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Corrugated plate heat exchanger review

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ABSTRACT

The developments and the enhancements in all the heat transfer equipments are mainly purposed for energy savings and savings in projects capital investment, through reducing the costs (energy or material). The better heat exchanger is one that transfer's high heat rate at low pumping power with a minimum cost. The spent of money for the research and development in corrugated plate heat exchangers, in last decades, from some companies, offered different and versatile types and models of that heat exchanger. In the current study I made a focus on researcher's efforts in research and developments for corrugated plate heat exchanger. This type of heat exchangers is widely used for different engineering fields and applications. Research reactors represent one of the important engineering fields that extensively use corrugated plate heat exchangers due to their simplicity in assembly/disassembly and their easy maintainability. The corrugated plate heat exchanger has a great flexibility than the other types of heat exchangers; both its heat transfer area and its cooling flow could be increased or decreased easily, so; it is commonly used for enlargement and upgrading works. The current revision incorporated different topics like; the plate heat exchanger structure, thermal performance, heat transfer enhancement mechanisms as well as plate heat exchanger advantages and limitations. The corrugated plate heat exchanger works efficiently in both single phase and two phase flow, while the two phase flow region still needs a lot of research work. Also; the corrugated plate heat exchanger thermal performance and pressure drop behaviours when using nano-fluids were discussed in the current revision.

1. Introduction

Heat exchangers are heat transfer devices that exchange thermal energy between two or more mediums. Heat exchangers play a significant role in the operation of many systems such as power plants, nuclear reactors, process industries and heat recovery units. The development of heat exchangers design, reliability and maintainability is always a required matter to enhance the overall systems performance. The heat exchangers have many different types, like; shell and tube (vertical/horizontal), plate heat exchanger (corrugated or flat - gasketed or brazed) and micro heat exchangers. Fig. 1 introduces a plate heat exchanger classifications based on their constructions. Two main categories of heat exchangers could be considered, the direct heat exchanger and the indirect heat exchanger. In a direct heat exchanger, the two mediums between which heat is exchanged are in direct contact, e.g. cooling towers. In an indirect heat exchanger, the two mediums between which heat is exchanged are separated by a wall as in plate heat exchanger. The classical method for the heat exchanger design is known as The LMTD (Log Mean Temperature Difference) and NTU (Number of Transfer Units) method. These methods are based on iterations and prototype assumptions through the design. Due to these reasons, Computational Fluid Dynamics (CFD) techniques are adopted in the design of heat exchangers.

2. Plate heat exchanger structures and geometry

Enhancement of heat transfer surfaces has developed over the years, and is the main focus in the heat exchanger industry. Enhanced surfaces yield higher heat transfer coefficient when compared to unenhanced surfaces. A surface can be enhanced by adding extended surfaces (e.g. fins), or employing interrupted surfaces (e.g. corrugations). The plate type heat exchangers are economic and efficient enough to be widely spread in many markets now days. With it's low cost, flexibility, easy maintenance, and high thermal efficiency. The plate proven design is the main parameter for its high efficiency. In addition to the plate efficiency, corrugation patterns that produce turbulent flows, it is not only cause's unmatched efficiency; it also produces a heat exchanger self-cleaning nature, which in turn reducing

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Nomenclature

A	Area (m^2)
A	Corrugation depth (m)
A(φ)	Corrugation depth (m)
B(φ)	Corrugation depth (m)
b	Corrugation depth (m)
C(φ)	Diameter (m)
d	Diameter (m)
f	Friction factor
G	Mass flux (Kg/m^2 s)
g	Acceleration of gravity (m/s^2)
L	Plate length (m)
N	Number of fluid passes
Nu	Nusselt Number
P	Prandtle Number
Pr	Prandtle Number
Re	Reynolds number
u	Plate width (m)
V	Plate width (m)
W	Plate width (m)

Greek symbols

φ	Plate chevron angle (deg)
β	Plate chevron angle (deg)
ϕ	Surface enlargement factor
ˆ	Plate corrugation pitch m
ρ	Thermal conductivity (W/m °C)
λ	Thermal conductivity (W/m °C)
μ	Dynamic viscosity (Pa s)
α	Heat transfer coefficient (W/m^2 °C)
ζ	Moody friction factor

Subscripts

b	bulk
e	equivalent
h	hydraulic
p	port
l	Laminar
t	turbulent
w	wall

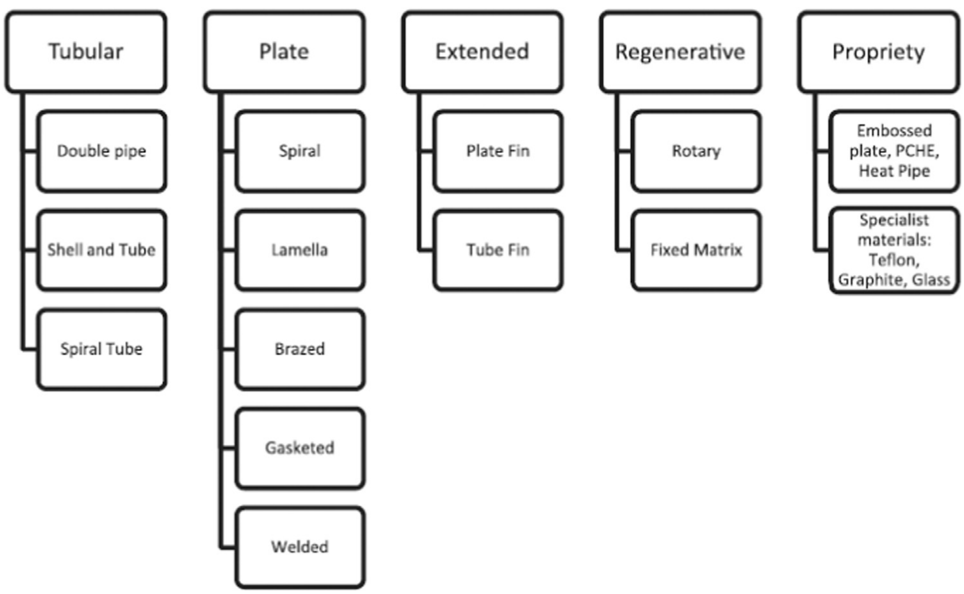

Fig. 1. Brief classification of heat exchangers [1].

the fouling effect [2]. The most common surface pattern used is the chevron design Fig. 2.

The corrugated plate heat exchanger consists of a number of gasketed plates constrained between an upper carrying bar and a lower guide bar. The plates are compressed between the fixed frame and the movable frame by using many tie bolts. [2]. The Structure of a typical gasketed plate heat exchanger with chevron plates is shown in Fig. 3.

The important geometrical parameters for a plate heat exchanger are introduced and defined as in Fig. 4a and b. The following parameters are considered essential parameters in plate heat exchanger simulations, the chevron angle (ϕ), the corrugation depth (b) and the corrugation pitch (ˆ) [3]. It has been convenient also to define the parameter "Surface enlargement factor" (ϕ) that calculated from the following relation.

$$\varphi = \frac{1}{\Lambda/2}\int_0^{\Lambda/2}\sqrt{1+\left(\frac{d}{d\zeta}(y(\zeta))\right)^2}\,d\zeta$$

For instance, using a radius of r=1.6 mm, corrugation pitch of ˆ=6.9 mm and a corrugation depth of=2 mm generates a surface enlargement factor of =1.189. Commercial plates have commonly surface enlargement factor of ϕ=1.15 to ϕ=1.25 [3].

3. Thermal-hydraulic parameters

The hydraulic diameter, Reynolds number, Nusselt number and the friction factor for the corrugated plate heat exchanger are defined in the following section [3]. Two different definitions of the hydraulic diameter are adopted. The most common definition used is similar to

Fig. 2. Chevron plate shape.