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# Plate Type Heat Exchanger – A Review Study

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***Abstract: -*** Heat exchangers are one of the most important heat transfer apparatus that find its use in industries like oil refining, chemical engineering, electric power generation etc. Plate type of heat exchangers has been commonly and most effectively used in Industries over the years. Plate heat exchangers are used regularly in the heating, ventilating, air conditioning, and refrigeration industry. There is an urgent need for detailed and systematic research regarding heat transfer and the fluid flow characteristics of these types of exchangers. As an initiative in this respect, a literature search is presented on plate heat exchangers. New correlations for evaporation heat transfer coefficient and friction factor are introduced, which are applicable to various system pressure conditions and plate chevron angles. This review paper presents the work of various researchers on the heat transfer enhancement of plate type heat exchanger.

***Keywords: -*** *Heat transfer, Plate heat exchanger, Design.*

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## I. INTRODUCTION

A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This has a major advantage over a conventional heat exchanger in that the fluids are exposed to a much larger surface area because the fluids spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change. Plate heat exchangers are now common and very small brazed versions are used in the hot-water sections of millions of combination boilers. The high heat transfer efficiency for such a small physical size has increased the domestic hot water (DHW) flow rate of combination boilers. The small plate heat exchanger has made a great impact in domestic heating and hot-water. Larger commercial versions use gaskets between the plates, smaller version tend to be brazed.

The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. In most cases, the exchanger consists of a coiled pipe containing one fluid that passes through a chamber containing another fluid. The walls of the pipe are usually made of metal or another substance with a high thermal conductivity, to facilitate the interchange, whereas the outer casing of the larger chamber is made of a plastic or coated with thermal insulation, to discourage heat from escaping from the exchanger.

The plate heat exchanger (PHE) was invented by Dr Richard Seligman in 1923 and revolutionised methods of indirect heating and cooling of fluids. Dr Richard Seligman founded APV in 1910 as the Aluminium Plant & Vessel Company Limited, a specialist fabricating firm supplying welded vessels to the brewery and vegetable oil trades.

Plate heat exchangers (PHEs) are not a new concept or technology. One of the first patents was issued in 1890 to Langem and Hundhanssen, a German company. In the past, this type of exchanger has been successfully used in industries such as dairy, process, paper/pulp, and heating, ventilating, and air conditioning (HVAC). The main purpose of this article is to direct potential researchers to the subject of PHE, because current industries lack fundamental information about them. These types of evaporators are being used in the heating, ventilating, air conditioning, and refrigeration (HVAC&R) industry on a regular basis, yet there is no guidance whatsoever. The objective here is to present the current

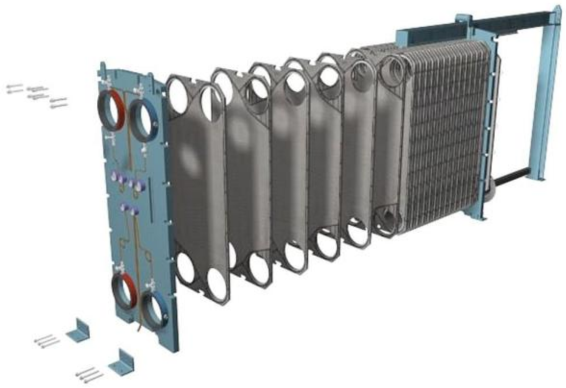

**Figure 1: Plate Heat Exchanger**

## II. LITERATURE REVIEW

**Ya-Ling He et al.** investigated the heat transfer enhancement and pressure loss penalty for fin-and-tube heat exchangers with rectangular winglet pairs (RWPs) were numerically investigated in a relatively low Reynolds number flow. The purpose of this study was to explore the fundamental mechanism between the local flow structure and the heat transfer augmentation. The RWPs were placed with a special orientation for the purpose of enhancement of heat transfer. The numerical study involved three-dimensional flow and conjugate heat transfer in the computational domain, which was set up to model the entire flow channel in the air flow direction. The effects of attack angle of RWPs, row-number of RWPs and placement of RWPs on the heat transfer characteristics and flow structure were examined in detail. It was observed that the longitudinal vortices caused by RWPs and the impingement of RWPs-directed flow on the downstream tube were important reasons of heat transfer enhancement for fin-and-tube heat exchangers with RWPs. It was interesting to find that the pressure loss penalty of the fin-and-tube heat exchangers with RWPs can be reduced by altering the placement of the same number of RWPs from inline array to staggered array without reducing the heat transfer enhancement. The results showed that the rectangular winglet pairs (RWPs) can significantly improve the heat transfer performance of the fin and- tube heat exchangers with a moderate pressure loss penalty.

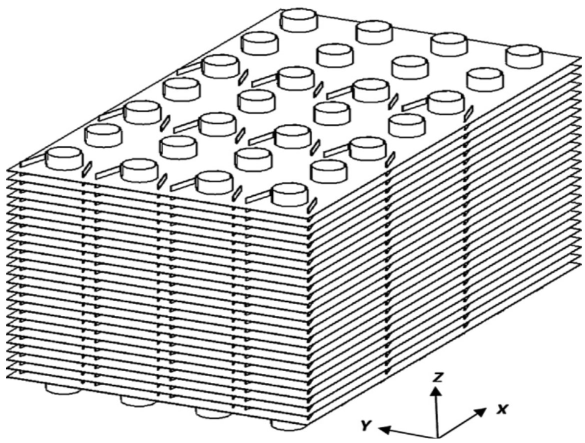


**Figure 2: Schematic diagram of core region of a fin-and-tube heat exchanger with RWPs.**

**S.M. Pesteei et al.** this paper present local heat transfer coefficients were measured on fin-tube heat exchanger with winglets using a single heater of 2 inch diameter and five different positions of winglet type vortex generators. The measurements were made at Reynolds number about 2250. Flow losses were determined by measuring the static pressure drop in the system. Results showed a substantial increase in the heat transfer with winglet type vortex generators. It has been observed that average Nusselt number increases by about 46% while the local heat transfer coefficient improves by several times as compared to plain fin-tube heat exchanger. The maximum improvement is observed in the re-circulation zone. The best location of the winglets was with DX = 0.5D and DY = 0.5D. The increase in pressure drop for the existing situation was of the order of 18%.

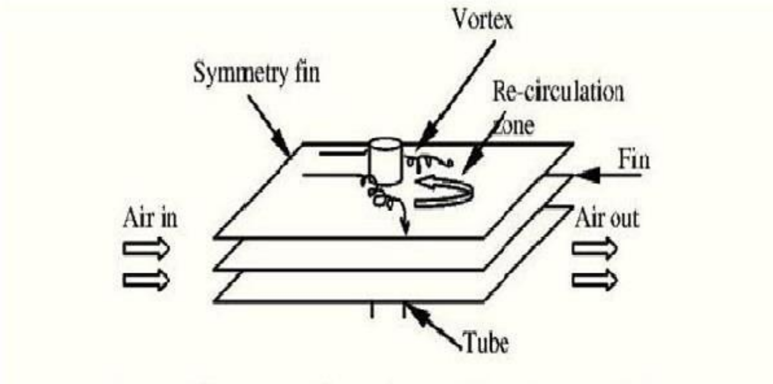


**Figure 3: Fin tube configuration and flow characteristics**

**C.B. Allison et al.** investigated the experimental analysis of the effects of delta-winglet vortex generators on the performance of a fin and tube radiator is presented. The winglets were arranged in flow-up configuration, and placed directly upstream of the tube. This is a hitherto untested configuration, but is thought to have certain advantages. In addition to vortex generation the flow is guided onto the tube surface increasing the localised velocity gradients and Nusselt numbers in this region. The study includes dye visualisation and full scale heat transfer performance measurements. The results are compared to a standard louvre fin surface. It was found that the winglet surface had 87% of the heat transfer capacity but only 53% of the pressure drop of the louvre fin surface.

They found that the heat transfer mechanisms of the two fin surfaces differ dramatically. The louver fin surface facilitates boundary layer renewal and has numerous leading edges. The delta-winglet fin has fewer leading edges and relies predominantly on increasing convection through vortex generation. According to the results, the louver fin is superior to the deltawinglet fin. Although coherent vortices were generated from the first row of winglets, we doubt wether the downstream winglets produce the same level of vorticity. This implies that only the first row of winglets may be effective in producing vortices which can improve heat transfer.

**M.C. Gentry et al.** investigated the heat transfer enhancement by various vortex generators mounted at the leading edge of a flat plate. They demonstrated a 50– 60% improvement in average heat transfer over the surface of the plate, using delta-wing vortex generators. It is worth noting that a delta-wing is like an isosceles triangle mounted symmetrically to the flow, and the angle of attack is measured between the plate and the lean of the delta. A delta-winglet on the other hand is like a right-angled triangle (or half delta) mounted perpendicular to the plate, but at an incident angle measured parallel to the inlet flow. Gentry and Jacobi varied the angle of attack from 25o to 55o, with the optimum enhancement occurring at an angle of attack of 40o.

**Y. Chen et al.** investigated the effect of punched longitudinal vortex generator in form of winglets staggered arrangements to enhance the heat transfer in high performance finned oval tube heat exchanger. Winglets in staggered arrangement bring larger heat transfer enhancement than in inline arrangement. K. Torii et al., propose a novel technique that can augment heat transfer but nevertheless can reduce pressure-loss in a fin tube heat exchanger with circular tubes. The winglets are placed with a heretofore-unused orientation for the purpose of augmentation of heat transfer. This orientation is called as ‘‘common flow up’’ configuration. The proposed configuration causes significant separation delay, reduces form drag, and removes the zone of poor heat transfer from the near-wake of the tubes. Jin-Sheng Leu et al., numerically and experimentally analyses the heat transfer and flow in the plate-fin and tube heat exchangers with inclined block shape vortex generators mounted behind the tubes. The results indicated that the proposed heat transfer enhancement technique is able to generate longitudinal vortices and to improve the heat transfer performance in the wake regions.

## III. DESIGN OF PHE

The plate heat exchanger (PHE) is a specialized design well suited to transferring heat between medium- and low-pressure fluids. Welded, semi-welded and brazed heat exchangers are used for heat exchange between high-pressure fluids or where a more compact product is required. In place of a pipe passing through a chamber, there are instead two alternating chambers, usually thin in depth, separated at their largest surface by a corrugated metal plate. The plates used in a plate and frame heat exchanger are obtained by one piece pressing of metal plates. Stainless steel is a commonly used metal for the plates because of its ability to withstand high temperatures, its strength, and its corrosion resistance. The plates are often spaced by rubber sealing gaskets which are cemented into a section around the edge of the plates. The plates are pressed to form troughs at right angles to the direction of flow of the liquid which runs through the channels in the heat exchanger. These troughs are arranged so that they interlink with the other plates which forms the channel with gaps of 1.3–1.5 mm between the plates.

The plates produce an extremely large surface area, which allows for the fastest possible transfer. Making each chamber thin ensures that the majority of the volume of the liquid contacts the plate, again aiding exchange. The troughs also create and maintain a turbulent flow in the liquid to maximize heat transfer in the exchanger. A high degree of turbulence can be obtained at low flow rates and high heat transfer coefficient can then be achieved.

The total rate of heat transfer between the hot and cold fluids passing through a plate heat exchanger may be expressed as:

$$Q = UA\Delta Tm$$

Where, U is the overall heat transfer coefficient, A is the total plate area, and $\Delta Tm$ is the temperature difference. U is dependent upon the heat transfer coefficients in the hot and cold streams

**Applications**

- **Power** - Auxiliary cooling circuit isolation, co-generation applications, geothermal applications, lubrication oil cooling, diesel engine cooling, heat recovery.
- **HVAC** - Cooling tower isolation, free cooling, heat pump systems, sea water isolation, thermal storage systems, pressure Interceptor.
- **Marine** - Seawater isolation exchanger, central cooling, jacket fresh water cooling, lube oil cooling, camshaft lube, oil cooling.

**Industrial**

**Mining** - Plating heaters & coolers, analyzing heaters & coolers, strike solution cooling, quench oil coolers, sulfuric acid, hydrochloric acid, hydrogen peroxide, titanium dioxide, chloride alkaline, soda ash, steel.
**Refinery** - Brine cooling, crude oil/water interchanger, treated crude oil / untreated crude oil interchanger.
**Dairy** - Milk pasteurization, milk reception, cultured milk treatment, UHT, cream pasteurization, ice-cream mix treatment, cheese milk heat treatment.

**Advantages:**

- Simple and Compact in size
- Heat transfer efficiency is more
- Can be easily cleaned
- No extra space is required for dismantling
- Capacity can be increased by introducing plates in pairs
- Leaking plates can be removed in pairs, if necessary without replacement
- Maintenance is simple
- Turbulent flow help to reduce deposits which would interfere with heat transfer

**Disadvantages:**

- Initial cost is high since Titanium plates are expensive
- Finding leakage is difficult since pressure test is not as ease as tube coolers
- Bonding material between plates limits operating temperature of the cooler
- Pressure drop caused by plate cooler is higher than tube cooler
- Careful dismantling and assembling to be done
- Over tightening of the clamping bolts result in increased pressure drop across the cooler
- Joints may be deteriorated according to the operating conditions
- Since Titanium is a noble metal, other parts of the cooling system are susceptible to corrosion

## IV. TYPES OF PHE

Several types of exchangers have been used in the refrigeration system, i.e., conventional gasketed plate and frame, all welded compabloc, compact brazed, semi welded, and shell and plate. The last three types are most common in the industry today, and they all have similar geometric characteristics.

### *Gasketed Plate and Frame*

Each plate is sealed via an elastomer gasket, resulting in alternating flow channels for each fluid, as shown in Figure 4. The first industrial refrigeration use of this type of exchanger was reported in 1984 in Germany. Between 1984 and 1991, when the first semi-welded plates were introduced, over 150 units of various sizes and capacities operating with R-12, R-22, ammonia, and propane were successfully installed world-wide (excluding the United States) in the dairy, food, beverage, mining, meat/poultry, chemical, plastics, wine, and general air-conditioning industries.

In the United States, the first industrial ammonia flooded chiller was installed in a soft drink bottling plant. It was a fully gasketed PHE with nitrile elastomer gaskets on both sides. The chiller is still operational, and there have been no reported leaks. However, in a few other cases, leaks were reported within a few months of start-up. The reasons for leaks were many, but the most important one was gasket material integrity. Nitrile is compatible with pure ammonia or oil, but there are no data available on the effect of an ammonia/oil mixture on this type of elastomer. On the other hand, the first unit never reported any leaks or failures, which indicates that the quality of oil management procedures plays a prominent role in the overall integrity of the system.

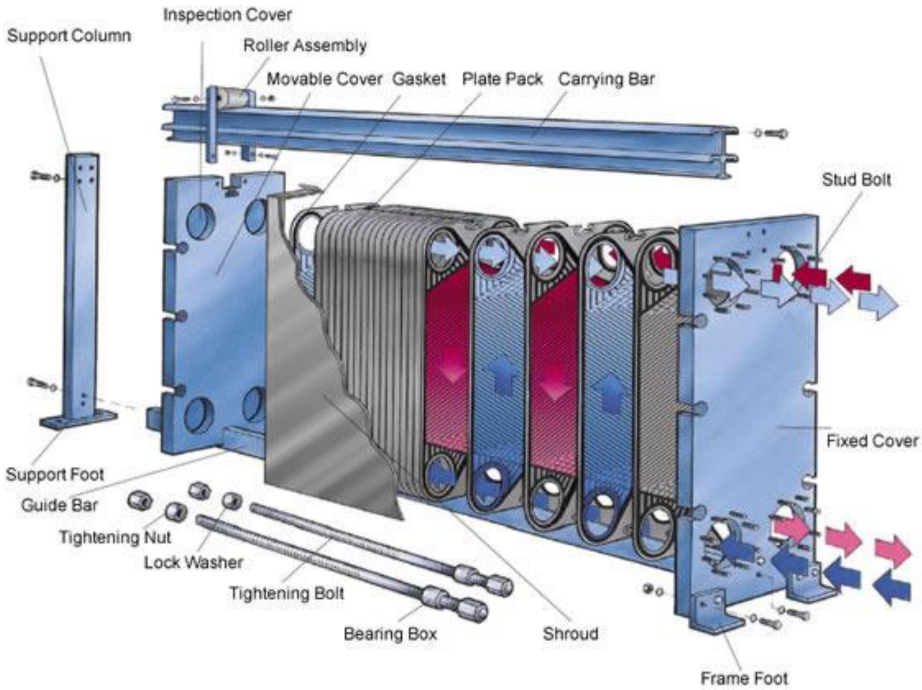


**Figure 4: Gasketed plate and frame exchanger**

***Brazed Plate Exchangers***

Figure 5 shows a typical compact brazed exchanger, commonly known as CBE. These units were initially designed for cooling oil and other liquid-to-liquid applications. However, the air-conditioning and heat pump industries were immediately attracted to its high performance characteristics and compactness. The manufacturers of chillers started using them as evaporators and condensers. Most of the time these units worked; however, failures occurred while they were used as evaporators for low temperature applications. They also showed poor performance at high load capacities, mainly because the exchangers that were designed for single phase application were used as "drop-in" substitutes for evaporators, with no consideration to the problems associated with two-phase flow distribution. During the past five years, this issue has been given due attention, and several manufacturers have incorporated provisions for improved refrigerant distribution. The most common technique used is the employment of a smaller size inlet port versus the outlet port and a perforated pipe inserted at the inlet. Some manufacturers utilize orifice rings at the entrance of each refrigerant channel or a two-chamber entrance that results in a uniform backpressure. Both methods result in improved distribution unless the orifices in the former case are clogged during the brazing process. There have been cases where the fine orifices were clogged and the exchangers had to be replaced. Ayub [2] proposed a drop-in insert that uses a concept of swirl flow in a constantly reducing flow area along the flow path in the inlet port chamber. Brazed exchangers cannot be mechanically cleaned and thus are limited to non-fouling applications only.

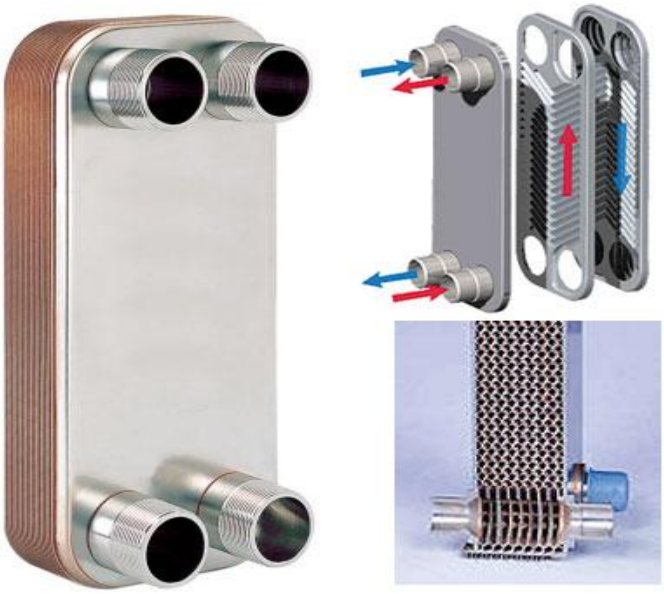

**Figure 5: Compact brazed exchanger**

***Semi-Welded Plate and Frame***

The semi-welded PHE is similar to a gasketed plate and frame except the two adjacent plates are welded. The welded pair is usually called a plate cassette, as shown in Figure 6. Two opposite-chevron plates are precision laser welded, therefore, eliminating the flow gasket on the refrigerant side. The refrigerant is confined within the cavity created by the welding of two adjacent plates. However, it is not a gasket-free unit. The ports have to be sealed with ring gaskets in order to avoid mixing the refrigerant and process fluid. Only the process fluid side can be cleaned once the refrigerant is totally pumped down. Extreme care has to be observed during the cleaning process, as trapped refrigerant could cause injuries or fatalities.

There is a slight misconception in the industry regarding welded plates. Many users believe that the plate pairs are 100% welded together. Unfortunately, that is not the case. In order to maintain the refrigerant flow, only Oaring gaskets maintain the seal, i.e., for every single cassette, there are still two O-Ring gaskets. These gaskets are around the ports where the velocity is maximum and hence highly prone to a leak—the majority of the leaks reported by the operators have been around the ports. Knowing this weakness, it is highly recommended to avoid loading the frame to its maximum plate capacity. A large plate pack could result in sagging of the carrying bars and, consequently, leakage at the ports, especially at the lower port due to tension at the lowest section of the plate. Another limitation is the ability to design for lower temperatures and higher pressures. Gasket material limits the temperature aspect, and end plate thickness limits the pressure aspect. The temperature limit is −40◦F to 300◦F, and the pressure limit is 300 psig.

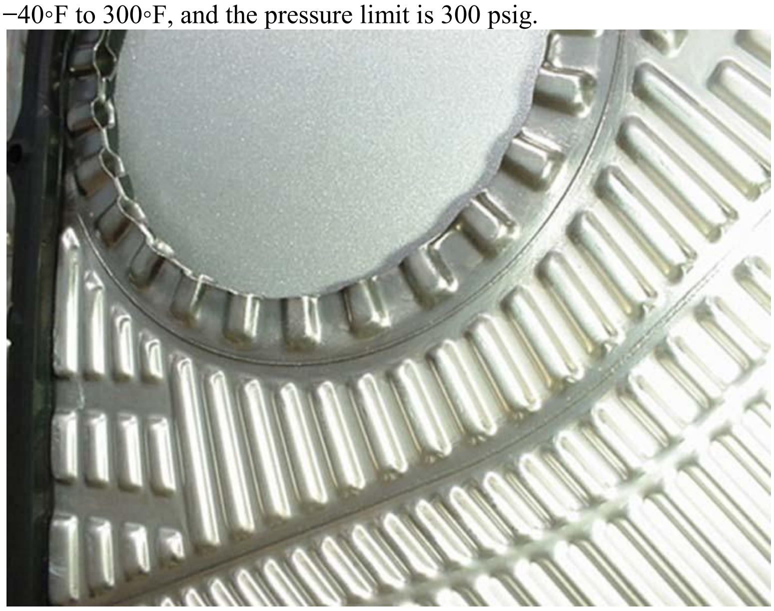

**Figure 6: Laser welded cassette**

***Shell and Plate***

Shell and plate is the newest design in the plate exchanger technology and has unique features. It combines the advantages of shell and tube and plate and frame technologies, with high mechanical integrity inherent to shell and tube and the superior thermal characteristics of plate and frame. A plate pack is welded together in such a way that the shell side is isolated from the plate side, and there is no gasket for sealing purposes except an O-ring for a body flange in the case of a removable plate pack. Figure 7 shows a shell and plate exchanger.

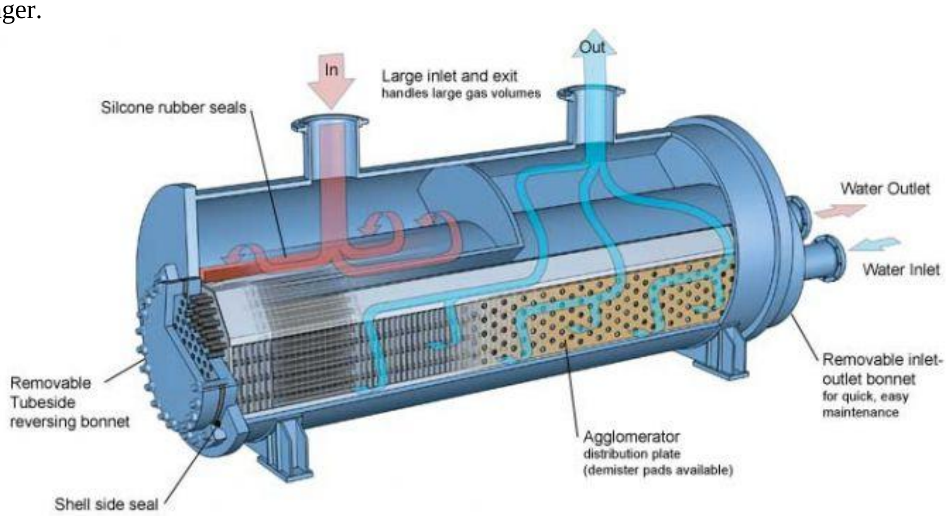


**Figure 7: Shell and Plate Heat Exchanger**

## V. CONCLUSION

Various type of possible and cost effective technique of the heat transfer enhancement were presented in this literature review. It is clear the vortex generator technique is one of the promising approaches of heat transfer enhancement. Lot of work been carried out on various designs and use of simulation software made it easier. A review on the methods and analysis of different parameters of plate heat exchanger were carried by different method of analysis like experimental, numerical and simulation. The parameter considered here in this review paper are thermal–hydraulic performance, flow pattern, material and structure, pressure drop and heat transfer characteristics, fin geometry and heat transfer and pressure drop correlations. Still there is a strong need for proposing further techniques to improve the parameters in plate fin heat exchanger which will have a direct impact on operational cost, and last and not least the use of Nano fluids and their role in the design aspects of the exchanger, which is considered a new growing research area.

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