EFFECT OF AMMONIA/WATER RATIO IN THE PERFOMANCE ABSORPTION CHILLER

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I declare that this thesis entitled 'Effect of ammonia/water ratio in the performance absorption chillers' is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted candidature of any other degree.

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Special dedicated to my beloved father, mother and my whole family members

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ABSTRACT

The main objective of this study is to determine the coefficient of performance (COP) for absorption chillers. By using a reversible Carnot cycle process the optimum coefficient of performance (COP) and ammonia/water ratio are obtained. Gas Absorption Refrigeration Unit (Model: RF 10) is a complete laboratory bench top unit for the demonstration and analyze the performance on effect of ammonia/water ratio in performance for absorption chillers. In this experiment the refrigerant is anhydrous ammonia and the absorber is water. The ammonia/water ratios used are in the range of 5% to 30% ammonia in water base on volume percentage in the solution. Assuming the absorption unit has complete cycle and stable system after 8 hours and the performance of the absorption chillers unit is constant for each experiment the value of coefficient of performance COP is calculated for each hour depending on the refrigerant/absorber ratio. Then, the graph for value of coefficient of performance (COP) verses time (hour) is plotted and analyzed. The COP increased with increasing generator temperature and with decreasing absorber and condenser temperatures for all the systems. Also, the lowest temperature at the evaporator is important in order to control the temperature for all the system cycle that affects the value of COP in absorption chillers. In conclusion, the optimum ammonia/water ratios that obtained in this experiment are 30% ammonia purity with 2.97 coefficient of performance.

ABSTRAK

Tujuan utama penyelidikan ini ialah untuk menentukan nilai akan prestasi yang alat penyerapan kesejukan. Dengan menggunakan proses yang dapat berbalik Carnot jumlah maksimum nilai akan prestasi dan nisbah ammonia/air dapat diketahui. Selain itu, unit gas penyerapan kesejukan (Model RF 10) ialah alat makmal yang sesuai digunakan untuk menunjukkan dan menganalisis kesan nisbah ammonia/air kepada alat penyerapan kesejukan. Dalam penyelidikan ini ammonia bertidak sebagai bahan penyejuk manakala air sebagai bahan penyerap. Nisbah ammonia dan air yang digunakan adalah diantara 5% hingga 30% ketulenan ammonia mengikut peratusan isipadu larutan. Tambahan pula, dengan beraggapan alat penyerapan membuat kitaran lengkap dan sistem yang stabil selepas 8 jam serta, prestasi alat penyerapan kesejukan sama pada setiap penyelidikan nilai akan prestasi dapat dikira pada setiap satu jam yang bergantung pada nisbah bahan penyejuk dan bahan penyerap. Kemudian, graf nilai akan prestasi melawan masa (jam) dilukis dan dianalisis. Nilai akan prestasi akan meningkat sekiranaya suhu alat pembangkit tenaga bertambah serta penurunan suhu pada alat penyerap dan alat kondensasi. Juga, suhu yang rendah pada alat penyerap penting untuk mengawal suhu pada keseluruhan sistem yang mempengaruhi nilai untuk prestasi alat penyerapan kesejukan. Sebagai kesimpulan, jumlah maksimum nilai untuk prestasi nisbah ammonia/air adalah pada 30% ketulenan ammonia dalam larutan dengan nilai 2.97 nilai untuk prestasi.

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LIST OF SYMBOLS

g	-	Gram
L	-	Liters
ml	-	Milliliters
Q	-	Heat transfer
S.G.	-	Standard gravity
T	-	Temperature
W	-	Work
η	-	Efficiency

LIST OF ABBREVIATION

COP	-	Coefficient of performance
CFC	-	Chlorofluorocarbon
CHP	-	Combine Heat Power
DCC	-	Double condenser couple
HFMAE	-	Hollow fiber membranes absorber heat exchanger
PHEFFA	-	Plate heat exchanger falling film type absorber
DACM	-	Diffusion absorption cooling machine
VAR	-	Vapor absorption refrigeration
CGS	-	Co-generation systems
HFC	-	Hydro fluorocarbons
HCFC	-	Hydro chlorofluorocarbons
ODP	-	Ozone depleting potential
GWP	-	Global warming potential

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The absorption cycle is a process by which refrigeration effect is produced through the use of two fluids and some quantity of heat input, rather than electrical input as in the more familiar vapor compression cycle. Both vapor compression and absorption refrigeration cycles accomplish the removal of heat through the evaporation of a refrigerant at a low pressure and the rejection of heat through the condensation of the refrigerant at a higher pressure. The method of creating the pressure difference and circulating the refrigerant is the primary difference between the two cycles. The vapor compression cycle employs a mechanical compressor to create the pressure differences necessary to circulate the refrigerant. In the absorption system, a secondary fluid or absorbent is used to circulate the refrigerant. Because the temperature requirements for the cycle fall into the low-to-moderate temperature range, and there is significant potential for electrical energy savings, absorption would seem to be a good prospect for geothermal application. [1]

Absorption machines are commercially available today in two basic configurations. For applications above 32^{o}F (primarily air conditioning), the cycle uses lithium bromide as the absorbent and water as the refrigerant. For applications below 32^{o}F, an ammonia/water cycle is employed with ammonia as the refrigerant and water as the absorbent. [1]

Most commercial and industrial refrigeration applications involve process temperatures of less than 32^{o}F and many are 0^{o}F. As a result, the lithium bromide/water cycle is no longer able to meet the requirements, because water is used for the refrigerant. As a result, a fluid which is not subject to freezing at these temperatures is required. The most common type of absorption cycle employed for these applications is the water/ammonia cycle. In this case, water is the absorbent and ammonia is the refrigerant. [2]

Use of water/ammonia equipment in conjunction with geothermal resources for commercial refrigeration applications is influenced by some of the same considerations as space cooling applications. Because most commercial and industrial refrigeration applications occur at temperatures below 32^{o}F, required heat input temperatures must be at least 230^{o}F. It should also be remembered that the required evaporation temperature is 10 to 15^{o}F below the process temperature. For example, for a +20^{o}F cold storage application, a 5^{o}F evaporation temperature would be required. [1]

The performance of the absorption chiller define base on efficiencies of absorption chillers are described in terms of coefficient of performance (COP), which is defined as the refrigeration effect, divided by the net heat input (in comparable units such as kBtu). [2]

1.2 Problem statement

Absorption chiller systems have greater resource efficiency than similar compressor systems and electric system. Only about 5% to 10% of the fuel resource is lost with an absorption chiller system. Additionally, electricity costs per Btu are typically three to four times the cost per Btu for electricity, so the cost of a unit of output (refrigeration) can often be lower with an absorption unit. Utilizing waste heat that would otherwise be unused greatly increases the cost-effectiveness of the systems, compared to consuming gas directly. The absorption system is the used of non-ozone depleting and low global warming potential working fluid pair, the most common of which is ammonia-water. [2]

The disadvantage of ammonia/water absorption system is the temperature at evaporator is high compare to compression system and electric system. To ensure the absorption system can be competitive with compressor system, the effect of ammonia/water ratio to the temperature at evaporator of absorption chiller is studied and the efficiency of the system can be improved. Also, the coolest temperature at evaporator is important in order to control the temperature of the system

1.3 Objective of study

The objectives of this research are to study the effect of ammonia/water ratio to the coefficient of performance (COP) for absorption chiller system. By calculating the COP value for every ammonia/water ratio that use in absorption chiller, the optimum refrigerant/absorbent that give optimum performance and efficiency can be measured.

1.4 Scope of research work

The ammonia/water ratio uses in this study are in the rage of 5% - 30% ammonia in water based on volume percentage in the solution and the coefficient of performance (COP) is calculated using a reversible Carnot cycle process of absorption chiller as the main scope of this research. Gas Absorption Refrigeration Unit (Model: RF 10) is a complete laboratory bench top unit for the demonstration of gas absorption refrigeration. The unit is a continuous absorption refrigeration system operated by application of a heat source either electrically or furnished by fuel gas.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is explained about all the improvements to the problem of ammonia/water absorption chiller unit that have been done by other researchers. The improvement processes are including simulation and experimental study to increase the performance of main components of the absorption chiller unit. The effect of working fluids in absorption chiller unit and latest application of the ammonia/water system also discuss in this chapter.

2.2 Problem with ammonia/water absorption chiller

Lazzarin et al. (1996) analyzed of a large amount of data on the failures of absorption refrigeration machines of the ammonia water type was carried out. The data derive from the records of a 10-year maintenance contract under which every machine was installed. The records were computerized for the period 1989-1992, and they refer to sales starting from 1980 (i.e. to 73 778 machines). The failures are classified, identifying the most serious (generator and solution pump). The rate of early failures is rather high, but the failures are generally minor and easily repaired. The production quality was not constant, with a very bad year in 1984. The failure rate is evaluated for the first 10 years of life of the equipment. In general terms, one machine in two does not require any intervention during that period. [7]

2.3 Improvement absorption process

Swinney et al. (2000) published the use of composition with the mixed refrigerant to achieve a temperature lift has been examined. It has demonstrated theoretically how this may be achieved by using a series of equilibrium stages with counter current vapor/liquid contacting. These stages could be arranged in column format. A simple graphical analysis of the system along the line of a McCabe-Thiele construction for distillation has been presented for the case of a binary mixture. The possibilities of integrating the column into a closed cycle have been examined, along with the practical implications of this in term of energy requirement. Performance is shown to be comparable to conventional absorption refrigerant unit bearing in mind the possibility of recovering much lower level heat. The designer has considerable flexibility over the use of shaft power and recovered low level heat. Like all absorption refrigerant based systems, the new cycle is best suited to situations where waste heat at low temperature is readily available. [8]

Ezzine et al. (2004) developed a thermodynamic simulation model of an ammonia–water double effect, double-generator absorption chiller. The limits of the various operating parameters are given on the basis of the fundamental data. Simulation enabled the study of the influence of the various operating parameters on chiller performance. An analysis of the Second Law of Thermodynamics was applied to quantify the irreversibility of each component. Results indicate that the absorber, solution heat exchangers, and condenser have the greatest potential to improve the chiller’s energy efficiency. Also they indicate that focusing on irreversibility is a more direct way of analyzing the potential for improving the efficiency of an ammonia–water absorption chiller. [9]

Matthew (2005) reported a micro channel heat and mass exchanger was tested as a disrober for application in an ammonia water absorption heat pump in this study. The experiments were conducted to investigate the effects of solution flow rate, vapor fraction and glycol/water flow rates on the heat and mass transfer performance. A model was developed to predict the performance of the heat and mass exchanger on a segmental basis through the disrober. This model used heat transfer correlations and the heat and mass transfer analogy to estimate heat and mass fluxes on a segmental basis in the heat and mass exchanger. A parallel resistance network as well as knowledge of the segmental heat duty was used to estimate the fraction of wetted tube area in each segment. The experiments indicated that the solution flow rate has the largest impact on the overall heat transfer coefficient of the disrober. The overall heat transfer coefficient ranged from 388 to 617 W/m^2-K and the solution side heat transfer coefficient ranged from 659 to 1795 W/m^2-K over the solution flow rates tested. The segmental analysis of the process revealed that the wetting ratio of the tubes is a major determining factor in the performance of the disrober. Previous work on this geometry had shown that wetting fractions as low as 20-30% were limiting the performance. The model in this study indicates that the average wetting ratios ranged from 25-69%. This increase in wetting ratio is most likely due to the new fluid distribution system used in this study. To further reduce the negative effects of incomplete wetting, it is recommended that the vertical height of the disrober be limited. By limiting the height of the disrober, and increasing the horizontal dimensions of the disrober to maintain adequate heat transfer area, the wetting fractions can be maximized. While increasing the horizontal dimensions of the heat and mass exchanger will reduce the flow rate per length of tube, the lowered heat transfer coefficient resulting from the lower Reynolds number will be offset by the advantages of maintaining a higher wetting ratio over a larger portion of the heat and mass exchanger. The model also revealed that rectification of the vapor stream occurs in the upper segments of the disrober. The result of this is a vapor stream with a very high concentration of ammonia, requiring the actual rectifier to be much smaller than would otherwise be necessary with a co-flow disrober design. This geometry is ideally suited for the indirect firing of a disrober, for example, in waste heat recuperation for cooling.[10]

Byongjoo Kim, and Jongil Park (2006) proposed paper a lumped-parameter dynamic model of a single-effect ammonia water absorption chiller is developed based on the conservation of mass, momentum and energy. Ordinary differential equations are derived and the constitutive relations are solved numerically. The dynamic two-phase thermal-hydraulic characteristics and system performance are investigated during the start-up operation of a 10.5 kW absorption chiller. The parameters considered are the bulk concentration and the mass of the ammonia water solution filled, the volume of key components, and the stepwise turn-up and turn-down of the flue gas flow rate during the primary stage of the start-up period. The time constant decreases as the bulk concentration of the solution increases. The mass of the solution filled should be small for rapidly attaining its rated cooling capacity. Larger volume of generator results in a smaller time constant. Optimum levels on the volume of generator, the bulk concentration and the mass of the solution filled for attaining the maximum cooling capacity exists. The best combination of these parameters for the shortest time constant without damaging the cooling capacity very much is a low mass of the solution of a stronger concentration contained in a larger generator. However, it is not easy to satisfy the optimum condition and the time constant is still too large. Therefore a simple and practical control strategy for markedly decreasing the time constant is a stepwise turn-up and turn-down of the flue gas flow rate during the primary stage of the start-up period.[11]

Junghui Chen et al. (2006) studied an innovative hybrid absorber heat exchanger device using hollow fiber membranes (HFMAE) and mathematical simulation has been conducted for performance study for application to the ammonia water absorption heat pump. The device utilizes porous fibers for the heat and mass transfers between the absorption solution phase and the vapor phase, while nonporous fibers are used to facilitate the heat transfer between the absorption solution phase and the cooling fluid phase. Application as a solution-cooled absorber, in-depth comparisons of HFMAE and plate heat exchanger falling film type absorber (PHEFFA) are conducted by simulation. Internal profiles, including temperature profiles, composition profiles, heat fluxes and mass fluxes, are established. The comparisons of fluid phase heat and mass transfer coefficients of both devices reveal that the vast interfacial area feature of HFMAE is the major reason for achieving higher absorption performance. The sensitivity analyses indicate that the absorption solution phase mass transfer and the vapor phase heat and mass transfers are major factors affecting the performance of PHEFFA. However, for HFMAE, the only significant factor is the absorption solution phase mass transfer. The utilization of HFMAE as the solution-cooled absorber and the water-cooled absorber in a typical ammonia water absorption chiller is analyzed. The use of HFMAE is accompanied by the adjustment of sizes of other components. The vase interfacial area of HFMAE allows the system operation to be more closely approaching the thermodynamic equilibrium. The energy efficiency is hence improved through the reduction of the flow rate of circulating lean absorption solution. The flow rate reduction is 43%. The increase in COP attended is 14.8% and the reduction in overall system energy loss attended is 26.7%. Although the performance of using HFMAE has been investigated in this paper by mathematical simulation, further confirmation of the feasibility of HFMAE by experimental study is essential. The applicability of the existing heat transfer and mass transfer correlations of hollow fiber membrane modules for the condensation or evaporation of binary mixtures requires further experimental investigation. HFMAE can also be considered for using as other mass transfer components in the absorption heat pump, including rectifier and generator. However, due to the polymer material constraint, the application of HFMAE for rectifier or generator is only feasible when the operating temperature is lower, such as in the solar-driven systems. [12]

Jakob, and Eicker (2006) published result of solar thermal driven or assisted absorption cooling machines are gaining increasing importance due the continually growing demand for air-conditioning in residential houses as well as office and hotel buildings. Considering these circumstances, the Stuttgart University of Applied Sciences has developed and set up three single-effect hot-water driven, solar powered diffusion absorption cooling machine (DACM) each with a design cooling capacity of 2.5kW. The first prototype showed that the value of COP range from 0.1 to 0.2, and the evaporator cooling capacity could reach 1.5kW. However, the auxiliary gas circulation of the first prototype was not high enough, leading to fast saturation of evaporated ammonia. The second compacted prototype showed stable and continuous temperature and pressure