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Study on a heat recovery system for the thermal power plant utilizing air cooling island

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A B S T R A C T

A new heat recovery system for CHP (combined heat and power) systems named HRU (heat recovery unit) is presented, which could recover the low grade heat of exhausted steam from the turbine at the thermal power plant directly. Heat recovery of exhausted steam is often accomplished by recovering the heat of cooling water in current systems. Therefore, two processes of heat transfer is needed at least. However, exhausted steam could be condensed in the evaporator of HRU directly, which reduce one process of heat transfer. A special evaporator is designed condense the exhausted steam directly. Simulated results are compared to experiments, which could include the calculation of heat transfer coefficients of different parts of HRU. It is found that about 25Mw of exhausted steam is recovered by this system. HRU could be promising for conventional CHP systems, which could increase the total energy efficiency obviously and enlarge the heating capacity of a built CHP system.

1. Introduction

Energy and environment are two significant issues requiring global attention. How to utilize fuel efficiently is a main research aspect at present. Making full use of low grade heat exhausted to the environment could mitigate global warming and save energy [1]. District heating is an efficient way to make full use of fuel. Application of district heating with CHP (combined heat and power) is promising and developing rapidly, which could combine the electric power and heat production in the thermal plant with higher energy efficiency.

Kelly and Pollitt discussed the application of district heating with CHP in UK, and some reasonable suggestions were given [2].The power plant of CHP could increase the total energy efficiency to be more than 90%, meanwhile, the energy efficiency is often less than 50% in a traditional fossil fuel fired electrical power. Therefore, CHP is quite promising and being employed widely [3]. It was reported that more than 80% of heating area was supplied by the CHP system in Denmark, which was more than 30% in China [3–4].

In a word, the district heating with CHP will play a more and more important role in the future [5,6]. However, there are some problems in current CHP systems.

1. The heating capacity of a built district heating system could not meet the rapidly increasing heating requirement due to more and more residents and industries. And it is difficult to build new heating sources in a built city [4].
2. The waste heat for cooling the exhausted steam of the turbine diminishes the total energy efficiency obviously, which could reach 20%–30% of total heat input [7].

Many efforts have been put on how to improve total energy efficiency of the thermal power plant of CHP [8–10].Gustafsson discussed a control method of IDH system to decrease the temperature of back water, which could enlarge temperature difference at the thermal substation [11].Sun employed absorption heat pumps at the power plant to recover low grade heat of exhausted steam, and AHE (absorption heat exchangers) were installed at the thermal substation to decrease the temperature of back water of primary pipe. Several different kinds of absorption heat pumps were applied to recover the waste heat of cooling water step by step, which could enlarge the total energy efficiency of CHP by more than 30% [4].

In a word, recovering the low grade heat at the thermal power plant for heating is an available and efficient way to solve current problems of CHP. Meanwhile, circulating water is often adopted as the heat transfer medium between the exhausted steam and heat pumps. Therefore, two processes of heat transfer are needed at least. However, HRU could recover the low grade heat of exhausted steam in its evaporator, which could reduce one process of heat

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Nomenclature

a	coefficient of heat diffusion, $m^2\ s^{-1}$
C	concentration of LiBr, wt%
c_p	constant-pressure specific heat, $J\ kg^{-1}\ k^{-1}$
D	coefficient of mass diffusion, $m^2\ s^{-1}$
HE	heat exchanger
HRU	heat recovery unit
F	area, m^2
g	acceleration of gravity, $m\ s^{-2}$
h	enthalpy, J
K	coefficient of heat transfer, $W\ m^{-2}\ k^{-1}$
k	coefficient of conduction, $W\ m^{-1}\ k^{-1}$
m	mass flow rate, $kg\ s^{-1}$
p	pressure, Pa
q	density of heat flux, $W\ m^{-2}$
Q	heat transfer rate, W
r	radius, m
s	distance between tubes, m
u	velocity in the x direction, $m\ s^{-1}$
v	velocity in the y direction, $m\ s^{-1}$
E	evaporator
G	generator
C	condenser of heat pump
A	absorber
CHP	combined heating and power
PP	primary pipe
SS	strong solution
WS	weak solution
α	coefficient of heat emission, $W\ m^{-2}\ k^{-1}$
μ	kinetic viscosity, Pa m
δ	thickness of film, m
ρ	density, $kg\ m^{-3}$
υ	kinematic viscosity, $m^2\ s^{-1}$
Γ	spray density of solution, $kg\ m^{-1}\ s^{-1}$
τ	absorption heat, $J\ kg^{-1}$
λ	coefficient of conduction, $W\ m^{-1}\ k^{-1}$
θ	angle, °
T	temperature, °C

Subscripts

a	absorption
b	bulk
drop	drop of LiBr solution
f	film
form	the region of drop formation
fall	the region of drop fall
in	inlet
l	liquid
out	outlet
s	surface/solution
v	vapor
w	wall/water

transfer. In order to simulate the HRU, 2D mathematical including the calculation of heat transfer coefficients is presented, which is compared to the experiment accomplished at an actual thermal power plant.

2. Principle of the HRU

The HRU is combined by a condenser and an absorption heat pump driven by the extracted steam from turbine, which is shown in Fig. 1. Exhausted steam of the turbine enters the condenser and the absorption heat pump in parallel. A new type of evaporator is applied in the absorption heat pump, which make the double side phase change inside and outside tubes come true. The exhausted steam becomes liquid inside tubes of the evaporator; meanwhile, the coolant water of the absorption heat pump becomes vapor outside these tubes.

The back water of the PP (primary pipe) is heated by the condenser firstly, however, the outlet temperature of back water is lower than the saturated temperature of exhausted steam. An absorption heat pump driven by extracted steam is employed to recover the waste heat of exhausted steam directly to heat the back water to a higher temperature. This driven steam is extracted from the turbine, and condensation water of extracted steam and exhausted steam join together in the end, which are heated by the boiler again to complete a cycle.

The back water of PP is often heated by the extracted steam from the turbine directly in a conventional CHP system, which will lead to high exergy loss due to high temperature difference. In other words, there is no energy loss when heat is exchanged between the exacted steam and back water without considering heat loss. However, exergy loss is quite huge. The temperature of extracted steam is often more than 200 °C, which could be utilized to drive an

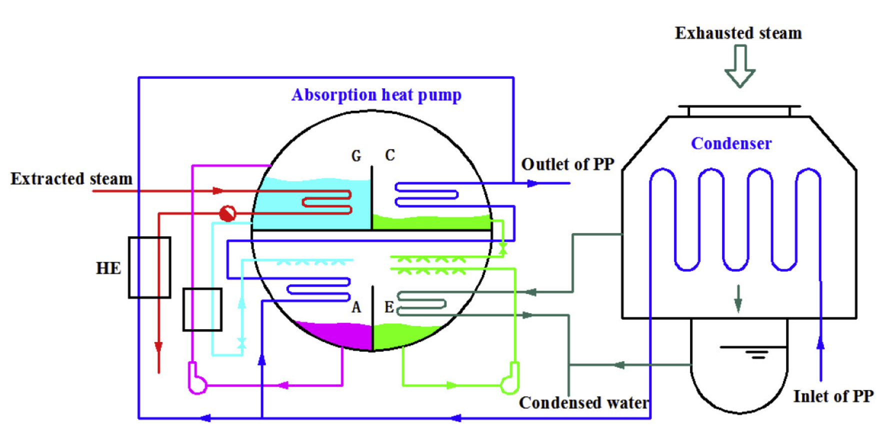

Fig. 1. Inside principle of the HRU.