A LITERATURE REVIEW ON REFRIGERANT PERFORMANCE FOR COOLING EFFECT

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Abstract - *System energy consumption are related to refrigerants for prevent refrigerated foodstuffs in supermarkets from being discarded on hot days, an optimization strategy by the Model Predictive Control (MPC) is proposed theoretically and experimentally investigates on the application of refrigeration performance. Studies conducted in this thesis prove that the CO_2 systems investigated are efficient solutions for refrigeration. For this work has to investigate some literature to evaluate the performance of cooling effect on refrigerant.*

Key Words**:** *Refrigeration, cooling effect, refrigerant, charges, energy consume.*

1. INTRODUCTION

Properties of CO2 are significantly different from other conventional and natural refrigerants. It has low critical and high triple points with considerably higher operating pressures. The volumetric refrigerating effect is much higher, the pressure drop is much lower as well as the corresponding temperature drop, which permits the design of smaller components and more compact systems. CO2 is being investigated and/or applied in different areas, such as; mobile air conditioning, hot water heat pumps, and commercial refrigeration. It demonstrates good competitiveness with conventional and alternative technologies with the potential for implementation in other application areas as well.

In order to reduce the refrigerant charge, systems that use an indirect solution were applied. Systems' tightness has been improved due to taxes enforced on leaking HFC refrigerants. Finding alternative, environmentally friendly solutions for commercial refrigeration (for supermarkets, shops, large kitchens, etc.) and cold storage will lead to significant improvements in terms of protecting the environment. It accounts for about 28% (135576 tons/year) of the worldwide consumption of refrigerants which makes it the second largest consuming application after mobile air conditioning, which accounts for 31% [17].

The energy consumption of any alternative solutions should be kept as low as possible given that supermarkets are high energy consumers. Electricity consumption in large supermarkets in the US and France is estimated to be 4% of national electricity use (Orphelin&Marchio, 1997). In Sweden, approximately 3% of the national electricity consumed is used in supermarkets (Sjöberg, 1997). Natural refrigerants are seen as a potentially permanent solution where CO_2 is the one that fits best in supermarket applications, mostly due to safety reasons, as it can be directly used in public areas. However, the application where the use of CO_2 was first suggested after its revival and where most of the research work has been directed is in mobile air conditioning. On the other hand, hot water heat pumps were found to be a very interesting area of application and it has been widely applied on a commercial scale in Japan [16]

1.1 PROPERTIES

The main characteristic that distinguishes CO2 from other refrigerants is its critical point. It has relatively low temperature of 31.06°C and high pressure of 73.8 bars. The triple point is at 5.2 bars and -56.6°C, which means that the operation in the refrigeration cycle will always be higher than the 5.2 bars limit, below which solid CO2 will be formed. This implies that a refrigeration cycle using CO2 will have a high operating pressure and for high heat sink temperatures heat rejection will take place in the super-critical region. In the sub-critical region the pressure and temperature are coupled and this relationship is expressed in the saturation temperature pressure curve. Above the critical point this relationship does not apply, it becomes arbitrary where the pressure and temperature can be regulated independently.

The fluid no longer exists in the two phase mode, there is no distinction between liquid and vapour and the fluid can neither be called liquid nor vapour/gas. This state is referred to as supercritical fluid. Heat rejection in the super-critical region takes place at constant pressure and the temperature changes in a similar manner to the single phase. However, near the critical point the properties of the supercritical fluid change rapidly with temperature in isobaric processes and this should be taken into consideration when performing heat transfer calculations.

In terms of thermal behavior, several parameters suggest that CO2 will have good heat transfer properties compared to other refrigerants in the sub-critical region. It has a relatively high thermal conductivity for liquid and gas and a high specific heat. Close to the critical point the vapour density becomes close to that of liquid, which will have a strong influence in determining the flow patterns and may result in a more homogenous flow in CO2 compared to other refrigerants. Another important characteristic of heat transfer is surface tension. Low surface tension will make boiling of the refrigerant easier by requiring less superheat to initiate bubble formation. However, a negative effect may result from the low surface tension due to poor wetting of the relatively hot surface during boiling.

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1.2 LITERATURE REVIEW

Smyth et. al. describes direct expansion (DX) refrigeration technology is almost exclusively used in multi-temperature transport refrigeration systems. Multi-temperature systems use up to three evaporators, requiring large refrigerant charges and system pressure control to operate over a wide range of set-point conditions. Despite incremental design improvements over the past decade, environmental and control issues continue to arise with DX systems. Deployment of indirect refrigeration systems (IDX) offers an alternative approach to address these issues. Indirect systems can however suffer from performance penalties, where reduced cooling capacity and COP occur under certain operating conditions. One strategy, aimed at offsetting the disadvantage of reduced refrigeration capacity, is to incorporate an economiser circuit into the primary cycle of the IDX system. Economiser cycles can enhance the refrigeration effect of the primary refrigerant in the primary to secondary heat exchanger of the indirect system. [1]

Smyth et. al. describes an approach for control of an economiser cycle based on the use of economiser pressure as the primary control parameter. In the study, the economiser cycle was used to optimise a multi-temperature indirect (IDX) transport refrigeration system, where hydronic secondary loops were utilised. In transport refrigeration applications, IDX systems can offer the potential to address a number of important environmental and control issues associated with direct expansion (DX) systems. IDX systems may also give rise to reduced capacity and COP through increased compressor pressure ratios associated with the hydronic secondary circuit and power requirements of the liquid secondary pumps. One approach by which this issue can be addressed is through use of an economiser cycle, which provides a mechanism for performance enhancement by augmenting the refrigeration effect of the primary refrigerant, in the primary to secondary heat exchanger of these systems. Previous work ascertained that by control of the mass-flow injection ratio, an economiser cycle can be used to optimise indirect multi-temperature systems for a wide range of diverse operating conditions.[2]

Finn et. al. describes a mathematical model of the defrost process for a finned-tube air chiller, utilised as a heat exchanger in a secondary loop multi-temperature transport refrigeration system, where an antifreeze mixture is deployed as a sensible secondary working fluid. Two defrost modes are modeled: an electric mode which effects defrost by localised resistance heating of the chiller secondary working fluid, and a hot gas primary circuit mode that indirectly heats the secondary working fluid by means of a primary to secondary heat exchanger. The model, which was implemented using the Engineering Equation Solver (EES), is based on a finite difference approach to analyse the heat transfer from the secondary working fluid, through a single finned heat exchanger section, to the frost. An iterative scheme is used to integrate for the overall heat exchanger, taking into account temperature glide associated with the secondary working fluid. The overall heat exchanger model is incorporated within a system defrost model, which allows the entire defrost process to be modeled. [3]

Winkle et. al. has been growing in recent years due to the high direct global warming potential of common HFC refrigerants. Despite the environment-friendly characteristics of CO2 as a refrigerant, due to high heat rejection temperatures and transcritical operation, CO2 cannot match the high energy efficiency associated with current HFC technology. Thus, additional measures must be taken to achieve high COP when using CO2. One approach is to use CO2 as one of the fluids in a cascade system along with a HFC refrigerant as the high side fluid. Such systems may have roughly 75% less HFC refrigerant charge, and the global warming potential is reduced compared to a baseline system using only HFC refrigerant. When used as a second fluid in a cascade system, the CO2 cycle remains in the subcritical region, thus increasing the cycle's COP. In this paper an approach to model cascade systems is presented. The model is validated using experimental data for a R404A/CO2 cascade system and results are discussed. [4]

Yamasaki et. al. describes the transcritical refrigeration cycle utilizing CO2 as working fluid which is composed with Gas cooler, Intercooler, Suction Line Heat Exchanger, Capillary tube and Rolling Piston type 2-Stage CO2

Compressor. The adoption of the Inter cooler between 1st discharge and 2nd suction reduced the 2nd discharge gas temperature. The adoption of the Suction Line Heat Exchanger enabled to have a sufficient superheat of 1st suction. The adoption of capillary tube as an expansion device helped the system simplicity. [5]

Pfafferottet. al. presents the current results of the development of a Modelica library for CO2-Refrigeration systems based on the free Modelica library ThermoFluid. The development of the library is carried out in a research project of EADS Airbus and the TUHH and is focused on the aim of getting a library for detailed numerical investigations of refrigeration systems with the rediscovered refrigerant carbon dioxide (CO2). A survey of the concept of an integrated cooling system on-board of airliners, the used modelling language Modelica™ and the developed CO2-Library is given and the modelling of CO2-Heat exchangers is described. A comparison with steady state results of heat exchangers is presented showing a very good agreement. The presented transient simulation results show the expected trends, but the models have not yet been validated with transient experimental data. [6]

Zimmerman et. al. s focused on the evaluation of the performance of a single stage CO2 reciprocating compressor working on a beverage cooler application. A glass door merchandiser (GDM) was tested to develop a procedure to determine the best combination of capillary tube and refrigerant charge. Fin and tube heat exchangers were used both for the evaporator and the gas cooler. The criteria are choosing the combination was the total energy consumption of the system. The theoretical optimum discharge pressure was determined point by point during the “ON” period of the cycle and was compared to the experimental discharge pressure. The results showed that the closer profile to the optimum profile was the best in terms of energy consumption. The system was also tested with R134a and the results were compared showing 26% of energy savings in favor of the CO2 system. [7]

Rogstamet. al. obtained results allow the collection of detailed information on air and CO2 across the coil. The results have been compared with those obtained on our laboratory test bench and the agreement between the predictions and experimental data is very satisfactory. The analysis has been limited to the evaporator coil from the thermal hydraulics point of view. The recirculation ratio, N has been varied in the range 1 to 4 and corresponding heat transfer coefficients, internal pressure drop and saturation temperature variations have been obtained. Despite a substantial improvement in heat transfer due to recirculation (in the order of 180% for N=4), the coil capacity remained almost unchanged while pressure drop has considerably increased and the corresponding saturation temperature dropped. [8]

Z. Aidounet. al. have dictated the identification and the development of substitutes for the current synthetic refrigerants replacement. Carbon dioxide is a natural alternative suitable for medium and low temperatures. Heat transfer between the refrigerant and the refrigerated medium occurs in the evaporator, whose design must be adapted to take advantage of the favorable properties of carbon dioxide. This paper presents a mathematical model to study in detail a counter-current type air/CO2 coil with corrugated fins. The model applies the conservation equations for mass, momentum and enthalpy on small volume elements. The solution procedure of these equations is based on the Forward Marching Technique. The computed results allow for detailed information on the air and refrigerant states in the coil. Local results can be integrated to obtain global values for engineering purposes. It is possible to qualify tube rows by determining their individual capacities in terms of their location in the coil. Experiments have been performed on an experimental facility in CTEC-V Laboratories. Results from this installation as well as those collected from the open literature have been used to validate the developed model. [9]

Kemal et. al. proposed during the last 25 years automotive air conditioning (AAC) systems have significant development introduced by the industry and research institutes in the world to minimize the global warming threat to the environment. This paper reports the results of a study on the performance of an AAC system with measuring the compressor driving speed and the refrigerant leakage. For this purpose an experimental set up is designed and constructed to investigate the system performance. Although, the manufacturer’s recommended amount for the tests with R-134a as refrigerant was 750 g, the experiments were also carried out by selecting different amount of the same refrigerant charges to analyse the coefficient of performance (COP), the cooling capacity and the compressor power change with respect to the rotating speed of the compressor. The evaluation of experimental data revealed that the best cooling capacity was achieved at 500 g refrigerant charge. Although, while the charge level decreased 40% below or increased 20% above the 500g of the charge amount, cooling capacity loss increased up to 25% when optimum value of 500 g of the cooling refrigerant was utilized. The test results proved in each case that increasing the compressor driving speed cause almost a linear change in the corresponding power level. [10]

Brown et. al. evaluates performance merits of CO2 and R134a automotive air conditioning systems using semi-theoretical cycle models. The R134a system had a current-production configuration, which consisted of a compressor, condenser, expansion device, and evaporator. The CO2 system was additionally equipped with a liquid-line/suction-line heat exchanger. Using these two systems, an effort was made to derive an equitable comparison of performance; the components in both systems were equivalent and deference in thermodynamic and transport properties were accounted for in the simulations. The analysis showed R134a having a better COP than CO2 with the COP disparity being dependent on compressor speed (system capacity) and ambient temperature. For a compressor speed of 1000 RPM, the COP of CO2 was lower by 21% at 32.2 C and by 34% at 48.9 C. At higher speeds and ambient temperatures, the COP disparity was even greater. The entropy generation calculations indicated that the large entropy generation in the gas cooler was the primary cause for the lower performance of CO2. [11]

Yang et. al. performed for the trans critical carbon dioxide refrigeration cycles with a throttling valve and with an expander, based on the first and second laws of thermodynamics. The effects of evaporating temperature and outlet temperature of gas cooler on the optimal heat rejection pressure, the coefficients of performance (COP), the energy losses, and the energy efficiencies are investigated. In order to identify the amounts and locations of irreversibility within the two cycles, energy analysis is employed to study the thermodynamics process in each component. It is found that in the throttling valve cycle, the largest exergy loss occurs in the throttling valve, about 38% of the total cycle irreversibility. In the expander cycle, the irreversibility mainly comes from the gas cooler and the compressor, approximately 38% and 35%, respectively. The COP and energy efficiency of the expander cycle are on average 33% and 30% higher than those of the throttling valve cycle, respectively. It is also concluded that an optimal heat rejection pressure can be obtained for all the operating conditions to maximize the COP. [12]

1 .3 OBJECTIVE

The performance of the carbon dioxide Tran critical power cycle has been simulated and compared with the other most commonly employed power cycles in low grade heat source. At the beginning of this study, basic CO2 power cycles, namely carbon dioxide transcritical power cycle, carbon dioxide Brayton cycle and carbon dioxide cooling and power combined cycle were simulated and studied to see their potential in different applications (e.g. low-grade heat source applications, automobile applications and heat and power cogeneration applications).During the study, the work also involved studies in other parallel and related topics such as component design for COP. By identifying the strength and weakness points in CO2 system solutions it is possible to apply and test modifications to optimize the system for its best cooling effect. By comparing the experimental and theoretical it is possible to point out potential improvements in the experimental rigs, and thereafter, conclude upon good CO2 system. The study subsequently focused mainly on carbon dioxide Transcritical power cycle, which has a wide range of applications.

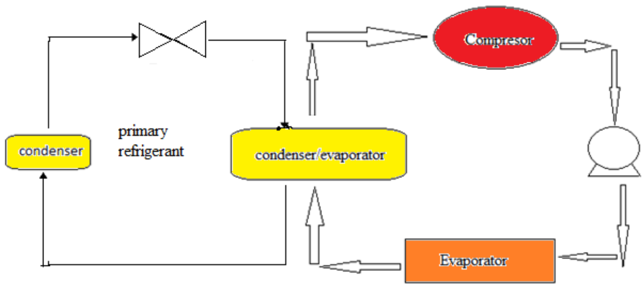

Fig 1-Basic CO_2 refrigeration circuit.

1.3. SUMMARY

Based on the results of the parametric analysis presented in the preceding sections, it will be possible to evaluate the performance with different system variations; thus the combination of variations which will give the best centralized system performance can be concluded. The COP is and presented as a percentage of improvement. The different modifications that can be applied to the system can be found in the schematic diagram in the following figure. The IHE used for low and high stages has an effectiveness of 50%; the design of the IHE is a tradeoff between heat transfer and pressure drop and this value is seen to be practically acceptable. Accordingly, this system is defined as the modified centralized solution due to it having the highest COP.

1.4 CONCLUSION

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1.5 FUTURE WORK

The simulation models used to evaluate the performance of CO2 systems can be refined by including detailed modeling of heat exchangers, especially the gas cooler/condenser. CO2 usually has a lower approach temperature difference in the gas cooler which may improve the system's COP compared to other systems. The centralized trans-critical solution should be evaluated experimentally in a similar way to that in which the cascade system has been tested.

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