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A comprehensive review on advances and applications of industrial heat pumps based on the practices in China

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HIGHLIGHTS

- Comprehensively reviewing industrial heat pump systems in China for the first time.
- Research and application advances in industrial heat pumps in China are discussed.
- Three typical examples of using industrial heat pumps are discussed in details.
- It identifies the further research needs on industrial heat pump in China.

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ABSTRACT

An industrial heat pump can upgrade heat from a low temperature level to a high temperature level with the aid of an external energy source. It has received considerable attention as an efficient means of waste energy recovery in the recent years in China. This paper summarizes the research work done and advances in the application of industrial heat pump systems in China, including advances in refrigerants, multistage system, double-effect absorption system, compression–absorption system, solar assisted system, and chemical heat pump system. Industrial heat pumps used in three industrial fields (drying of wastewater sludge, crude oil heating in oil field, and process heating in printing and dyeing) are discussed in detail. Three basic problems in designing an engineering heat pump system, i.e., selection of the type of heat pump and determination of its capacity, energetic and exergetic analyses of the heat pump, and estimation of investment payback time are discussed in the above three industries, respectively. Further research needs in China on industrial heat pumps are proposed, which may also be beneficial to the international community.

Contents

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Nomenclature

COP	coefficient of performance
P	input energy
Q	useful heat/heat transfer rate (kW)
W	work (kW)
T	temperature (°C)
m	mass flow (kg/s)
x	concentration of LiBr solution (%)
h	enthalpy (kJ/kg)
s	entropy (kJ/(kg K))
e	exergy (kJ/kg)
η	efficiency (%)

Subscripts

0	dead state
1, 2, 3...	state points in Fig. 25
A	absorber
G	generator
E	evaporator
C	condenser
SHX	solution heat exchanger
s	strong solution
w	weak solution
r	refrigerant
i	inlet stream
o	outlet stream

1. Introduction

With the increase in global energy consumption, energy issues and environmental problems are becoming increasingly prominent. At present, fossil fuels are the main sources of energy, and their depletion is a major challenge for humanity. In the year 2012, the global consumption of coal, which is increasing at the highest speed among all fossil fuels, increased by 2.5%; meanwhile, coal consumption in China contributed to more than half of the world's total consumption for the first time [1]. The consumption of large amounts of fossil fuels leads to a severe problem of environmental pollution, and China is now a large contributor to the greenhouse gas emissions. Faced with the problems of gradual exhaustion of fossil fuels and pollution of the environment, researchers are making efforts in two areas: developing new energy sources, especially renewable energy sources such as solar energy, wind energy, and tidal energy; and improving energy efficiency to reduce the consumption of fossil fuels and the pollution caused by their usage.

Process industries are some of the major consumers of energy; in China, they are the predominant consumers. The statistics of energy consumption in China during the year 2010 are shown in Fig. 1. It can be seen that the primary energy consumption of industry takes 71.1% of the total national energy consumption [2]. At present, the efficiency of energy utilization by the industries in China is lower than the world averaged, and more than half of the energy consumed in process industries is turned into the waste heat in the form of exhaust gases and waste water. It is estimated that only 30% of the waste heat is reused in China [3], which is one of the reasons for the low efficiency of energy utilization. The industrial high-grade waste heat can be reused for power generation. The large amount of low-grade waste heat, with low and moderate temperatures (up to a maximum of 100 °C), can be utilized with the help of a heat pump. Industrial heat pumps can recover the waste heat from industrial processes and transfer the heat from the low temperature medium to a high temperature medium with an aid of an external energy source. The high-

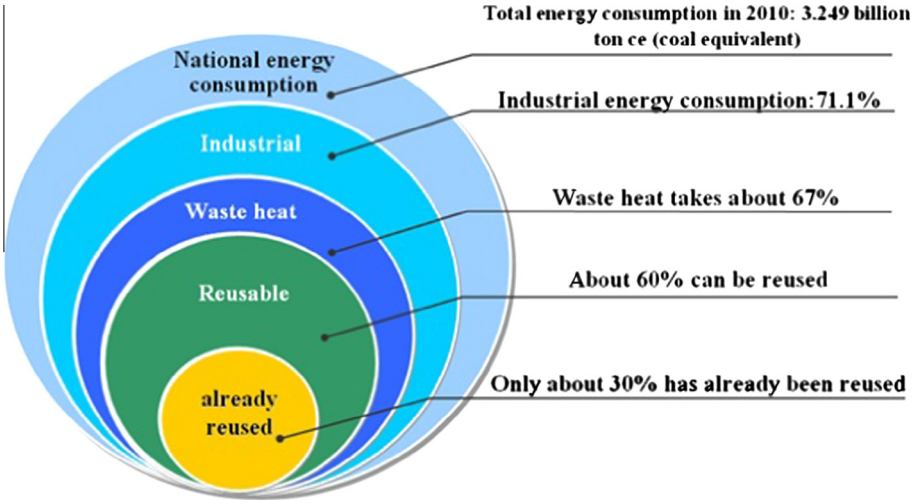

Fig. 1. An estimation of waste industrial heat in China [2].