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Chapter 1

Introductory Chapter: Heat Exchangers

Laura L. Castro Gómez

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1. Introduction

Nowadays, engineering has a lot of challenges to improve or completely change equipment and devices used in industry, laboratory, and daily life. Examples of these devices are heat exchangers, which, as their name refer, exchange energy from a hot fluid to a cold fluid or vice versa. These devices could be as small as the cooling system of a CPU processor or as big as used in the industry of many meters of height and length.

Heat exchangers are used in almost all systems that could need heating or cooling of equipment or process fluids in industry.

2. Types of heat exchangers

Heat exchangers could be constructed in many arrangements, depending on their application. The most usual classification has been given by several authors like Shah [1] and Cengel [2]. This classification could be:

1. Contact of fluids
   a. Direct: could be of immiscible fluids, vapor-liquid or gas-liquid
   b. Indirect: could be of storage, fluidized bed
2. Flow of working fluids
   a. Single pass: counterflow, cross flow, parallel flow, etc.
   b. Multipass: extended surface, shell and tubes, and plates

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3. Compactness
    a. Compact
    b. Noncompact
4. Construction
    a. Tubular: double pipe, shell and tube, and pipe coils
    b. Plate: spiral and plate coil
    c. Extended surface: finned tube or plates
    d. Regenerative: rotatory and mixing matrix

From this classification, it can be noted that there are several design options to select the exchanger that suits the needs of a process or the available space capacities.

Usually, this equipment is manufactured on materials with high heat transfer capacity, such as metals, but they can be designed for special operating conditions where metals have no good performance, like heavy fouling, highly viscous fluids, erosion, corrosion, and so on. So, they could be constructed with a variety of nonmetal materials: graphite, glass, and Teflon [3].

In the matter of working fluids, the same case of materials are used with good heat transfer capacities to maintain either its low or high temperature. Some fluids could be selected as coolants, such as brine; ammonia solutions; R-134; other organic fluids such as toluene, R-12, and Therminol; water; or others for heating systems [4, 5].

3. Advances on heat exchangers

As can be seen in the previous section, there are many opportunities to improve heat exchangers.

The present book compiles some advances in these issues. In the matter of design, three chapters and one chapter for working fluids are presented. In the first chapter, advances in a finned heat exchanger for thermal storage are presented. In in the second chapter, investigations relative to techniques of heat transfer for heat exchangers are presented. In the third chapter, advances for integrated structures in heat exchangers are presented. Finally, in the fourth chapter, advances in the use of nanofluids for heat exchangers are presented.

In the first chapter in design section, "Numerical Investigation of PCM Melting in a Finned tube Thermal Storage," authors propose a numerical investigation based on an enthalpy formulation to study the melting of a PCM in a finned heat exchanger. This numerical approach simultaneously gives the temperature distributions in the PCM storage system and temporal propagation of the solidification front during the solidification of the PCM when it is exposed to a cold air flow. Also, the transient evolution of the longitudinal air temperature profiles is given in this study.

The second chapter "Heat Transfer Enhancement in Tubular Heat Exchangers," by Martín Picón-Núñez et al. describes the concept of heat transfer enhancement and the ways it is applied to the development of new heat exchanger technology. Heat transfer enhancement refers to the application of basic concepts of heat transfer processes to improve the rate of heat removal or deposition on a surface. In the flow of a clean fluid through the tube of a heat exchanger, the boundary layer theorem establishes that a laminar sublayer exists where the fluid velocity is minimal. Heat transfer through this stagnant layer is mainly dominated by thermal conduction becoming the major resistance to heat transfer. From an engineering point of view, heat transfer can be enhanced if this stagnant layer is partially removed or eliminated. In single-phase heat transfer processes, three options are available to increase the heat transfer rate. One of them is the choice of smaller free-flow sectional area for increased fluid velocity bringing about a reduction of the thickness of the laminar sublayer. A second option is the engineering of new surfaces which cause increased local turbulence, and the third option consists in the use of mechanical inserts that promote local turbulence. The application of these alternatives is limited by the pressure drop.

In "Integrated Structures for Heat Exchangers" by Uwe Scheithauer et al., authors refer to the advantage of additive manufacturing (AM) technologies, enabling a radical paradigm shift in the construction of heat exchangers. In place of a layout limited to the use of planar or tubular starting materials, heat exchangers can now be optimized, reflecting their function and application in a particular environment. The complexity of form is no longer a restriction but a quality. Instead of brazing elements, resulting in rather inflexible standard components prone to leakages, with AM, we finally can create seamlessly integrated and custom solutions from monolithic material. To address AM for heat exchangers, we both focus on the processes, materials, and connections as well as on the construction abilities within certain modeling and simulation tools. AM is not the total loss of restrictions. Depending on the processes used, delicate constraints have to be considered. On the other hand, the materials used to manufacture heat exchangers with this technique could operate in a wide temperature range. It is evident that conventional modeling technics cannot match the requirements of a flexible and adaptive form finding. Instead, we exploit biomimetic and mathematical approaches with parametric modeling. This results in unseen configurations and pushes the limits of how we should think about heat exchangers today.

The section of working fluids, "Heat flow inside heat exchanger using Al_2O_3 nanofluid with different concentrations" by Jaafar Albadr, shows an experimental investigation on a forced convection heat flow and characteristics of a nanofluid containing water with different volume concentrations of Al_2O_3 nanofluid (0.3–2%) flowing inside a horizontal shell and tube heat exchanger in a counterflow under turbulent conditions. The Al_2O_3 nanoparticles of about 30 nm diameter are utilized. The results indicate that the convective heat transfer coefficient of nanofluid is higher than that of the base liquid at same inlet temperature and mass flow rate. The heat transfer coefficient of the nanofluid increases with the increase in mass flow rate. Furthermore, the heat transfer coefficient increases with the increase in the Al_2O_3 nanofluid volume concentration. Results illustrate that the increase in volume concentration of the nanoparticles leads to an increase in the viscosity of the nanofluid which causes an increase in friction factor. The effects of Peclet number, Reynolds number, and Nusselt number have been investigated. Those dimensionless number values change with the change in the working fluid viscosity, Prandtl number, and volume concentration of suspended nanoparticles.

4. Conclusion

Advances on studies for improvements on heat exchangers have been performed by several researchers, and in the present book, some of them are presented. These advances are focused on heat transfer enhancement, manufacturing, and working fluids.

Author details

Laura L. Castro Gómez

Address all correspondence to: lauracg@uaem.mx

Centro de Investigación en Ingeniería y Ciencias Aplicadas (CIICAp), Universidad Autónoma del Estado de Morelos (UAEM), Cuernavaca, Mexico

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