compactness

Compared to shell-and-tube exchangers, compact heat exchangers are characterized by a large heat transfer surface area per unit volume of the exchanger, resulting in reduced space, weight, support structure and footprint, energy requirements and cost, as well as improved process design and plant layout and processing conditions, together with low fluid inventory.

A gas-to-fluid exchanger is referred to as a compact heat exchanger if it incorporates a heat transfer surface having a surface area density greater than about 700m2/m3 (213 ft2/ft3){or a hydraulic diameter Dh _ 6mm (14 in.) for operating in a gas stream and 400m2/m3 (122 ft2/ft3) or higher for operating in a liquid or phase-change stream. A laminar flow heat exchanger (also referred to as a meson heat exchanger) has a surface area density greater than about 3000m2/m3 (914 ft2/ft3) or 100 mm _ Dh _ 1 mm. The term micro heat exchanger is used if the surface area density is greater than about 15,000m2/m3 (4570 ft2/ft3) or 1mm _ Dh _ 100 mm.

A liquid/two-phase fluid heat exchanger is referred to as a compact heat exchanger if the surface area density on any one fluid side is greater than about 400m2/m3. In contrast, a typical process industry shell and- tube exchanger has a surface area density of less than 100m2/m3 on one fluid side with plain tubes, and two to three times greater than that with high-.n-density low-finned tubing. A typical plate heat exchanger has about twice the average heat transfer coefficient on one fluid side or the average overall heat transfer coefficient U than that for a shell and- tube exchanger for water/water applications.

A compact heat exchanger is not necessarily of small bulk and mass. However, if it did not incorporate a surface of high-surface area density, it would be much more bulky and massive. Plate-fin, tube-fin, and rotary Regenerators are examples of compact heat exchangers for gas flow on one or both fluid sides, and gasketed, welded, brazed plate heat exchangers and printed-circuit heat exchangers are examples of compact heat exchangers for liquid flows.

Basic flow arrangements of two-fluid compact heat exchangers are single-pass cross flow, counter flow, and multiphase Cross-counter flow. For noncompact heat exchangers, many other flow arrangements are also used. The aforementioned last two flow arrangements for compact or noncompact heat exchangers can yield a very high exchanger effectiveness value or a very small temperature approach between fluid streams.

A spectrum of surface area density of heat exchanger surfaces is shown in Fig. 1.2. On The bottom of the figure, two scales are shown: the heat transfer surface area density _ (m2/m3) and the hydraulic diameter Dh, {(mm), which is the tube inside or outside Diameter D (mm) for a thin-walled circular tube. Different heat exchanger surfaces are Shown in the rectangles. When projected on the _ (or DH) scale, the short vertical sides of a rectangle indicate the range of surface area density (or hydraulic diameter) for the Particular surface in question. What is referred to as _ in this figure is either _1 or _2, Defined as follows. For plate heat exchangers, plate-.n exchangers, and regenerators,

Classification According To Construction Features

Heat exchangers are frequently characterized by construction features. Four major construction types are tubular, plate-type, extended surface, and regenerative exchangers. Heat exchangers with other constructions are also available, such as scraped surface exchanger, tank heater, cooler cartridge exchanger, and others (Walker, 1990). Some of these may be classified as tubular exchangers, but they have some unique features compared to conventional tubular exchangers. Since the applications of these exchangers are specialized, we concentrate here only on the four major construction types noted above.

Although the "-NTU and MTD methods (see end of Section 3.2.2) are identical for Tubular, plate-type, and extended-surface exchangers, the influence of the following Factors must be taken into account in exchanger design: corrections due to leakage And bypass streams in a shell-and-tube exchanger, effects due to a few plates in a plate exchanger, and fin efficiency in an extended-surface exchanger. Similarly, the "-NTU method must be modified to take into account the heat capacity of the matrix in a Regenerator.

Shell-and-Tube Exchangers.

This exchanger, shown in Fig. 1.3, is generally built of a bundle of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One fluid flows inside the tubes, the other flows across and along the tubes. The major components of this exchanger are tubes (or tube bundle), shell, frontend head, rear-end head, ba.es, and tube sheets, and are described briefly later in this subsection.

A variety of different internal constructions are used in shell-and-tube exchangers, depending on the desired heat transfer and pressure drop performance and the methods employed to reduce thermal stresses, to prevent leakages, to provide for ease of cleaning, to contain operating pressures and temperatures, to control corrosion, to accommodate highly asymmetric flows, and so on.

Shell-and-tube exchangers are classified and constructed in accordance with the widely used TEMA (Tubular Exchanger Manufacturers Association) standards (TEMA, 1999), DIN and other standards in Europe and elsewhere, and ASME (American Society of Mechanical Engineers) boiler and pressure vessel codes. TEMA has developed a notation system to designate major types of shell-and-tube exchangers. In this system, each exchanger is designated by a three-letter combination, the first letter indicating the front-end head type, the second the shell type, and the third the rear-end head type. Some common Shell-and-tube exchangers are AES, BEM, AEP, CFU, AKT, and AJW. It should be emphasized that there are other special types of shell-and-tube exchangers commercially available that have front- and rear-end heads differ rent from those in Fig. 1.4. Those exchangers may not be identifiable by the TEMA letter designation.

Summary

Heat exchangers have been classier according to transfer processes, number of fluids, Degrees of surface compactness, construction features, flow arrangements, and heat Transfer mechanisms. A summary is provided in Fig. 1. The major emphasis in this Chapter is placed on introducing the terminology and concepts associated with a broad Spectrum of commonly used industrial heat exchangers (many specialized heat exchangers Are not covered in this chapter). To acquaint the reader with specifict examples, major Applications of most types of heat exchangers are mentioned. With a thorough understanding of this broad overview of deferent types of exchangers, readers will be able to apply the theory and analyses presented in the succeeding chapters to their septic needs. One example of the optimization process for the area reduction ratio (ReH = 300 and Lp = 1.0 mm) is shown in

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