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Compression–absorption cascade refrigeration system

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Abstract

This paper describes the study carried out to analyse a refrigeration system in cascade with a compression system at the low temperature stage and an absorption system at the high temperature stage to generate cooling at low temperatures, as well as the possibility of powering it by means of a cogeneration system. CO_2 and NH_3 have been considered as refrigerants in the compression stage and the pair NH_3–H_2O in the absorption stage. The analysis has been realized by means of a mathematical model of the refrigeration system implemented in a computer program and taking into account the characteristic operating conditions of a cogeneration system with gas engines. The paper presents the results obtained regarding the performance of the refrigeration system and the adaptability between the power requirements of the refrigeration system and the power supplied by the cogeneration system taking into account the present Spanish Regulations about the use of cogeneration systems.
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Keywords: Cascade refrigeration; Cogeneration; Compression; Absorption

1. Introduction

The integration of environmentally friendly refrigeration with cogeneration systems [1] appears to be an interesting option since it could lead to autonomous systems with on-site power generation independent from the electric grid [2].

In the refrigeration field there are applications which require the production of very high cooling power at low temperatures, such as freezing processes and cold stores for the storage of frozen products. Currently, different configurations of vapor compression systems of double stage with ammonia or synthetic refrigerants are generally applied to this type of applications. Two stage vapor compression systems in cascade are also considered in the general literature [3]. Moreover, recently the two stage compression systems in cascade with CO_2 as refrigerant in the low temperature stage are the object of important research and nowadays there are already several industrial and commercial installations successfully running [4,5]. However, the disadvantage of the compression systems in this type of applications is their high electricity consumption.

In this paper the analysis of an alternative refrigeration system that could reduce the electricity consumption in those applications is realized. The system is a two stages cascade that consists of a single stage compression system for the generation of the cooling power at low temperature and an absorption system in the high temperature stage, as shown in Fig. 1. Both systems share a heat exchanger, which operates simultaneously as the condenser of the compression system and as the evaporator of the absorption system. This refrigeration system would decrease the electricity consumption compared to the two stages compression systems, since it is only required to operate the compression system at the low stage; meanwhile the absorption system is driven by heat. Moreover, it could use environmentally friendly working fluids such as carbon dioxide or ammonia in

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Nomenclature

COP	coefficient of performance (–)
E	electrical power (kW)
EEE	equivalent electric efficiency (–)
P	pressure (Pa)
PE	primary energy per unit time (kW)
PER	primary energy ratio (–)
Q	heat (kW)
Q_0	cooling duty (kW)
T	temperature (°C)

Subscripts

a	absorption system
c	compression system
com	compression, compressor
con	condensation, condenser
el	electrical
eva	evaporation, evaporator
ex	extra
exh	exhaust gases
g	global
gen	generation, generator
h	heat
int	intermediate
lim	limit
max	maximum
minEEE	minimum equivalent electric efficiency
opt	optimal
p	pump
rec	recovered, reused
w	water

the compression stage and the pairs ammonia–water or water–lithium bromide in the absorption system.

Furthermore, this cascade refrigeration system could be integrated with a cogeneration system, since this would supply simultaneously the electricity to the compression system and the heat to the absorption system. At a first glance, it would bring an additional advantage, since the global system could be designed as a stand-alone device independent of the electric grid. However, making use of these benefits requires knowledge of the adaptability of the energy needs of the refrigeration system (electricity and heat) to the power distribution supplied by the cogeneration system.

Therefore, the objectives of the paper are twofold, on the one hand, to simulate and analyse the influence of the key design parameters and the operating conditions on the performance of the compression–absorption cascade refrigeration system, and on the other hand, to determine and evaluate the adaptability, from the viewpoint of the energetic requirements, between the refrigeration and the cogeneration systems. Moreover, the performance of the global refrigeration–cogeneration system is also obtained.

The analysis has been carried out using a mathematical model of the refrigeration system implemented in a computer program and taking into account the general performance of a cogeneration system employing gas engines. This has been defined according to the available literature data [6]. The energy adaptability between the cogeneration and the refrigeration systems is evaluated based on the current Spanish regulations [7] about the use of cogeneration systems. These regulations define the parameter named as Equivalent Electric Efficiency (EEE), which takes into account the electrical power generated, the heat recovered, and the primary energy

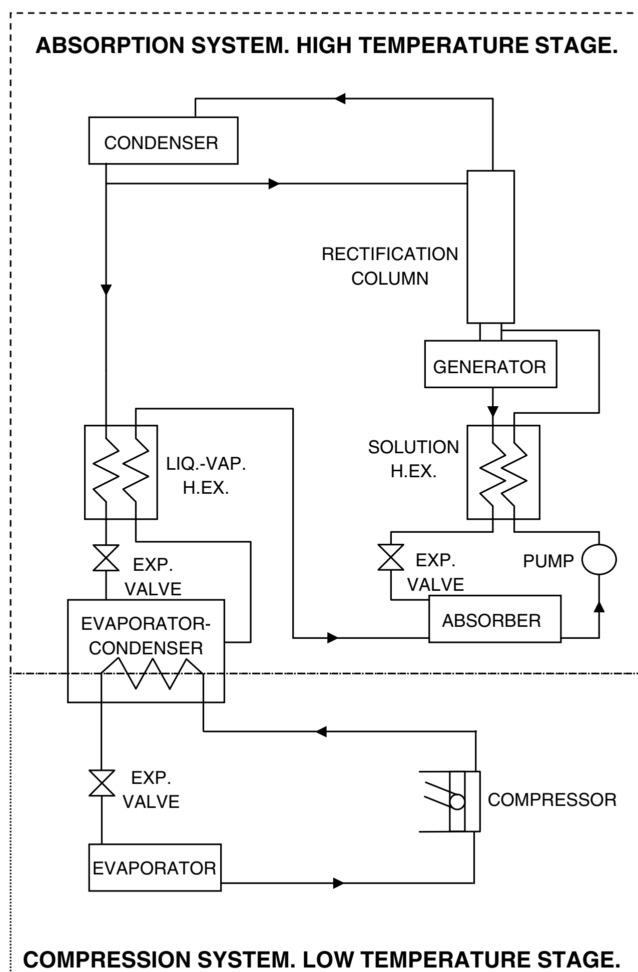

Fig. 1. Schematic diagram of the compression–absorption cascade refrigeration system.

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