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Comparative study of conventional and micro-channel heat exchangers considering evaporator and condenser applications

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Abstract: **The purpose of this paper is to briefly learn various types of heat exchangers. In this paper we have focused mainly on two types of heat exchangers- conventional heat exchangers and compact heat exchangers. A comparative study is done on both type of heat exchangers. A further classification on compact heat exchanger is discussed. A complete assembly and the reasons to use micro channel heat exchanger as evaporator and condenser has been illustrated. Required dimensionless numbers related to two- phase flows are Reyonlds number , Evotos number, liquid Weber number and gas Weber number . Considering single- phase flow related equations by assuming laminar flow and turbulent flow the frictional factor and Nusselt number is evaluated. The evaluation is presented for circular tubes and rectangular pipes based on some assumptions. The methods of optimizing the geometry and performance of heat exchanger are summarized. The drawbacks of conventional heat exchanger are analyzed.**

Keywords-Condenser, Evaporator, Evotos -number, Frictional factor, Heat-exchanger, Nusselt number, Reyonlds number, Weber number.

I. INTRODUCTION

Since the last two decades, thermodynamic systems have achieved better performances. One of the reasons behind this is better understanding of the processes occurring in these systems which leads to better optimization of their design and functionality. Another supporting factor for the advancement is the use of new materials which lead to enhanced heat transfer rate per unit volume and a higher heat transfer coefficient. In recent years the use of nano-technologies has led to the production of new generation of compact heat exchangers with micro-channels. Very small sizes are possible which leads to a very effective heat transfer process. Being 45% more compact then the conventional heat exchangers, these new types of heat exchangers provides high heat transfer coefficients. Due to such advantages, the use of micro-channel heat exchangers has increased rapidly finding its use in both single-phase and two-phase heat exchangers.

Tuckerman and Pease were the two personalities to introduce the concept of micro-channel heat exchangers back in 1981.

II. HEAT EXCHANGERS

Heat exchanger is an indispensable equipment to enhance or facilitate the flow of heat. There is a heat transfer between two or more fluids due to temperature difference. This transfer can be done in an arrangement of liquid-liquid, gas-gas and gas–liquid. It is used in order to cool the hot fluid or to warm a cold fluid or both together depends on the application. Heat exchangers find a wide variety of applications in power plants, refineries, petrochemical, process industries, food and drug industries, heat and air conditioner.

These are of two types:

1. Conventional type
2. Compact type

III. CONVENTIONAL HEAT EXCHANGERS

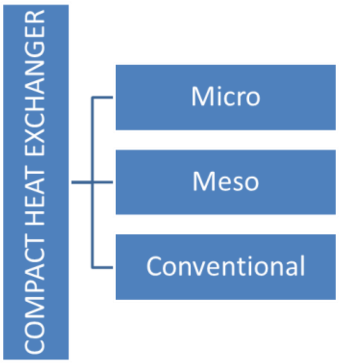
Conventional heat exchanger is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher- pressure applications. This type of heat exchanger consists of a shell (a large vessel) with a number of tubes arranged in a sequence inside it. Heat is transferred between the fluids by running one fluid inside the tube and other fluid over the tube (i.e through the shell). It is simple in manufacturing.

IV. Compact Heat Exchangers

Compact heat exchanger(introduced by Mehendale) are the heat exchangers in which fluid flows in a lateral direction in a confined area such as a tube (size less than the shell and tube heat exchanger) or small cavity. Fluid flowing through the channels on a plate evaporates or condenses, and heat is transferred. Use of this type of heat exchanger results in higher heat transfer rate, reduced weight, reduction in space, cost, energy and material.

Compact heat exchangers are categorized as follows:

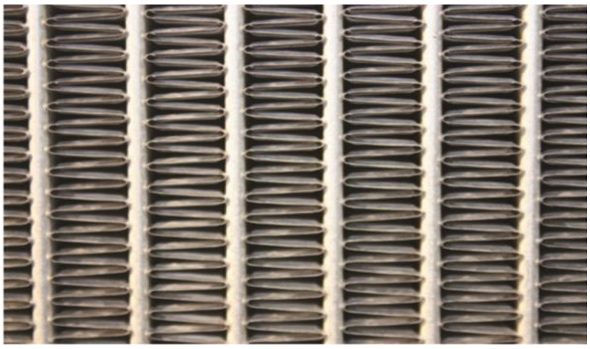
1. Micro size: Diameter of tube ranging from 1 to 100 microns
2. Meso size: Diameter of tube ranging from 1 to 6 millimetre
3. Convectional size: Diameter of tube is usually greater than 6 millimetre

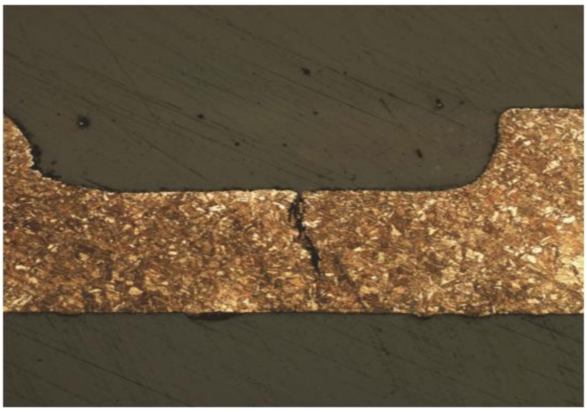


IV. Micro-channel Heat Exchanger As An Evaporator

Micro-channel coils are used in a micro-channel evaporator. The main reason for use of micro-channel coils is the problem of evaporator-coil leaks and formicary corrosion. Formicary literally means “ants’ nest.” So, formicary corrosion, as it relates to evaporator coils, is referring to small wandering pits that resemble the tunnels in an ants’ nest.

Above figure shows micro-channels and fins





Above figure shows a traditional copper coil showing formicary corrosion

Micro-channel coils are aluminium-extruded channels that are mechanically brazed to aluminium fins. The coil has three basic components:

1. micro-channel tubes
2. aluminium fins
3. two manifolds

Above figure shows complete assembly of a micro-channel evaporator

IV. Micro-channel Heat Exchanger As A Condenser

Micro-channel condenser coils consist of all aluminum coils with multiple flat tubes having small channels (micro-channels) through which the refrigerant flows.

The coil is composed of three components:

1. **Micro-channel tubes**
2. **Fins**
3. **Two refrigerant manifolds**

Aluminum-zinc alloy is used as a brazing material to join these components with two refrigerant manifolds. Baffles are placed in the distribution manifolds to feed the refrigerant through the flat tubes.

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Above figure shows the complete assembly of a micro-channel condenser

V. Design Parameters

For two-phase flows, the following dimensionless numbers are taken into account:

1. Reynolds number for liquid (Re_L)
2. Reynolds number for gas (Re_G)
3. Eotvos number

   Eotvos number is used to check the dominancy of gravitational forces over surface tension forces. In this case it is given by

$$Eo = (\rho_L - \rho_G) g D^2 / \sigma$$

4. Liquid Weber number

$$We_L = j_L^2 D \rho_L / \sigma$$

5. Gas Weber number

$$We_G = j_G^2 D \rho_G / \sigma$$

In micro-channel the value of Eo is very small which shows that the surface tension force dominates the gravitational force.

Now considering single phase flows:

1. Laminar flows

   For circular tubes the frictional factor satisfies

$$fRe_D = 16$$

   For rectangular pipes

$$fRe_{D_h} = 24(1 - 1.3553AR + 1.9467AR^2 - 1.7012AR^3 + 0.9564AR^4 - 0.2537AR^5)$$

   Where, AR is the aspect ratio

   Also, the Nusselt number for circular tubes is given by

   $Nu_D = 4.36$ (For constant heat flux)

   $Nu_D = 3.66$ (For constant wall temperature)

   For rectangular tubes

$$Nu_{D_h} = 8.235(1 - 2.0421AR + 3.0853AR^2 - 2.4765AR^3 + 1.0578AR^4 - 0.1861AR^5)$$

   Where AR is the aspect ratio

2. Turbulent flows

   For circular tubes the frictional factor satisfies

$$f = 0.079 Re_D^{-0.25}$$

Also, the Nusselt number for circular tubes is given by

$$Nu_D = \frac{\left(\frac{f}{8}\right) Re_D Pr}{1.07 + 12.7\left(\frac{f}{8}\right)^{1/2}\left(Pr^{2/3} - 1\right)}$$

VI. Comparative Study

1. **Higher Heat Transfer rate**
2. **Higher Internal Heat Transfer Coefficient:**

   Tubes with small section provide higher refrigerant speed and higher turbulence besides a bigger internal surface.
3. **Higher External Heat Transfer Coefficient:**

   The overall tubes surface touched by the air is much bigger than in T&F coils.
4. **Less air pressure drops.**
5. **Reduction in volume of condenser by 30%.**
6. **No risk of galvanic corrosion.**
7. **Coils easy to recycle.**
8. **The whole system is cost effective.**
9. **Compressor work is reduced.**

VII. Conclusion

After receiving the knowledge related micro channel heat exchanger it has been increasingly used in HVAC&R(Heating, Ventilation, and Air Conditioning & Refrigeration) field. Various researches related to micro channel heat exchanger has attracted the world wide attention. A more detailed analysis of micro channel heat exchanger will lead us to develop a optimized heat exchanger. That is we will be able to resolved various problems which is encountered in conventional heat exchanger (like manufacturing issuses, weight and space issues etc.) with the help of micro channel heat exchanger. Hence micro channel heat exchanger can be widely used.

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