Study on Suitability and Safety of Parallel Flow Heat Exchanger in Dry Condition

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Abstract

Stating heat transfer and fluid flow characteristics of parallel flow heat exchanger used as evaporator, analyzing its difference of working in dry condition and the existing problems. Then compare with conventional finned-tube heat exchanger, discussing suitability and safety of parallel flow heat exchanger in dry condition.

Keywords: parallel flow heat exchanger; finned-tube heat exchanger; dry condition; suitability; safety

1. Introduction

In recent years, with the increasingly prominent of building energy consumption problem and the improvement of people's pursuit of quality of life, due to the advantages of saving energy, improving indoor air quality, increasing thermal comfort, temperature and humidity independent control air conditioning system received more and more research and application. In this system, terminal equipment just undertakes part of indoor sensible heat load, running in dry condition. Compared with wet condition, cooling capacity of the device in dry condition is greatly reduced for the improvement of supply water temperature. It's easy to occur short of indoor cooling capacity in the practical application, particularly in the occasion that has relatively large sensible heat load. To improve cooling capacity of the equipment in dry condition, we can't increase device model, add equipment investment blindly, and we should take measures of enhancing heat transfer. One of the effective ways to enhance heat transfer is using efficient heat exchanger to replace conventional heat exchanger in the fan coil. Parallel flow heat exchanger has characteristics of efficient, compact, light weight, high reliability, so it can be considered to be used in terminal equipment to improve heat exchange amount.

2. Structure features of parallel flow heat exchanger

Parallel flow heat exchanger is developed on the basis of pipe-band heat exchanger; it uses flat tube extrusion, louvered fin and vacuum brazing technology. Flat tube is not bent into serpentine, each of them is truncated. There is a collecting pipe on both sides, refrigerant flows into collecting pipe from the pipe joint, then bypass flows into porous flat tube, arrives at opposite collecting pipe parallelly, finally flows out from another pipe joint.

Parallel flow heat exchanger is divided into two types: one is called single-pass parallel flow heat exchanger, its collecting pipe is non-segmented, and refrigerant flow direction is same; another is called multi-pass parallel flow heat exchanger, its collecting pipe is segmented, there are septate to interrupt, the number of tubes of each piece is different. Its structure is shown in figure 1, 2.

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3. Heat transfer and flow characteristics of parallel flow heat exchanger as evaporator

3.1. Characteristics of heat transfer and medium flow inside of the tube

Currently, parallel flow heat exchanger is primarily used as condenser and evaporator in automotive air conditioner. As evaporator, working medium in the tube will change phase in the process of flow and heat transfer, there are both gas and liquid in the tube, becoming gas-liquid two-phase flow. Because of the impact of surface tension, viscous force, gas-liquid two-phase flow in its small hydraulic diameter porous flat tube has a big difference with the two-phase flow and heat transfer characteristics in the conventional scale. Due to the difference of pressure, flow rate, heat flux and pipeline geometry, working medium in the tube shows different flow pattern in the flow process. Different flow pattern has a great effect on the heat transfer and flow characteristics of heat exchanger. Yet universal flow pattern and distribution of gas-liquid two-phase flow in micro channel is not got, and further research is needed.

3.2. Characteristics of heat transfer and air flow outside of the tube

Louvered fin structure is adopted outside of parallel flow heat exchanger's tube. Louver fin is considered one of the most efficient heat transfer surfaces, has been vigorously developed in Europe from the 1990s. Its specific structure is cutting the metal fin by a certain pitch, then turn around the cutting part to a certain angle, forming fin on the surface, likes louver. When the air flows through the louvered fins, louvered fins can reduce the thickness of air boundary layer in the direction of flow significantly; reduce thermal resistance, enlarging the disturbance of the fluid simultaneously, and enhancing heat transfer, so as to improve the heat transfer efficiency effectively.

4. Heat transfer and flow characteristics of parallel flow heat exchanger as dry condition exchanger

The difference between parallel flow heat exchanger used as heat exchanger in dry condition and used as condenser or evaporator is mainly that working medium in the tube will not change phase in the process of flow and heat transfer when it runs in dry condition, this belongs to temperature difference heat exchange. But as condenser, the gas will contact with the wall that its surface temperature is lower than the gas's saturation temperature in the flow process, release latent heat of vaporization to the solid wall, and form condensate on the wall surface, condensation heat transfer occurs. Meanwhile, as evaporator, the liquid will contact with the wall that its surface temperature is higher than the gas's saturation temperature, then be heated vaporized to produce large amounts of air bubbles, occur boiling heat transfer. Condensation and boiling heat transfer would release or absorb a large amount of latent heat of vaporization during phase transformation, so its heat transfer coefficient is higher than heat transfer coefficient of single-phase flow. Literature\(^1\) shows that at the same temperature difference, micro channel heat exchanger's heat transfer coefficient without phase change is 10~15W/(cm\(^2\)·k), but heat transfer coefficient with phase change reaches 30~35W/(cm\(^2\)·k). What's more, outside of the tube, the surface of
heat exchanger will not produce condensate water in dry condition; flow resistance of the air is less than that of the evaporator.

Currently, air conditioning terminal equipment mainly adopts finned-tube heat exchanger, so if we want to use parallel flow heat exchanger in terminal equipment, we must compare its performance with finned-tube heat exchanger. And compared with finned-tube heat exchanger, parallel flow heat exchanger has the following advantages:

- Finned-tube heat exchanger sets the entire aluminum fins on the copper tube which is stampinged by a certain rute, then let them contact well after expanding. While parallel flow heat exchanger adopts overall brazing structure, the thermal contact resistance between tube and fins is smaller.
- The diameter of copper tube in finned-tube heat exchanger is generally 8-16mm, while because of using porous flat tube structure; hydraulic diameter of parallel flow heat exchanger's rectangular micro channel is usually only 1-3mm. According to the heat transfer theory, the smaller diameter, the larger heat transfer coefficient. What's more, when the diameter is less than 3mm, the law of gas-liquid two-phase flow and phase change heat transfer is different from conventional larger size, the smaller channel, the more obvious effects of this size. If inner diameter of the tube is 0.5~1mm, coefficient of convective heat transfer would increase 50%~100%[1]. Furthermore, parallel flow heat exchanger's flat tube is not bent into serpentine, each of them is truncated, and passing distance of the fluid is much shorter than serpentine pipe of finned-tube heat exchanger, so pressure drop of the fluid in the flow process would also be smaller. Chang Yong Park[3] carried on experimental research to two R410A air conditioning systems that used parallel flow heat exchanger and finned-tube heat exchanger of the same size as condenser separately, other parts are the same, under the same test conditions with 35℃ outdoor dry bulb temperature, 23.9℃ wet bulb temperature, and 26.9℃ indoor dry bulb temperature, 19.4℃ wet bulb temperature, they found cooling capacity of the system that used parallel flow heat exchanger is 3.4% larger than the one used finned-tube heat exchanger, and COP is 13.1% larger, while pressure drop inside the tubes of parallel flow heat exchanger is only 57kPa, and fin-tube heat exchanger's pressure drop is 166KPa.
- Outer size of porous flat tube in windward sectional direction is much smaller than circular tube, which can greatly reduce the vortex of leeward side, decrease resistance in air side, as figure 3 shows. Carrier company used parallel flow heat exchanger as condenser in its 30XA series of air-cooled screw chiller, compared with finned-tube, air side resistance of parallel flow condenser is reduced by 50%.

![Figure 3. Comparison of air-side airflow organization between parallel flow heat exchanger and finned-tube heat exchanger](image)

- Parallel flow heat exchanger uses all aluminum production, light weight, easy to install.

5. Suitability and safety

From the foregoing, parallel flow heat exchanger has more advantages in thermal performance than finned-tube heat exchanger. But to be used as heat exchanger in dry condition, the following problems need to be solved: Firstly, now production technology of finned-tube heat exchanger has been very mature, whether it's feasible to use parallel flow heat exchanger replacing it in technical and economic aspect. Secondly, the above performance comparative experiments between parallel flow heat exchanger and finned-tube heat exchanger are used them as a condenser or evaporator, if heat exchanger is used to run in dry condition, whether or not it also has the same advantages.

For these two problems, first of all, with the development of our country in the field of brazing, such as investment of large-scale brazing equipment, manufacturing process of parallel flow heat exchanger is is being completed. Though its processing costs are still relatively high, in the same heat transfer, its size is smaller than finned-tube heat exchanger, not only the cost price of materials is much lower, but also the installation cost will be lower. Therefore, it's feasible to use parallel flow heat exchanger replacing finned-tube heat exchanger in technical and economic aspect. For another, though the existing performance comparative experiments between parallel flow heat exchanger and finned-tube heat exchanger are used them as a condenser or evaporator, the main difference of parallel flow heat exchanger in dry condition and parallel flow evaporator or condenser is that working fluid in the tube would not change phase, the advantages of porous micro
channel and overall brazing structure of parallel flow heat exchanger in heat transfer and flow characteristics aspect will not change, therefore, even runs in dry condition, parallel flow heat exchanger's performance should be better than finned-tube heat exchanger.

Further, in the respect of safety and reliability, overall brazing structure of parallel flow heat exchanger ensure it can resist greater vibration, having high mechanical strength, and the performance changes litter in long-term operation. Moreover, parallel flow heat exchanger is produced by all aluminum material, which is able to reduce common electrochemical corrosion risk of finned-tube heat exchanger greatly, antioxidation coating plated on the surface of the fins can further enhance its corrosion resistance, extend its service life, and improve its safety and reliability. Literature [4] pointed out that parallel flow heat exchanger can bear salt spray and acidulous corrosion test 600 hours in automotive air conditioning standard.

6. Conclusion

Compared to common finned-tube heat exchanger in air conditioning terminal equipment, parallel flow heat exchanger has better thermal performance; it's able to meet the requirements of suitability and safety when running in dry condition. However, in the practical application, we should comprehensively adjust the structural parameters of parallel flow heat exchanger in dry condition to optimize their performance and make it matches the dry condition better.

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