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Thermodynamic feasibility study of absorption diffusion machine working with hydrocarbons

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ABSTRACT

We propose in this work a thermodynamic feasibility study of absorptiondiffusion refrigerating machine working with hydrocarbon mixtures. We used a machine of low power (300 W) that operates with generator temperatures lower than 150 °C (fossil energy or solar energy can be used) and where the condenser and absorber temperatures are taken equal to 42 °C. The inert gas used is helium and the total functioning pressure is about 17.5 bars. A modeling on suitable software was made to simulate the machine functioning for four binary mixtures which are: propylene/hexane, propylene/heptane, propylene/octane and propylene/nonane. The validation of our model was made by comparison with the results taken from literature and the optimal operating conditions are determined.

Introduction

The human tendency consists continuously in search of the comfort state and the field of the production of cold does not escape the rule, especially if we remember that 15% of the worldwide production of electricity is intended for the refrigeration [10].

In addition, today refrigerating industry is touched of full whip by the consecutive directives with the protocol of Montreal (1987) and with the agreements of Kyoto (1997) on the use of the refrigerants.

Indeed, the use of CFC (chlorofluorocarbons) is prohibited and the HCFC refrigerants (hydro chlorofluorocarbons) are subjected to an increasingly severe regulation because of their contribution to the destruction of the layer of ozone. They are also shown to contribute to the greenhouse effect and must be consequently used with prudence. It is in this general context some alternative research solutions are developed. The development of the absorption refrigeration technology that uses new fluids witch respect the environment presents an efficient solution to resolve this problem.

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Karamangil et al. [4] presented a literature review on the absorption refrigeration systems and the pairs of cooling agent currently used with their substitutes.

Moreover, they carried out a thermodynamic analysis of the absorption refrigeration systems using refrigerants usually met in the literature.

The numerical results showed that the system working with the $LiBrH_2O$ mixture has the higher energetic performance.

In other hand, Starace et al. [12] provided a parametric study of the diffusion absorption refrigerator without any assumption regarding the purity of the refrigerant. The study gives a better prediction of the real operation of the refrigerator.

Also, Ersoz [13] had given an experimental study of the effect of three different generators, heat inputs (62, 80 and 115 W) on the energy performance of the DAR cycle.

In another study, Zhenlong et al. [5] developed a numerical model for the simulation of TFE – TEGDME couple used as working fluid in an absorption–diffusion refrigeration system with two refrigeration vectors witch are water (with 32 °C) and the air (with 35 °C). It is noted that, the optimal temperature for the generation of TFE – TEGDME system (DAR) is about 170 °C and the coefficient of performance is up to 0, 45. On the other hand for a water cooling, the optimal temperature of generator is lower than 130 °C and a COP reaching to 0, 56.

By comparing the performances of TFE – TEGDME system and NH_3–H_2O system, Zhenlong et al. [5] concluded that mixture TFE – TEGDME is a good working fluid for DAR cycle.

Ben Ezzine et al. [7] carried out an experimental study of absorptiondiffusion machine cooled by the air and working with a binary of light hydrocarbons butane – nonane and helium as inert gas. The capacity of cooling is respectively in the order 0.40–0.47 kW and the temperature of cold water is about between 9 and 11 °C. According to Ben Ezzine et al., the cold is produced at temperatures between −10 and 10 °C for a temperature of control ranging between 120 °C and 150 °C.

In addition, they affirmed that the lowest temperature attack at the inlet of evaporator is about −10 °C; this value corresponds to a temperature of generator of 138 °C and for a machine power of 260 W.

Moreover the COP of the machine reaches a maximum of 0, 14 for a temperature of water equal to 9 °C and a power of 275 W.

Sayadi et al. [8] studied theoretically an absorption–diffusion machine cooled by water for a refrigerating capacity equals to 1 kW. This study is made by HYSYS software and the used fluids are the mixtures of light hydrocarbons (C_3/nC_6, C_3/cC_6, propyléne/cC_5, propyléne/iC_4, propyléne/iC_5) in combination with helium like inert gas.

The heat is supposed to be provided by a field of vacuum solar collector where its temperature reaches 121 °C and an evaporator exit temperature of 0 °C. The rate of flow of cooling water circulating between the coolers and the tower of cooling is of 140 L/h.

In another study, Bouaziz et al. [14] presented an energy and exergy analysis of a novel configuration of absorption cooling system operating. In their work, authors presented a double stage cycle operating with water-ammonia. Also, a thermodynamic model based on the energy and exergy balances is developed. The results of the study presented the performance of the novel configuration witch compared with the two stage conventional configuration.

Mbarek et al. [11] carried out an experimental study on a refrigerating machine functioning with absorption–diffusion cycle by using light hydrocarbons. The used couple is N-butane/octane with helium like an inert gas. According to the authors, for a power value of 270, 6 W, the evaporator temperature was about of 10 °C.

Dixita et al. [15] studied thorough analysis of water-ammonia generator-absorber-heat exchanger (GAX) and hybrid GAX (HGAX) absorption refrigeration cycles based on energy and exergy. In the aim to study the effect of generator temperature, condenser temperature and evaporator temperature, Dixita et al. [15] calculated the coefficient of performance (COP) and exergetic efficiencies at various operating conditions. It is observed that the increase in approach temperature from 0 °C to 14 °C causes decrease in COP of GAX cycle by 30% and of HGAX cycles by 40%–45%.

Hamed et al. [16] had predicted, analyzed and optimized the performance of the double-effect absorption system. Also it is required to predict the coefficient of performance (COP) and exergetic efficiency (ηex) of the system, and to formulate them in equations as functions of the operating parameters of the cycle. In this study, authors presented the energetic and exergetic performance of the double-effect absorption cycle for evaporator temperature range of 2–10 °C, absorber and condenser temperature range of 28–45 °C, and HPG temperature range of 100–200 °C, two equations, which are functions of the operating temperatures, have been developed to predict the performance of the cycle.

Dardour et al. [9] carried out the study of the absorption–diffusion machine performance using the mixture/n-nonane propane as working fluid and hydrogen as inert gas.

The results of this study showed that in mode of cooling by the water and in an interval driving heat temperature ranging between [110 °C–125 °C], the coefficient of performance is about 0.51, this value makes this couple competitive compared to certain working liquids used in marketed machines with absorption and allows him to be presented it as a form of a possible substitute.

In this context, our study aims to exanimate the use of mixtures of hydrocarbons like working fluids in the refrigerating machines operating according to an absorption–diffusion cycle. All the combinations of mixtures formed by the couples refrigerant/absorbent, following Table 1, are considered.

Table 1 – Binary of studied hydrocarbons.

Solvent	n-C_6H_{14}	n-C_7H_{16}	n-C_8H_{18}	n-C_9H_{20}
Solute	C_3H_6	C_3H_6	C_3H_6	C_3H_6