Waste heat drying system design

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Abstract

The general principle of the utilization of flue gas waste heat should be based on the thermodynamics point of view, according to the "quality energy, cascade utilization", for the waste heat recovery and utilization of flue gas with different temperatures and different tastes. In this paper, the flue gas waste heat drying system scheme is designed, and the main components are designed and calculated. Through the analysis and evaluation of the system's thermal economy and environmental protection, it is concluded that the thermal efficiency of the system is 78.7%, the investment recovery period is 0.42 years and it has good energy saving and emission reduction effects.

Keywords

Waste, system design.

1. Introduction

During the production process, the primary energy fuel is converted into a large amount of heat during the reaction process, and the heat therein cannot be fully utilized, and the remaining heat is converted into the waste heat resource after the reaction is completed. On the one hand, it is necessary to make full use of industrial waste raw materials for production and utilization, such as secondary production of slag, gas and other raw materials to reduce the consumption of other resources; on the other hand, it is necessary to reduce waste of resources in the production process, for example, using waste heat resources to support waste heat power generation equipment to reduce Energy consumption. The waste heat resource belongs to secondary energy, and its resources are abundant in the production process of various industries, especially in the power, steel, petroleum, chemical, building materials and other industries.

Various forms, divided by temperature, can be roughly divided into several types, one is high temperature waste heat, the residual heat temperature is higher than 600 ° C; the other is medium temperature waste heat, the residual heat temperature is between 230 ° C and 600 ° C; After heat, the residual heat temperature is lower than 230 °C. Flue gas waste heat accounts for a large proportion of all waste heat resources. The development of flue gas waste heat utilization technology, through the full recovery of waste heat energy in the flue gas, not only removes the comprehensive utilization efficiency of energy, but also plays an important role in improving environmental protection benefits and promoting energy conservation and emission reduction.

There are many uses of flue gas waste heat. The waste heat recovery of flue gas can be divided into the following aspects: (1) According to the different heating medium, it is divided into: heating condensate, preheating and drying fuel, heating heating network Water, etc. (2) According to the position of the flue gas arrangement, it can be divided into: the front part of the air preheater, the front part of the precipitator, the front part of the desulfurization absorption tower, and the like. (3) According to the different heat exchange modes, it is divided into: direct heat exchange and indirect heat exchange, that is, the flue gas can be directly contacted with the heat absorbing medium, or the corresponding intermediate medium should be used as the heat medium, and the intermediate medium is used. The absorption of residual heat of the flue gas is carried out, and then the heat is transferred to the corresponding heat absorbing medium. (4) According to the way of energy utilization, the corresponding classification: one is to use the relevant energy conversion equipment to convert and recycle the corresponding flue gas waste heat, and the second is to pass the relevant heat exchange equipment to the flue gas. The residual heat is recovered in the form of corresponding heat energy.

2. Organization of the Text

A drying device composed of a heat pump combined with various drying devices is called a heat pump drying device. The main principle of the heat pump applied to the drying process is to use the heat pump evaporator to recover the heat release in the exhaust gas during the drying process, and then heat the cold dry air through the heat pump condenser, thereby greatly reducing the energy consumption in the drying process. The treated fresh clean air circulates in a closed system consisting of a drying chamber, an evaporator (air side), a condenser (air side) and a duct.

The main indicator reflecting the overall performance of the heat pump drying unit is the dehumidification energy consumption ratio SMER (the amount of water in the wet material removed by the unit energy)

Main features of heat pump drying:

(1) It can realize low temperature air closed circulation drying, and the material drying quality is good. By controlling the working condition of the heat pump drying device, the temperature of the hot air entering the drying chamber is between 20 ° C and 80 ° C, which can meet the high quality drying requirements of most heat sensitive materials; the closed cycle of the drying medium can avoid the outside world The gas exchange may contaminate the impurities of the material, which is especially important for food, medicine or biological products. In addition, when the material is sensitive to oxygen in the air (easy to oxidize or burn), an inert gas medium can be used instead of air as a drying medium to achieve oxygen-free drying.

(2) Energy saving and efficient. Since the heat of the heated air in the heat pump drying device mainly comes from the sensible heat and latent heat contained in the warm and humid air discharged from the recovery drying chamber, the energy input is only the residual heat of the flue gas. The SMER value of the heat pump drying device is usually 1.0 to 4.0, while the conventional convection dryer has a SMER value of 0.2 to 0.6.

(3) Temperature and humidity control is convenient. When the material has high requirements on the temperature and humidity of the air entering the drying chamber, the evaporation temperature and condensation temperature of the heat pump working medium in the evaporator and the condenser can be adjusted to meet the requirements of the material on the texture and appearance.

(4) Useful volatile components in recyclable materials. Some materials contain volatile components (such as aroma and other ingredients). When dried by a heat pump, in the drying chamber, volatile components and moisture are vaporized into the air together, and the air containing volatile components is cooled by the evaporator. The volatile component is also liquefied, discharged together with the condensed water, and the condensed water containing the volatile component is collected, and the volatile component is separated by an appropriate method.

(5) Environmentally friendly. In the heat pump drying device, the drying medium is closed in circulation, no material dust, volatile substances and odors are polluted by the dry exhaust gas to the environment; the residual heat in the drying chamber is directly recovered by the heat pump, and there is no heat pollution of the unit to the environment.

(6) Multi-functionality can be realized. The heat pump in the heat pump drying device also has a cooling function, which can realize low-temperature processing (such as quick freezing, refrigerating)

or fresh-keeping processing of suitable materials when the drying task is small, and can also utilize the heating function of the expansion heat pump in the cold. Heating plants or farms in winter.

(7) Compared with other drying methods, equipment investment is small and operating costs are low. The equipment cost of the heat pump drying device is mainly the heat pump part and the drying room part, wherein the drying chamber part has the same requirements as the ordinary convection drying room, and has no special air tightness and pressure bearing requirements; some parts of the heat pump and the working medium can be borrowed and applied widely. The cost and cost of the relevant components and working fluids of air conditioning and refrigeration equipment that meet the requirements of working conditions can also be effectively controlled. For small and medium-sized heat pump drying units, the payback period is generally 0.5 to 3 years.

(8) Applicable materials for heat pump drying. The materials suitable for drying by heat pump are mainly a large class of materials with a temperature tolerance between 20 and 80 ° C in the drying process, or although the materials can withstand higher heat, the heat pump is used to dry the energy-saving or safe materials. Researches such as wood (such as oak), grains, seeds, mushrooms, herbs, fungus, scallops, ginseng, fresh oysters, bioactive products, edible fungi, tea, oats, paper, bananas, etc.

In this drying system, the heat pump uses an absorption type lithium bromide unit, and the drying chamber temperature is maintained at 45 °C. The specific calculation is as follows;

The circulating medium is the heat transfer amount of each major component per unit mass flow:

Checking the flue gas temperature shows that the flue gas is 9805.72KJ/m^3 at 450 degrees Celsius and 2090.95KJ/m^3 at 100 degrees Celsius. Therefore, the heat pump generator heat absorption Q = 2738.7 kW . Let the mass flow rate of the circulating medium be D. Generator heat consumption = 2738.7 kW . So the solution is D=0.81kg/s.

Set the solution circulation rate a = 15.5,

A, the heat absorption of the evaporator = 1888.92 kW

B, the heat release of the condenser =2019.51 kW

C, the heat release of the absorber = 2558.37 kW

D, solution heat exchange amount:=591.43 kW

E, unit heat balance analysis

Heat into the unit ==4627.62 kW

The heat output of the unit == 4778.8 The basic energy balance of the unit is considered to be basically correct.

F, thermal coefficient:=5261.94/3109.89=1.71)

Calculation of parameters of the components of the absorption heat pump.

Heat transfer area of each component:

The condenser, the temperature at which the heated air enters the condenser and the temperature at which the absorber exits are calculated as: $Q_C V_W C_P (T'-T_{WC}) = Q_A V_W C_P (T_{WAO} - T)$

(1) The average heat transfer temperature difference of the condenser, the heated air inlet temperature is 30 ° C, the outlet temperature is 45 ° C, and the working fluid condensation temperature is 55 ° C. If the heat transfer process, the temperature of one fluid remains the same (if the fluid is condensing or evaporating) When there is no difference in the average heat transfer temperature difference between the forward and reverse flow heat exchangers, calculated by equation. $\delta T = \dfrac{t_2''-t_2'}{\ln \dfrac{t_1 - t_2'}{t_1 - t_2''}}$

It was calculated to be 16.4 ° C.

According to the empirical data, the heat transfer coefficient of the condenser based on the inner surface is taken: the heat transfer area of the condenser is calculated by the formula .

$K_c = 1600 \mathrm{W/(m^2 \cdot °C)}$

The average heat transfer temperature difference between the evaporator and the evaporator; the low temperature heat source water inlet temperature is 13 ° C, the outlet temperature is 8 ° C, the circulating working fluid evaporating temperature is 6 ° C, and the average heat transfer temperature difference is calculated by the formula .

$$\delta T_{em} = \frac{t_2''-t_2'}{\ln\frac{t_1-t_2'}{t_1-t_2''}}$$

It is calculated to be 4 ° C. According to the empirical data, the heat transfer coefficient of the evaporator based on the inner surface is taken: = 4400, and the heat exchange area of the evaporator is calculated by the formula.

$$F_e = \frac{Q_E}{Ke\delta Tem} \text{ (internal surface area)}$$

(2) Absorber, average heat transfer temperature difference of the absorber: the temperature of the heated air inlet is 30 ° C, and the outlet temperature is 37.32 ° C. Since the solution at the initial temperature in the absorber enters the absorber, it is cooled first, and then absorbs heat from point 6 to release the temperature. In this process, the heated water mainly carries away the heat released during the absorption process. And cooling the solution from temperature to just need

Use a heat transfer area of 3% to 6%. Therefore, the amount of heat transfer in the absorber can be approximated by the fact that the solution changes from temperature to the process, transferring the heat of the heated water, so the solution inlet temperature is 52 ° C and the outlet temperature is 42 ° C. Further, the heat transfer mode of the solution in the absorber and the heated water is approximately a cross flow, which is calculated by the formula .

$$\delta Tam = \frac{(t_1'-t_2') - (t_1''-\frac{t_2'+t_2''}{2})}{\ln\frac{t_1'-t_2'}{t_1''-\frac{t_2'+t_2''}{2}}}$$

Average heat transfer temperature difference of the absorber: δTam = 17.47 °C. Based on empirical data, take the heat transfer coefficient of the absorber based on the inner surface: $K_a = 1600 \mathrm{W/(m^2 \cdot °C)}$ The heat transfer area of the absorber is calculated from equation . $F_a = \frac{Q_A}{K_a T_{am}}$ =145.29 (internal surface area)

(3) Generator, generator average heat transfer temperature difference: drive heat source temperature is 450 °C. The solution enters the generator at temperature and the temperature rises to the temperature at which the generator exits. The amount of heating of the driving heat source is mainly consumed in the evaporation of the solution. Therefore, it can be approximated that the inlet temperature on the solution side is 85 ° C and the outlet temperature is 94 ° C. Calculated by equation.

$$\theta_m = \frac{t_2''-t_2'}{\ln\frac{t_1-t_2'}{t_1-t_2''}}$$

Get: δT_{gm} = 360.48 ° C. Based on empirical data, the heat transfer coefficient of the generator based on the inner surface is taken: The heat transfer area of the generator is calculated by equation.

$$F_{\mathrm{g}}=\frac{Q_{\mathrm{G}}}{K_{\mathrm{g}}\delta T_{\mathrm{gm}}}=\frac{3109.89\times 1000}{1800\times 360.48}$$ =4.8 (internal surface area)

(4) solution heat exchanger, the average heat transfer temperature difference of the solution heat exchanger: in the solution heat exchanger, usually the concentrated solution flows in a meandering manner at right angles to the tube, and the overall effect is to flow in the opposite direction to the dilute solution in the tube, It can be approximated as countercurrent heat transfer. The inlet temperature of the dilute solution is 42 ° C, the outlet temperature is 71 ° C; the inlet temperature of the concentrated solution is 94 ° C, and the outlet temperature is 60 ° C. The average heat transfer temperature difference of the countercurrent heat exchanger is calculated by the formula.

$$\delta T_{\mathrm{exm}}=\frac{(t_1'-t_2'')-(t_1''-t_2')}{\ln\frac{t_1'-t_2''}{t_1''-t_2'}}$$

It is found that δT_{exm} = 20.4 °C. Based on empirical data, the solution heat exchanger is based on the heat transfer coefficient of the inner surface: K_{ex} = 530 W/(m^2·°C).

The heat transfer area of the solution heat exchanger is calculated by equation.

$$F_{ex}=\frac{Q_H}{K_g\delta T_{exm}}=\frac{679.83\times 1000}{530\times 20.4}$$ =62.88 (internal surface area)

The basic working process is as follows:

The hot dry air enters the drying chamber, absorbs the moisture of the material, and cools and humidifies itself. When the heat loss in the drying chamber is neglected, the enthalpy of the hot dry air before entering the drying chamber in the process is equal to the enthalpy of the warm and humid air in the drying chamber; The warm and humid air in the chamber enters the evaporator, and is first cooled to a saturated humid air state in the evaporator, and further cooled down along the saturated wet air line until it becomes a cold, dry air state with a lower temperature and a little water content. Entering the condenser; in the condenser, the cold dry air is heated into hot dry air, and then enters the drying chamber to start the next cycle, so that the moisture in the wet material is continuously sucked away in the drying chamber, and continuously in the evaporator The moisture is condensed and discharged, thereby achieving continuous drying of the wet material.

3. System thermal economic analysis and evaluation

The analysis method based on the first law of thermodynamics mainly uses the principle of heat balance and the thermal efficiency as the basic criterion to analyze and evaluate the energy efficient utilization of energy utilization equipment and systems. In terms of quantity, it reflects the conservation of energy, such as primary energy utilization rate, primary energy saving rate and so on.

The heat method measures the thermal performance of the system by the magnitude of thermal efficiency or heat loss rate. Among them, the thermal efficiency reaction thermal equipment converts energy into or outputs effective energy. Calculated that the thermal efficiency of the system is 78.7%.

The investment payback period refers to the time required for the net income of the project to repay the total investment. It is generally divided into years. It is divided into static investment payback period and dynamic investment payback period. The former does not consider time value, and the latter considers the time value of funds. .

If the initial investment of the system is F and the annual net income is equal, both are A, then according to the definition of the payback period, the static investment payback period Ns is:

$$N_s=\frac{F}{A}$$

According to the calculation, the investment recovery period is 0.42 years.

The environmental performance evaluation of the system is closely related to the low carbon economy. Low-carbon economy refers to the concept of sustainable development, through technological innovation, institutional innovation, industrial transformation, new energy development and other means, to reduce coal, oil and other high-carbon energy consumption as much as possible, reduce greenhouse gas emissions, and achieve economic An economic development pattern in which social development and ecological environmental protection are mutually beneficial.

It is calculated that the scheme is equivalent to reducing 3208.9t of standard coal consumption per year; reducing carbon ash emissions by 2182t; reducing CO_2 emissions by 7998.2t; and reducing SO_2 emissions by 240.7t. Have good energy saving and emission reduction effects.

References

[1] Yu Jianzu. Principle and design of heat exchanger [M]. Beijing University of Aeronautics and Astronautics Press.2006

[2] Shi Meizhong. Principle and Design of Heat Exchanger [M]. Southeast University Press. 2014

[3] Yan Junjie, Huang Jintao, He Maogang. Cogeneration technology [M]. Chemical Industry Press. 2006

[4]]Wu Yezheng. Principles of refrigeration and low temperature technology [M]. Higher Education Press.2007

[5] Chen Dong, Xie Jihong. Heat pump technology and its application [M]. Chemical Industry Press.2008

[6] Li Changjian. Theory and Engineering of Biogas Technology [M]. Tsinghua University Press. 2016

[7] Li Zifu, Fan Xiaolin. Analysis of current status of biogas projects in Germany[J]. 2010, 28(4): 141～144

[8] Huang Xinyuan, Wang Jiaming, Sun Qichao. Research on retrofit technology of boiler installed low-pressure economizer[J]. Electric Power Construction.2008

[9] Thomas Arink.Metal scrap preheating using flue gas waste heat[J].2017:4788～4795