Design scheme and selection of tubular heat exchanger

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Abstract

Heat exchanger is an indispensable equipment in the process of energy utilization, which should be used in almost all industrial fields.In recent years due to development of new technology and new energy development and utilization, more and more brought to the attention of the industry, various types of heat exchanger and heat exchanger is a key equipment in the energy saving measures, therefore, whether from the development of industry, or from the efficient use of energy, proper design and selection of heat exchanger has very important significance.

Keywords

Heat exchanger, classification, design, selection.

1. Introduction

Shell and tube heat exchanger is easy to manufacture, low production cost, wide material selection, convenient cleaning, strong adaptability, large capacity, reliable operation, and can adapt to high temperature and high pressure. Shell and tube heat exchangers are still dominant in heat transfer equipment used in petroleum, chemical and energy sectors. The development of heat exchanger to high temperature, high pressure and large capacity adds new vitality to the tubular heat exchanger. The design and analysis of shell and tube heat exchangers include many aspects, including thermal design, flow planning, structural design and strength design.Shell and tube heat exchangers generally have three structural forms: fixed tube plate type, floating head type and U tube type.

2. Classification of shell and tube heat exchangers

2.1 Fixed tube-plate heat exchanger

When the temperature difference between two fluids is large, a compensation ring (or expansion joint) is welded to the appropriate position of the shell.When the shell and tube bundle are not expanding at the same time, the compensation ring generates slow elastic deformation to compensate for the thermal expansion caused by temperature difference stress.Features: simple structure, low cost, shell cleaning and maintenance difficulties, shell side must be clean and non-dirty materials.The fixed tubeplate heat exchanger is mainly composed of shell, tubesheet, tube bundle and gland.Structure characteristic of fixed tube plate heat exchanger is set in the shell tube bundle, use the method of welding or expansion on both ends of the tube bundle tube fixed on the tube plate, on both ends of the tube plate and shell directly welded together, the import and export of shell side tube directly welded on the shell, tube plate head bolt and the flange outer circumference and the import and export of tube side tube and head directly welded together, according to the length of the heat exchanger set inside tube bundle several pieces of baffle plate.The pipe of this heat exchanger can be divided into any number of passes by a separator.The fixed tube-plate heat exchanger has simple structure, low manufacturing cost and convenient cleaning of the pipe. The pipe can be divided into multiple courses, and the shell can be divided into two courses.Cleaning of shell side is difficult. It is not suitable for dirty or corrosive media.When the expansion difference is large, expansion joints can be set on the shell to reduce the thermal stress caused by temperature difference between tube and shell.

2.2 Floating head heat exchanger.

The two ends of the tube plate of the floating-head heat exchanger have only one end fixed with the shell, and the other end can move freely relative to the shell, which is called floating-head.The floating head is composed of floating tube plate, hook ring and end cover of the floating head.The thermal deformation of the tube bundle and the shell is not restrained, so the thermal stress is not produced.The advantages are easy cleaning between pipes and inside pipes without producing thermal stress.However, its structure is complex, the cost is higher than the fixed tube-plate heat exchanger, the equipment is bulky, the material consumption is large, and the small cap of floating head end cannot be checked in operation, and the sealing requirements are higher when manufacturing.It is suitable for the occasions where the wall temperature difference between shell and tube bundle is large or the shell side medium is easy to scale.

2.3 U tube heat exchanger.

U-tube heat exchanger is composed of tube plate, shell and tube bundle.Under the same diameter, the U tube heat exchanger had the largest heat transfer area.It has simple structure, compact, high sealing performance, convenient maintenance and cleaning, minimum metal consumption and lowest cost under high temperature and high pressure.U-tube heat exchanger has only one tube plate, with good thermal compensation performance and strong pressure bearing capacity. It is suitable for operation under high temperature and high pressure conditions.There is only one tube plate for u-tube heat exchanger, both ends of the tube are fixed on the same tube plate, the tube can freely expand and expand without thermal stress, and the thermal compensation performance is good.The pipe is made of double pipe with longer flow, higher flow rate, better heat transfer performance and strong pressure capacity. The pipe bundle can be drawn from inside the shell for easy maintenance and cleaning, simple structure and cheap cost.However, due to the limitation of curvature radius of the curved pipe, the heat exchange pipe is arranged less, the distance between the inner tube of the tube bundle is larger, the utilization rate of the tube plate is lower, and the fluid on the shell is easy to form short circuit, which is unfavorable to heat transfer.When the pipe is leaking and damaged, only the u-tube at the periphery of the tube bundle is easy to replace. If the inner heat exchanger tube is damaged, it cannot be replaced and can only be blocked. Besides, if one u-tube is damaged, it is equivalent to two tubes, and the scrap rate is higher.

3. Design of shell and tube heat exchanger structure

3.1 Consideration

The structure of the shell and tube heat exchanger is determined by the differences in the use situation, purpose and physical properties of the heat exchanger.6 aspects are mainly considered in the design of heat exchanger :

Heat load and flow rate;

Fluid properties;

The range of temperature pressure and allowable pressure drop;

Requirements for cleaning and maintenance;

Equipment structure, material, size and weight;

Price, safety and life..

3.2 Design of tubular shape of heat exchanger

Tube shape has light tube, thread tube.Under the same conditions, the heat transfer area can be increased by about twice as much as that of the optical tube.At the same time, the screw thread structure of the pipe can effectively destroy the fluid boundary layer and effectively improve the heat transfer capacity of the heat exchanger.When the shell side medium is easy to scale, the hard scale on the outer wall of the heat exchanger tube falls off due to the expansion and contraction of the outer thread tube bundle along the axis, which has a good self-cleaning effect, which can effectively prevent the scaling on the outer wall of the heat exchanger, reduce the heat resistance on the shell side of the heat exchanger, and improve the heat transfer capacity of the heat exchanger.

3.3 Design of heat exchanger pipe diameter

As the small diameter heat exchanger has large heat transfer area per unit volume, tight heat exchanger structure, low metal consumption and high heat transfer coefficient, in the design of heat exchanger structure, the use of small diameter tube bundle can effectively increase the heat transfer area for the medium with clean and not easy to scale.Under the same conditions, the use of the bright 19mm tube bundle can increase the heat transfer area by 30%~40% and save more than 20% of metal.

3.4 Design of heat exchanger tube arrangement

The pipe is arranged in equilateral triangle, square and concentric circle, etc. For the medium with shell side, which is not easy to scale or can be cleaned by chemical methods, triangular arrangement can reduce the outer diameter of heat exchanger by 15%. For the pipe bundle that needs mechanical cleaning, square arrangement should be adopted.For heat exchanger less than 300mm, concentric circle arrangement can be adopted to make the tube bundle compact [3].

3.5 Design and selection of pipe and shell range

When the heat exchanger has a large heat exchange area and the pipe cannot be long, the pipe bundle shall be separated to improve the flow rate of the fluid in the pipe.However, due to too many processes, the flow resistance and power energy consumption in the pipeline are increased, and the average heat transfer temperature difference is decreased. Therefore, the design should be balanced.There are four types of pipe lengths in the series of shell-and-tube heat exchangers: 1, 2, 4 and 6.When the correction coefficient of temperature difference is less than 0.8, multi-shell side should be adopted.The shell square can be obtained by installing a partition parallel to the tube bundle.However, because the shell side partition is very difficult to manufacture, install and repair side, it is generally not suitable for use.The common method is to use several heat exchangers in series, instead of shell square multipath [4].

3.6 Structure design of baffle

The structure design of baffle includes pattern determination, shape design, notch height design and baffle spacing design.The baffle side baffle of heat exchanger can be divided into transverse baffle and longitudinal baffle. Because it is difficult to install longitudinal baffle on shell side and the pressure drop on shell side increases, the baffle side is generally used to install transverse baffle.Shell side mounted to the horizontal baffle plate, the shell side heat transfer medium Re0 Reynolds number 100 or higher, the shell side medium of turbulence, can effectively improve the heat transfer ability of the heat exchanger, lateral baffle often use bow and dish - ring, segment baffle plate processing, manufacturing and assembly is convenient, the most common use, a ring baffle plate is mainly used in small heat exchanger.In the structure design of heat exchanger, reasonable design of baffle ask distance is the key to ensure that the pressure drop of heat transfer medium on the shell side meets the design requirements [5-6].

4. Selection of fluid parameters in shell and tube heat exchanger

4.1 Determination of fluid path on shell side.

In the heat exchanger, which kind of fluid goes inside the tube, and which kind of fluid goes outside the tube, this problem is restricted by many factors, some principles of selection are as follows.

(1) The fluid that is not clean and easy to deposit should go through the pipe for cleaning.

(2) The fluid with low flow rate and the liquid with high viscosity should go through the pipe. As the pipe is easy to be made into multi-path structure, a larger flow rate can be obtained and the heat transfer coefficient can be increased.

(3) The corrosive fluid should go through the pipe to prevent the tube bundle and shell from being corroded at the same time.

(4) The fluid with high pressure should go through the pipe, which can reduce the mechanical strength requirements on the shell.

(5) The saturated steam should go through the shell, because the flow rate has little influence on the condensation heat coefficient of the saturated steam, and the condensation surface of the saturated steam does not need to be cleaned, so it is easy to remove the condensed water in time by the flow on the shell side.

(6) The cooled fluid should go through the shell, so that the shell can be used to dissipate heat to the environment and enhance the cooling effect.

(7) Toxic media go through the pipeline, because the risk of pipeline leakage is small..

4.2 Fluid velocity selection.

According to experience, the flow rate range of the fluid is as follows. see Table 1.

Table 1 The flow rate range of the fluid

Flow rate of pipe flow		Shell flow velocity	
Cooling water (fresh water)	0.7-3,5m/s	water and water solution	0.5-1.5m/s
Cooling book (seawater)	0.7-2.5m/s	low-viscosity oil	0.4-1.0m/s
Low viscosity oils	0.8-1.8m/s	high viscosity oils	0.3-0.8m/s
High viscosity oils	0.5-1.5m/s	oil vapour	3.0-6.0m/s
Oil vapor	5.0-1.5m/s	gas-liquid mixture	0.5-3.0m/s
Gas-liquid mixture	2.0-6.0m/s		

4.3 Fluid allowable pressure drop selection.

For the heat transfer without phase change, the higher the flow rate and the greater the heat transfer intensity, the smaller the area of the selected heat exchanger, the lower the production cost, and conducive to inhibiting the formation of dirt, but too high the flow rate can cause increased pressure drop, increased power consumption and intensified erosion of heat transfer pipe.Therefore, the pressure drop should be controlled to the allowable range in the design of heat exchanger.

When the thermal resistance of shell side is the control side, the flow velocity of shell side can be increased and the heat transfer resistance can be reduced by increasing the number of baffles or reducing the shell diameter.However, there is a limit to reducing the deflection distance of the baffle, which generally cannot be less than 1/5 or 50mm of the shell diameter.When the thermal resistance of the pipe is the control side, the flow rate can be increased by increasing the number of pipe runs.The number of pipe runs is 1, 2, 4, 6, etc., which has a great impact on pressure drop. The requirements of allowable pressure drop must be met in design [7].

4.4 Value of temperature difference of cold and hot fluid at both ends of heat exchanger.

The large temperature difference between the heat exchanger and the hot fluid can make the heat transfer area of the heat exchanger small and save equipment investment.However, in order to make the temperature difference between cold and heat flow large, the temperature of the coolant outlet becomes low, which leads to the large dosage of the coolant and increases the operation cost.Therefore, when one side of the heat exchanger fluid is the coolant, the value of the temperature difference between the two sides of the heat exchanger should be taken into account.That is, to choose suitable heat exchanger both ends of the cold, heat flow temperature difference, so that the sum of investment and operation costs is minimal.It is generally considered that it is more economically rational to use the values listed below.

(1) Cold hot end of the heat exchanger, heat flow temperature difference should be in more than 20 ℃.

(2) When using water or other cooling medium, the cold end temperature difference can be smaller, but not less than 5%C.

(3) When condensing liquid containing inert gas, the outlet temperature of the coolant is at least 59C lower than the dew point of the coolant.

(4) The temperature difference between air cooler and heat flow should be greater than 15C, preferably greater than 20~250C.

(5) When water is used as the coolant, the temperature difference between the inlet and outlet of the cooling water is usually 5-10 0C. Large temperature difference is used in water-deficient areas, while small temperature difference is used in water-rich areas.

5. Conclusion

By fixed tube plate heat exchanger, floating head heat exchanger and u-tube heat exchanger are discussed, the structure and characteristics of the heat exchanger determines the different heat exchanger used in working condition, this article from the two aspects of the structure of the heat exchanger and internal flow parameters and summarizes from the aspects of material performance, economy and so on, lay a foundation for design and selection of heat exchanger.

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