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ARTICLE

HEAT PIPE TECHNOLOGY AND ITS APPLICATION ANALYSIS

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ABSTRACT

This paper briefly introduced the heat pipe and its heat exchanger development status which were mainly applied in the of geothermal energy use, waste heat recovery, conservation of raw materials, and lower costs in such areas. Especially in the industrial use of waste heat played an increasingly important role and made significant economic benefits.

KEYWORDS

Heat-Pipe, Heat Exchanger, Heat Transfer

1. INTRODUCTION

The heat pipe is a heat transfer element with extremely high thermal conductivity, which has developed rapidly in recent decades. American Gaugler proposed the concept of the heat pipe in 1942. He envisioned applying heat pipes to freezers, but it never came to fruition. Since the 1970s, due to the special requirements of space navigation for heat transfer, coupled with the huge role of heat pipes in energy saving, thermal management theory research, and engineering applications have developed rapidly. In the early 1980s, the focus of heat pipe research in my country turned to energy saving and rational utilization of energy, and various products such as heat pipe gas-to-gas heat exchangers, heat pipe waste heat boilers, high-temperature heat pipe steam generators and high-temperature heat pipe hot blast stoves were successively developed [1]. With the continuous improvement of the level of science and technology, the application range of heat pipes has expanded from the temperature and temperature control in aerospace and spacecraft to various fields of industrial technology, chemical, energy, power, metallurgy,

Various sectors such as electronics, machinery, and medicine have applied heat pipe technology. People's continuous research on heat pipes will surely further improve the performance of heat pipes and expand the scope of application [2].

2. HEAT PIPE AND ITS WORKING PRINCIPLE

A common heat pipe consists of a pipe shell, a porous structure (wick and working medium for transferring heat energy) with capillary action. The wick is firmly adhered to the inner wall of the pipe shell and soaked by the working medium. The heat pipe itself forms a high-vacuum closed system. Its structure is shown in Figure 1.

The heat pipe can be divided into three sections along the axial direction, namely the evaporation section, the condensation section, and the adiabatic section. Its working principle is as follows. The heat of the external heat source increases the temperature of the liquid working medium through the heat conduction of the tube wall of the evaporation section and the liquid absorbent core filled with the working medium; the liquid temperature rises, and the liquid surface evaporates until it reaches the saturated evaporation pressure. Heat is transferred to the steam as latent heat. The saturated vapor pressure in the evaporation section increases as the liquid temperature increases. Under the action of the pressure difference, the vapor flows to the condensation section with low pressure and low temperature through the vapor passage, and condenses on the gas-liquid interface of the condensation section, releasing latent heat. The released heat is transferred from the gas-liquid interface to the external cooling source through the liquid-absorbing core filled with the working medium and the heat conduction of the tube wall. The condensed liquid is returned to the evaporation section through the wick to complete a cycle. In this way, heat is continuously transferred from the evaporation section to the condensation section. In addition to providing a channel for the fluid, the function of the adiabatic section also separates the evaporation section and the condensation

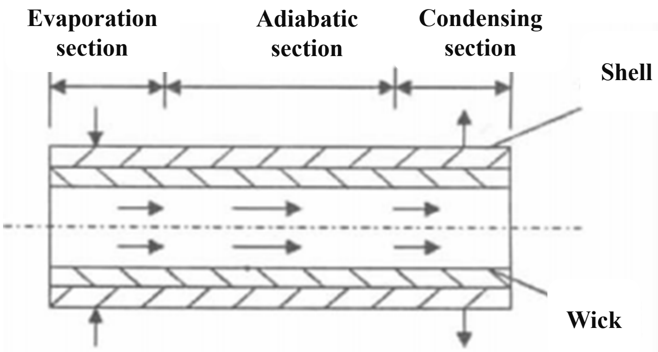

Figure 1: Schematic diagram of heat pipe structure

section, so that the working medium in the tube does not transfer heat with the outside world [2].

Inside the heat pipe, because the heat transfer is carried out through the process of boiling and condensation, the boiling and condensation coefficients are large, and the steam flow resistance is small, so the temperature of the tube wall is quite uniform. The apparent thermal conductivity calculated from the heat transfer of the heat pipe and the corresponding temperature difference of the pipe wall is 100 to 1000 times that of the best metal heat conductors [3].

3. CLASSIFICATION OF HEAT PIPES

According to the different structural forms of heat pipes, they are mainly divided into axial heat pipes and radial heat pipes.

3.1 Axial Heat Pipe

The early heat pipes were all axial heat pipes. The working medium vaporized in the evaporation section took away latent heat, flowed to the condensation section, condensed into a liquid, and released latent heat, and the working medium flowed along the length of the tube. If there is no absorbent core in the heat pipe, the condensate can return to the evaporation section by its own gravity, which is called gravity heat pipe (or thermosiphon heat pipe); the heat pipe can also be rotated around the axis (the heat pipe must have a certain taper) so that the working rotates with the housing. The condensate is evenly distributed on the inner wall of the tube under the action of centrifugal force, which can not only strengthen the heat transfer but also make it return to the evaporation section. If a liquid wick is laid on the inner wall of the pipe, this porous material is equivalent to a capillary pump, and with its suction, the condensate can be returned to the evaporation section. This heat pipe is called a wick heat pipe (or capillary heat pipe).

3.2 Radial Heat Pipe

The working fluid of the radial heat pipe flows in the radial direction. The wick is close to the inner wall of the outer tube, and its interior is filled with a working medium. The working fluid goes on and on in the closed vacuum tube in a cycle of vaporization and condensation, which continuously transfers heat from the hot fluid outside the tube to the cold fluid in the inner tube [4].

At the same time, according to different classifications, it can also be divided into different types of heat pipes such as flat heat pipes, loop heat pipes, and pulsating heat pipes [5]. It can also be divided into low-temperature heat pipe, medium-temperature heat pipe and high-temperature heat agent (Freon), liquid nitrogen, liquid oxygen, and some other inorganic salts. The type of heat pipe shell and working fluid depends on its application. For example, when the temperature is above 1000 °C, liquid metals such as potassium and sodium are often used inside the heat pipe; at -190 °C, liquid nitrogen is often used [6].

4. APPLICATION OF HEAT PIPE HEAT EXCHANGER

Heat pipe heat exchangers are used in many applications, including spacecraft, industrial boilers or industrial furnaces, HVAC systems, and electronic components.

4.1 Average Temperature and Temperature Control of Spacecraft Components

Satellites, space stations, spacecraft, and other spacecraft operating in space all face the same problem of “hot and cold”, that is, the side of the spacecraft facing the sun suffers from high temperature, while the side facing away from the sun suffers from the low-temperature test. Since it is impossible to adjust the temperature through the air, the temperature difference between the two sides of the aircraft is as high as 300°C. Although the surface of the spacecraft is specially treated, such a large temperature difference can still cause it to deform, which has serious consequences. The huge temperature difference between the sunny side and the shady side of the spacecraft can be eliminated by using a heat pipe [7].

4.2 Waste Heat Recovery of Industrial Boilers or Industrial Kilns

The heat pipe air preheater is a typical representative of waste heat recovery. It uses the waste heat of exhaust smoke from boilers to preheat the combustion air entering the furnace, which can not only improve the thermal efficiency of the furnace but also reduce pollution to the environment. Heaters have been widely used in waste heat recovery and utilization. The shape of the heat pipe air preheater is generally a cuboid, and the main components are the heat pipe bundle, the shell, and the partition. The space between the baffle, the inner wall of the shell, and the outer wall of the heat pipe bundle are the hot and cold fluid flow channels. The baffle plays a part in supporting the heat pipe bundle, and its main function is to seal the flow channel to prevent the two fluids from mixing with each other [2].

4.3 Heat (Cold) Recovery of Air Conditioning System

The energy consumption of air-conditioning has become the focus of attention, and energy consumption of air-conditioning has accounted for 30% to 40% of the energy consumption of the entire building. In the air-conditioning system, most of the air-conditioning return air is cooled and reheated as supply air. The room is air-conditioned, while the rest of the return air is exhausted outside. The heat (cold) carried by this part of the return air is wasted. At the same time, the supply air must be heated (cooled) when it enters the air-conditioned room, which consumes a lot of energy. Therefore, the heat pipe heat exchanger is used to heat the return air of the air-conditioning system. (Cold) energy recovery, and then used in air conditioning systems, has important significance for the energy saving of air conditioning systems [8].

4.4 Electronic Component Cooling

Heat pipe technology has achieved many application results in the cooling of electrical equipment and electronic components, the heat dissipation of semiconductor components, and large-scale integrated circuit boards. Among them, the most potential ones include small and micro heat pipes, loop heat pipes and capillary pump loop heat pipes, pulsating heat pipes, etc. Small and micro heat pipes have been widely used for electronic cooling. With the rapid development of computer technology, the central processing unit (CPU) of high-performance computers generates more and more heat, and conventional natural cooling methods and forced cooling by fans are difficult to meet the requirements. Efficient heat pipe cooling has become the preferred cooling method [5].

5. FACTORS RESTRICTING THE APPLICATION OF HEAT PIPE HEAT EXCHANGERS

The performance of the heat pipe heat exchanger is good, but there are still many problems to be solved in order to achieve the best performance of the heat pipe heat exchanger.

5.1 Heat Pipe Working Fluid

At present, one of the restrictive factors limiting the application of heat pipes is the selection of working fluids for heat pipes. The working fluid must be selected according to the actual application ambient temperature. At present, there is no working fluid suitable for various working temperatures. If the ambient temperature in which the heat pipe heat exchanger operates changes, the efficiency and reliability of the heat pipe heat exchanger will change.

5.2 Heat Pipe Parameters

The diameter of the heat pipe, the length of the heat pipe, and the structural parameters of the fins (spacing, length of the fins, thickness of the fins) determine the efficiency of the fins and the finning ratio, which have a great influence on the heat transfer and flow resistance performance of the heat pipe heat exchanger, and involve the exchange of Heater compactness, investment and operating costs. The design of the heat pipe is based on experience. When the flow rate and temperature of the exhaust gas are constant, how to determine the diameter, fin height, fin thickness, fin spacing, heat pipe spacing, heat pipe length, and other structural dimensions of the heat pipe have no accurate basis. That also affects the application of heat pipe heat exchangers.

5.3 Dust Accumulation on Heat Pipe Fins

For the flue gas with more dust, if its flow speed in the heat pipe heat exchanger is too high, although it can improve the heat exchange capacity of the heat pipe, it will accelerate the wear of the heat pipe and increase the flow resistance of the flue gas; if the flow speed is small, the heat pipe fins It is easy to accumulate ash on the chip, which reduces the heat exchange capacity of the heat pipe, and in severe cases, the heat exchanger is blocked, making it ineffective [9].

6. CONCLUSIONS

The heat pipe heat exchanger has such characteristics as excellent heat exchange capacity, simple structure, lightweight, small volume, no power consumption for working fluid circulation, no moving parts, no noise, high reliability, and less maintenance. Therefore, heat pipe heat exchangers have been widely used, such as air preheating, automobile exhaust heat recovery, heat dissipation of electronic components, heat recovery of various boilers, etc. In view of some defects of heat pipe heat exchangers, such as the short life of heat pipes, fouling of fins, dew point corrosion of heat pipes, etc., relevant scholars have made efforts to explore and research, and put forward some corresponding solutions. For example, the service life of the heat pipe was extended by the synergistic methods of in-tube passivation, adding corrosion inhibitors in the working medium, and hydrogen removal by oxidation. The fouling of the heat pipe fin can be reduced through the constant flow rate method. The wall temperature of the heat pipe can be raised above the dew point temperature, thereby effectively solving the dew point corrosion problem, and so on. With the continuous maturity of heat pipe technology, the performance of heat pipe heat exchangers is becoming more and more perfect, and its application fields are bound to be wider.

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