Design of an electromagnetic induction steam generator device based on air source heat pump

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Abstract. Aiming at the current problems of coal-fired boilers and electromagnetic induction steam generators for environmental pollution and high energy consumption, this article combines air source heat pumps and electromagnetic induction heating technology, and at the same time carries out the structure of the condensate tank and electromagnetic induction steam generator. Redesign. Through trial production and experimentation of the prototype, the results show that compared with traditional coal-fired boilers and separate electromagnetic induction heating technology to generate steam, this device not only achieves energy saving and environmental protection, but also the stability of the steam outlet temperature and the amount of steam generated. Compared with the use of electromagnetic induction heating alone, it has increased by 20%. It can be seen that the use of air source heat pump' electromagnetic induction heating technology to generate steam saves energy and increases the amount of steam generated.

Keywords: Air source heat pump, Electromagnetic induction, Steam generator, Amount of steam.

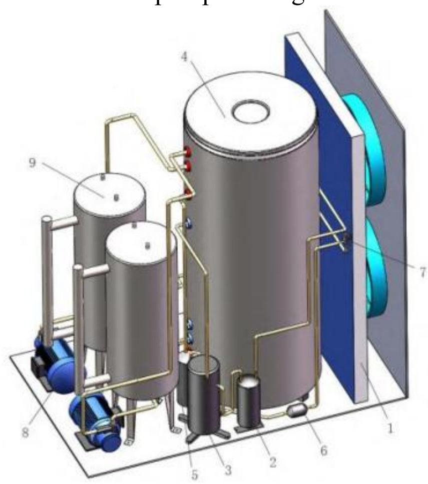
1 Introduction

With the continuous development of society and science and technology, people's demand for steam production is constantly changing, and people urgently need steam generators with high heat transfer efficiency, energy saving and environmental protection. Coal-fired boilers have improved the boiler efficiency through various methods[1,2], but the development of various harmful substances and dusts produced by burning coal has restricted its development; although gas-fired boilers have environmental advantages[3], due to natural gas it is easy to burn and explode, and the application range is not very wide. Electric heating steam generator came into being. Xu Qingjun et al.[4] introduced an electric steam generator for sterilization; Zhang Zichang[5] proposed a method based on electromagnetic induction. Technical steam generators, but due to excessive electrical power consumption, they are not used on a large scale.

The research purpose of this design is to reduce the energy loss when using electromagnetic induction steam generators. Aiming at this goal, air source heat pump technology and electromagnetic induction heating technology is combined to achieve the effect of reducing the energy loss.

2 Machine mechanism

At present, most traditional equipment commonly used in steam generating devices uses coal, natural gas or electric heating pipe devices, which not only generates waste and pollute the environment, but also have a low energy usage rate. This article improves and redesigns the form of steam generation on the basis of the existing steam generation device, which can achieve the purpose of reducing the energy loss. The device is mainly composed of an evaporator (with a fan on its end surface), a four-way reversing valve, a gas-liquid separator, a compressor, a condensate tank, a liquid storage tank, a filter dryer, an electromagnetic expansion valve, a circulating water pump and a steam generator[6], figure 1 shows the dual-system air source heat pump steam generator.



1.Evaporator 2.Gas-liquid separator 3.Compressor 4.Condensate tank 5.Liquid storage tank 6.Filter drier 7.Electromagnetic expansion valve 8.Circulating water pump 9.Steam generator

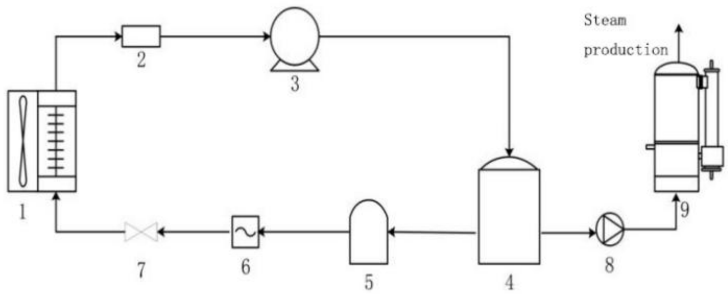
Fig. 1. Air source heat pump steam generator system model.

3 Working principle

Its working principle is shown in figure 2: when the fan at the right end of the evaporator is energized, it will extract natural wind from the outside and act on the tube-fin evaporator to form forced convection. The working fluid inside the evaporator will absorb the outside air. The energy is heated to evaporate to form high-temperature and low-pressure steam, which then flows through the gas-liquid separator through the working fluid outlet of the evaporator, where moisture will be absorbed; at the same time, the working fluid gas flows to the compressor, and the compressor transfers the high-temperature and low-pressure working fluid the gas is compressed into high-temperature and high-pressure gas; and then flows through the condensate tank. Because the water tank is filled with water at room temperature, the high-temperature and high-pressure gas will emit heat when flowing through the disk-shaped pipe in the water tank. After the water is preheated, the high-temperature and high-pressure working fluid gas will be It gradually becomes a low-temperature and high-pressure working medium gas; and then flows through the liquid storage tank. The function of the liquid storage tank is to adapt to the demand for the supply of the evaporator's load changes. When the evaporation load increases, the supply also increases, and its supply The volume is replenished by the liquid storage in the liquid storage tank; the load becomes smaller, the required liquid volume becomes smaller, and the excess liquid is stored in the liquid storage tank; then it flows through the filter drier, where the dust and dirt in the pipeline will be absorbed. Ensure that the system is clean and dry; then flow through the electromagnetic expansion valve to convert the low-temperature and high-pressure working fluid steam into low-temperature and low-pressure working fluid steam, and finally return to the evaporator to complete an internal cycle. This cycle is repeated until the water is heated to 60℃.

At the same time, the circulating water pump will pump the pre-heated water in the water tank from the hot water outlet of the condensate tank into the electromagnetic induction steam generator furnace body. The outer wall of the furnace is wound with a coil. When the coil is energized, the outer shell is heated and it has been pre-heated. The water is heated again to evaporate, and then form water vapor.

Compared with the heating method of direct heating from the normal temperature water stage to the steam stage, the heat required from the normal temperature stage to the medium-high temperature stage is saved by using the air source heat pump technology. Therefore, the main energy-saving process is reflected in the use of air source heat pumps to produce medium and high temperature water.



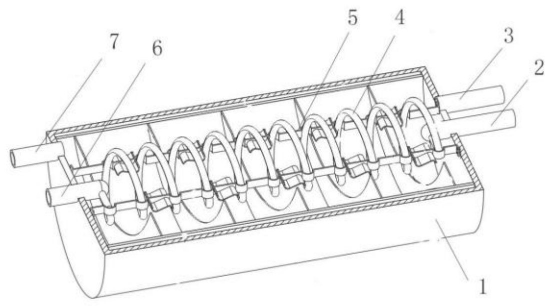
1.Evaporator 2.Gas-liquid separator 3.Compressor 4.Condensate tank 5.Liquid storage tank 6.Filter drier 7.Electromagnetic expansion valve 8.Circulating water pump 9.Steam generator

Fig. 2. Working principle diagram.

4 Key component design

3.1 Condensate tank design

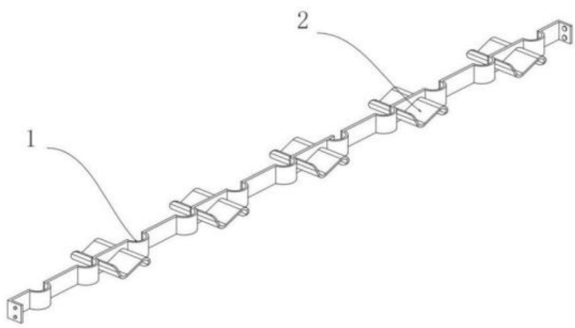
The condensate tank is an important part of the air source heat pump and is responsible for preheating the water. Therefore, the structure of the condensate tank is a key part of whether the working fluid energy can be transferred to the water in the tank. Compared with the straight-through pipeline of the original water tank, the working fluid steam will quickly flow through the pipeline, and the pipe body cannot fully absorb the working fluid energy. This design changes the original straight-through pipeline to a disc-shaped pipe, and at the same time, it is still in the pipeline the pipe body positioning frame is added to the upper part, the purpose is to increase the flow time of the working fluid in the pipeline, and at the same time increase the heat transfer area, so that the pipe body can better absorb the working fluid energy, and its structure is shown in figure 3.



1.Box 2.Working fluid entrance 3.Room temperature water inlet 4.Pipeline 5.Tube positioning frame 6.Working fluid export 7.Hot water outlet

Fig. 3. Structure diagram of condensate tank.

Among them, the positioning arc groove on the tube positioning frame (as shown in Figure 4) can play the role of fixing the condenser tube. At the same time, the tube body positioning frame is in contact with the condenser tube. The tube body positioning frame is also made of aluminum alloy, which can absorb part of the heat of the condenser tube body. The exchange plate on the tube body positioning frame can increase the contact area with water, and further improve the heat exchange between the water and the condensing tube, and complement the spiral condensing tube, so that the working fluid steam can fully release heat in the pipeline.



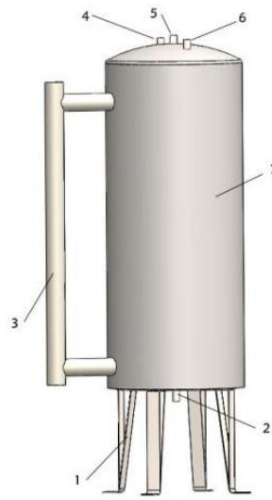
1.Positioning arc groove 2.Swap piece

Fig. 4. Structure diagram of the pipe positioning frame.

3.2 Steam generator design

The steam generator is a key device for generating steam. Compared with heating by coal-fired boilers, gas-fired boilers, or heating by electric heating rods, the use of electromagnetic induction heating can increase the energy usage rate without polluting the environment. At the same time, it will not directly go deep into the water to heat like an electric heating rod, which will cause scale on the electric heating rod and affect the heating efficiency of the electric heating rod.

Its structure is shown in Figure 5, consisting of 7 parts: base bracket, water inlet, handle, pressure relief valve, thermocouple, steam outlet, and furnace body. The water inlet refers to the medium and high temperature water extracted from the condensate pump; the steam outlet is the outlet of the generated high-temperature steam; the function of the pressure relief valve is to release the pressure in the furnace body when the pressure in the furnace body exceeds the preset pressure, so as to avoid excessive pressure in the furnace body and cause the furnace body to explode; the function of the thermocouple is The temperature of the steam in the furnace is detected; the handle is hollow, and a liquid level probe is arranged in it, and the water volume in the furnace is monitored by the liquid level probe. At the same time, asbestos is used to wrap the outer wall of the furnace to reduce the rate of energy dissipation. Then use electric coils to wrap the asbestos in a spiral shape. On the one hand, the asbestos can be in closer contact with the furnace body. On the other hand, the furnace body is wrapped by the coil. After the coil is energized, the water in the furnace body is heated.



1.Base bracket 2.Water inlet 3.Handle 4.Pressure relief valve 5.Thermocouple 6.Steam outlet 7.Furnace

Fig. 5. Structure of electromagnetic induction steam generator.

The working principle of induction heating of the steam generator is shown in Figure 6. The heating device control power supply converts the three-phase power frequency alternating current into a pulsating direct current after being rectified by a rectifier, and then filtered into a stable direct current through a filter, and finally through the action of the inverter and transformer , transforming the stable direct current into frequency and voltage adjustable frequency and voltage adjustable alternating current [7], after the alternating current is delivered to the induction coil, an alternating magnetic field is generated around it, when the furnace body is placed in the alternating magnetic field , An alternating electric potential is generated inside, and the furnace body produces an eddy current effect under the action of the alternating electric potential[8,9]. When the free electrons in the furnace body move in the metal body, heat is generated, thereby achieving heating and heat conduction. The heat in the process is determined by the strength of the vortex.

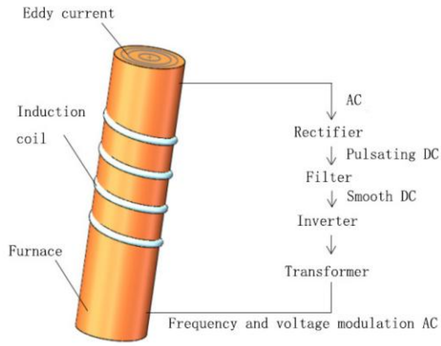


Fig. 6. The working principle of induction heating.

5 Control system design

4.1 Controller selection

The controller adopted in this design is S7-1200 of Siemens of Germany. This PLC has the characteristics of strong function, high reliability, flexible and convenient use, easy to program and suitable for industrial environment. The main loop control part of this design is temperature control. At present, in the induction heating power supply, the temperature control usually adopts PID control[10]. Because this system has small requirements for temperature error, only PID control can meet the requirements.

PLC mainly realizes the start and stop of the water pump, the on and off of the main power supply and the control of the valve through the feedback of various sensors.

4.2 System control flow

The system control process is mainly divided into air source heat pump preheating link (liquid heating link) and electromagnetic induction secondary heating link (liquid heating and gasification link). The system control flow chart is shown in Figure 7. The liquid heating process is mainly as follows: When the main power is turned on, the water level probe in the water tank monitoring the water level information, starts to control the external water pump to pump normal temperature water into the water tank, and also monitors the highest water level in the water tank. When the water level reaches the maximum allowable water level, the external water pump is controlled to stop working. The fan at the right end of the evaporator starts and the compressor starts to form high-temperature and high-pressure gas, gradually heating the normal temperature water in the water tank to medium-high temperature water. When the temperature of the water in the water tank reaches the temperature set by the temperature sensor in the tank, the system will control the circulating water pump to pump the water in the condensate tank into the steam generator body. When the water level in the water tank drops to the critical point, the external water pump starts to work, and the steam generator stops working until the water replenishment is completed, and so on.

The electromagnetic induction secondary heating link is mainly included: when the medium and high temperature water extracted from the condensate tank reaches the water level in the furnace body, the coil is energized. The vortex effect is used to further heat the water into steam. The thermocouple located at the top of the furnace body is used to detect the temperature of the furnace body. The pressure relief valve detects the temperature in the furnace body through a pressure sensor located in the furnace body, when the temperature in the furnace body exceeds the critical temperature. The system will control the pressure relief valve to open for pressure relief. At the same time, a water level probe arranged on the handle part of the furnace body detects the amount of water remaining in the furnace body as the steam is generated. When the water in the furnace is below the critical minimum water level. The system will cut off the power of the coil, and at the same time control the circulating water pump to pump water to the condensate tank to add water to the furnace body, and so on, until the main power is manually turned off, the system stops working.

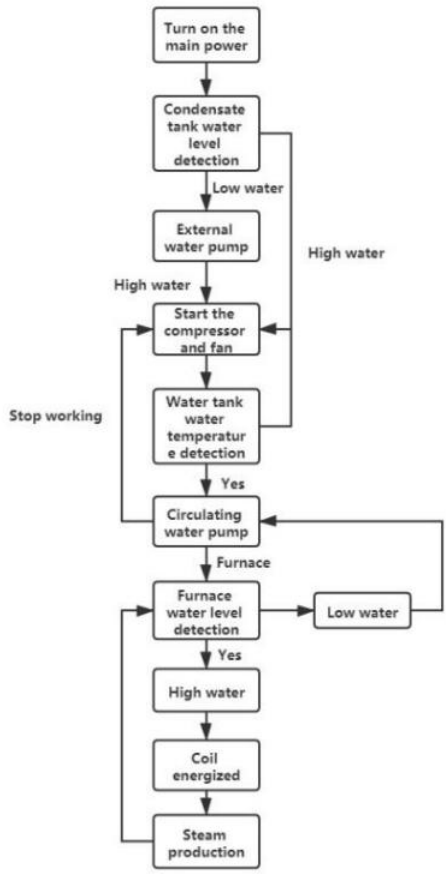


Fig. 7. System control flow chart.

6 Experimental data

5.1 Steam outlet temperature

The total input power of this device is 65KW. The input power of the air source heat pump is 5KW, the measured temperature of the heat pump condensate tank is 63.9℃; the input power of the electromagnetic induction steam generator is 60KW, and the target steam generator working pressure is set to 0.5MPa, and the saturated steam temperature at this pressure is 151.867℃. Set the system steam temperature to 140℃, and record the outlet steam temperature during a period of operation of the device.

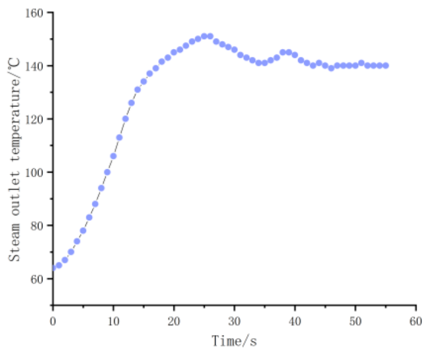


Fig. 8. Temperature change curve of steam outlet.

The temperature change of the steam outlet is shown in Figure 8. The medium and high temperature water in the condensate tank is pumped by water pump and enters the steam generator furnace body. After turning on the power of the coil, the system responds quickly. The furnace body is heated by electromagnetic induction in a short time. The temperature rises rapidly, and the medium and high temperature water is quickly vaporized in the furnace body. It can be seen from Figure 8 that the vaporization temperature rises to 151℃ at 25s, reaching the highest; then it gradually decreases, and the output steam temperature gradually stabilizes after 42s.

5.2 Amount of steam

In order to compare the difference between this device and the electromagnetic induction steam generator alone (the coal-fired boiler will burn a large amount of coal during operation, resulting in a large amount of harmful gas and dust in the air, because this method has large environmental pollution and does not meet energy saving the emission reduction target, and its heat transfer efficiency is low, so it is not compared here), the control experiment is set according to the steam outlet flow rate, the original design is set as the experimental group, and the electromagnetic induction steam generator alone is set as the control group. The initial working conditions and other conditions are the same. Set target working conditions: steam temperature 140℃, steam pressure 0.5MPa, respectively record the steam output per hour, 10 times in total, the test results are shown in Table 1.

Table 1. Comparison of steam volume between prototype and electromagnetic induction steam generator.

Serial number	Stress/MPa	Steam temperature/℃	Steam outlet flow / kg/h	
			Experimental group	Control group
1	0.5	150	91.4	76.2
2	0.5	150	91.0	76.3
3	0.5	150	90.9	75.9
4	0.5	150	91.5	76.0
5	0.5	150	91.2	75.8
6	0.5	150	91.3	76.1
7	0.5	150	91.1	75.7

8	0.5	150	90.8	76.2
9	0.5	150	91.4	76.0
10	0.5	150	91.4	75.8

It can be seen from Table 1 that under the same conditions, the average steam production of this device is 91.2kg/h, the average steam production of the electromagnetic induction steam generator alone is 76kg/h, and the steam production has increased by 20% year-on-year. Aware, this device uses an air source heat pump to extract water during water harvesting, and then enters the electromagnetic induction furnace to heat the steam. The steam saves energy consumption during heating time and reduces energy consumption. The temperature varies from normal temperature water to steam generation process is improved, and the steam different output of the system is improved at one time. Figure 9 is a physical display of a winery in Maotai Town, Guizhou Province using this device to distill wine.

Fig. 9. Physical display diagram.

7 Conclusion

Aiming at the environmental pollution of coal-fired boilers and the high energy consumption of a single electromagnetic induction steam generator, this paper carried out a design of an electromagnetic induction evaporator based on an air source heat pump, and conducted a comparative experiment with this design and a single electromagnetic induction steam generator. When the steam outlet temperature of this design is 140℃, the average steam volume is 90.2kg/h, which is an increase of 20% compared with the electromagnetic induction steam generator alone. It can be inferred that the device can be used more save energy to a certain extent and increase the steam output. At the same time, the device was applied to a winery in Moutai Town, Guizhou Province for testing, and good results were achieved.

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