PERFORMANCE ANALYSIS OF AN AIR CONDITIONING SYSTEM USING ROTARY COMPRESSOR

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JUDUL : PERFORMANCE ANALYSIS OF AN AIR CONDITIONING SYSTEM USING ROTARY COMPRESSOR.

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"I hereby declare that this thesis entitled 'Performance Analysis of an Air Conditioning System Using Rotary Compressor' is the result of my own research except those cited in references."

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Date : 2 FEBRUARY 2006

To my beloved wife,

Zue

To my baby,

Afiq

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First and foremost, all praise and thanks go to Allah s.w.t who has given me the strength and blessings to make it possible to complete this thesis title of **Performance Analysis of an Air Conditioning System Using Rotary Compressor**.

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ABSTRACT

The most air-conditioned vehicle is the automobile including car, busses, trains, trucks, recreational vehicles, air craft and ships. The major contributions to the cooling load in the transport are the heat from solar radiation and the heat from human especially in of public transport. The performance of car air conditioning system is driven by the rotation of RPM engine. The changes of rotation at high and low speed will give significant effect to the system. This project presents mathematical modelling and analysis computer simulation of car air conditioning systems with the four basic components consisting of compressor, condenser, evaporator and expansion valve. This air conditioning system will be using a rotary compressor with five sliding vanes. A computer simulation model has been developed and the effects of system performance are indicated by compressor speed, pressure ratios have been evaluated. The main objective of this work is to identify the performance of car air conditioning system using a rotary compressor .A FORTRAN programming was applied for the system modelling with R134a as the test refrigerant properties. For the validation of the perform a comparison study of this work with the previous experimental data to determine the accuracy of program as well to evaluate of the simulation results. The expectations of this project is to have an agreement between the simulation result and theory and these will be a fundamental to the future research from the aspect of the design compressor and the development of an air condition system.

ABSTRAK

Penyaman udara merupakan suatu sistem yang terdapat pada kebanyakan kenderaan seperti kereta, bas ,keretapi, pikap, kenderaan reaksi, kapal terbang dan kapal. Tujuan utama pengunaan sistem penyaman udara ini adalah untuk menyingkirkan haba yang terhasil daripada pancaran dan sinaran matahari. memandangkan penyaman udara pada kenderaan mengunakan kuasa putaran roda kuasa aci,jesteru itu, perubahan halaju putaran enjin akan mempengaruhi keupayaan kuasa dan prestasi sistem ini. Projek ini adalah untuk mengkaji permasalahan yang timbul melalui permodelan analisis matematik dan juga membuat suatu program komputer yang mengandungi komponen asas penyaman udara kereta seperti pemampat, pemeluwap, injap pengembangan dan juga penyejat. Sistem ini juga akan menggunakan pemampat berputar silinder oval yang mempunyai lima bilah. Tujuan utama projek ini adalah untuk mengenalpasti keupayaan prestasi sistem penyaman udara yang menggunakan pemampat berputar. Sistem simulasi ini mengunakan FORTRAN sebagai aturcara program dan R134a sebagai bahan penyejuk. Bagi tujuan penentusahkan keupayaan program, perbandingan telah dibuat dengan menggunakan data eksperimen. Maka dengan terhasilnya program simulasi penyaman udara ini, ia boleh digunakan sebagai rujukan dalam penyelidikan dan pembangunan pemampat dan juga sistem penyaman udara.

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NOMENCLATURE

A	Area, m^2
COP	Coefficient of performance, dimensionless
Cp	Specific heat, $kJ\ kg^{-1}$
h	specific enthalpy, $kJ\ kg^{-1}$
mr	refrigerant mass flow rate $kg\ s^{-1}$
N	compressor speed, RPM
n	polytrophic index, dimensionless
p	pressure, bar
Qc	heat rate rejection at condenser, kW
Qe	Refrigerant Capacity, kW
R	gas constant, $kJ\ kg^{-1}\ k^{-1}$
T	temperature, K
t	temperature , ^0C
AU	overall heat transfer coefficient, $kW\ k^{-1}$
WC	Compression work, kW
P	Compressor Power, kW
RPM	revolutions per minute

Greek letters

γ	Specific heat ratio $(cp=cv)$
η	Efficiency
ρ	Density $(kg\ m^{-3})$

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CHAPTER 1

INRODUCTION

1.1 Introduction

The largest application of refrigeration, which is the process of cooling, is in air conditioning. In the tropics an air conditioning system is widely used in vehicles such as cars, buses, trains, trucks, recreational vehicles, air craft and ships. Its main purpose is for comfort cooling as these vehicles are directly exposed to solar radiation and also receive heat from other source such as human being, engine and environment at higher temperature. The major contributions to the cooling load in the transport are the heat from solar radiation and the heat from human especially in of public transport. The performance of car air conditioning system is driven by the rotation of RPM engine. The changes of rotation at high and low speed will give significant effect to the system. According to the phenomenon, this project presents mathematical modeling and analysis computer simulation of car air conditioning systems with the four basic components consisting of compressor, condenser, evaporator and expansion valve. This air conditioning system will be using a rotary compressor with five sliding vanes because the capacity and the performance of compressor is better compare with other compressor. Computer simulation model has been developed and the effects of system performance are indicated by compressor speed, pressure ratios have been evaluated.

This thesis presents the computer simulation of car air conditioning systems. The class of equipment here studied is shown in figure 1.1. The system consists of the four basic components, namely the compressor, evaporator, expansion valve and condenser. This air conditioning system will using rotary compressor with five sliding vane manufactured by Patco Malaysia Berhad (table A.2).Many research endeavors have been pursued in the past few years aiming the numerical simulation of such systems. For the reason, the obtaining of general and flexible design methods is very important in the applications and the optimization of air conditioning system in order to take into account different aspects such as the Coefficient of the performance (COP), the characteristic of the rotary compressor and other components.

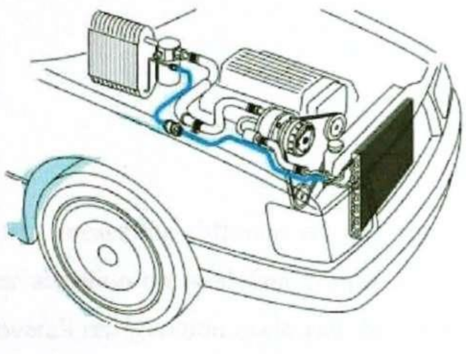

Figure 1.1: Car air conditioning system

1.2 Objective

The main objectives of this project are to determine and compare the performance of air conditioning system using rotary compressor. Car air conditioning is performed with compact compressor operating over large domain of rotation speed. On other hand, the mass flow rate and refrigerant capacity my have to be taken into account for low and higher speeds speed compressor. The compressor model is analysis with the mathematical models and simulated with a computer program. The simulation program will generate result to compare with previous experiment data and validate the accuracy and reliability program of air conditioning system being developed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The several works presenting different models can be found in scientific literature, focusing their attention on modeling typical vapor compression system, their components, the overall refrigeration cycle and their experimental comparison. Additionally, research work conducted by the research and engineering department of university is seldom openly published. The history literature review of air conditioning and refrigeration is shown in table 2.1.Research on performance of air conditioning system using rotary compressors can be broadly classified into 3 broad aspects.

2.2 Air Conditioning System

Davis (1972), the reference report shows the results were provided in the form of an in-car average temperature which compared well with hot room test data. The effect of solar loading and one occupant in the car during the actual test was incorporated in the computer simulation. To simplify the calculation, Cheng and

Davis neglected the pressure drop in the components and hoses. This would account for deviations between their results and with experimental data.

J.M. Saiz Jabardo, W. Gonzales Mamani, M.R. Ianella (2001) also studied on a steady state computer simulation model has been developed for refrigeration circuits of automobile air conditioning systems. An experimental bench made up of original components from the air conditioning system of a compact passenger vehicle has been developed in order to check the results from the model. Effects on system performance of such operational parameters as compressor speed, return air in the evaporator and condensing air temperatures have been experimentally evaluated and simulated of developed model. The results deviate from the experimentally obtained within 20% range though most of them are within 10% range. Effects of the refrigerant inventory also have been experimentally evaluated with results showing no effects on system performance over a wide range of refrigerant charges.

Other groups of researcher on the air conditioning system are M.Hosoz and M.Direk (2005), the reference report shows the study deals with the performance characteristics of an R134a automotive air conditioning system capable of operating as an air-to-air heat pump using ambient air as a heat source. The performance characteristics of an integrated automotive AC and air-to-air HP system using R134a as the working fluid have been experimentally evaluated. Based on the experimental evidence, the final conclusions reached in this study can be summarized as follows.

(a) Although the HP operation provides sufficient amounts of heat to the indoor air stream at mild weather conditions, the heating capacity would drop at more severe conditions due to both decreasing evaporating temperatures and activation of the capacity control system. Therefore, an air-to-air automotive HP must be considered only as a supplementary heating method to be used in energy efficient automobiles lacking waste heat.

(b) Both the heating and cooling capacities of the system increase with compressor speed, while the COPs for both cases decrease. Furthermore, the COPs for heating outperform the COPs for cooling due to the fact that the former takes into account the heat equivalent to the work of compression.

Shujun Wang, Junjie Gu, Tim Dickson, Jennifer Dexter, Ian McGregor(2005) also agree with the finding from other researcher, the reference report shows the results on the performance of an automotive air conditioning system with measuring the vapor quality. The total mass flow rate increases with the increase of refrigerant charge, evaporator air inlet temperature, and condenser water temperature also compressor speed. The total quality at the accumulator outlet increases with the increase of evaporator air inlet temperature, and decreases with the increase of refrigerant charge, condenser water temperature and compressor speed. The cooling capacity does not change with the variation of refrigerant charge, but increases with the increase of evaporator air inlet temperature and compressor speed, and decreases with the increase of condenser water temperature. COP of the system decreases with the increase of refrigerant charge, condenser water temperature and compressor speed, increases with the increase of evaporator air inlet temperature. The compression ratio decreases with the increase of refrigerant charge and evaporator air inlet temperature, increases with the increase of condenser water temperature and compressor speed. The change of compressor volumetric efficiency is opposite to the compression ratio.

Based on the research that had been done, Marcelo J.S de Lemos and Edson Luiz Zaparoli (1996) reported on the simulation of the "steady state operation of the four basic components of domestic refrigeration units". Based on individual mathematical models and appropriate input parameters, equilibrium conditions are numerically searched for all components. The simulation shows that using the different type of the refrigerant will affect pressure at condenser and evaporator, mass flow rate and also compressor discharge temperature.

2.3 Refrigerant Properties

I.Eames and M.Naghashzadegan (1996), reported on the computer program was written to calculate the cycle characteristic such as cooling capacity, coefficient of performance(COP),pressure ratio, system pressure and temperature, compressor power for design and part load performance which is also our base of comparison.

This paper investigates the use of ISCEON 49, a refrigerant blend R134a/R218/R600a (88%/9%/3%) which has thermo physical properties similar to those R12 and R134a. It is also compatible with compressor lubricants which the expansion valve does not need to replace and the fluid is non-flammable.

Other groups of researcher on the refrigerant properties are T.Kiasiriroat and T.Euakit (1996) also studied on the on the "Performance analysis of an automobile air-conditioning system with R22/R124/R152A refrigerant". A mathematical model of each component is developed and used to simulate the system performance. The system coefficient of performance (COP) and energy efficiency ratio (EER) increase with the reduction of the mass fraction of R22.

Based on the research that had been done, J. Steven Brown,Samuel F. Yana-Motta ,Piotr A. Domanski c,(2001) reported on the paper evaluates performance merits of CO_2 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 analysis showed R134a having a better COP than CO_2 with the COP disparity being dependent on compressor speed (system capacity) and ambient temperature. For a compressor speed of 1000 RPM, the COP of CO_2 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 calculations indicated that the large entropy in the gas cooler was the primary cause for the lower performance of CO_2.

2.4 Compressor

Chang. K.Y. (1983), the reference thesis shows that the low pressure air compressor in the form of air bellows were used in metallurgical processes about 5000 years ago, but there was a small development in compressor technology till 1770 when the first low air pressure compressor driven by water wheels was built .It was not only until around 1860 that high air pressure compressors (about 6 bars) were built. By 1888, there was widespread use of stationary air compressor both for domestic and industrial purposes. Since then, high pressure compressed air became the medium for energy distribution before the emergence of electricity distribution.

Eur.Ing.Ian M.Arbon,CEng (1994), the reference book shows that the function of a compressor is to take a definite quantity of fluid (usually a gas, and most often air) and deliver it at a required pressure. The most efficient machine is one which will accomplish this with the minimum input of mechanical work. Both reciprocating and rotary positive displacement machines are used for a variety of purposes. The two types by defining the reciprocating type as having the characteristics of a low mass rate of flow and high pressure ratios(up to 500 bar and above) and the rotary type as having a high mass rate flow and low pressure ratios. The pressure range of atmospheric about 9 bars is common to both types. Over the years a number of different types have evolved and there is now a wide variety of compressor, as shown in figure 2.1

2.4.1 Rotary Compressor

Whittaker Hall (1936), the history of rotary type compressor started with the development of the sliding vane compressor in 1930. This took the form of the Witting compressor design by R.S Witting and built and mass produced by Whittaker Hall in 1936.These machines operated at pressures up to 7 bar (100 lbf/in^2) using 2 stages, but were inefficient, losing most of the power through friction between the vanes and the stator. It was not until around 1946 that oil injection was introduced, a solution proposed by Major P.C. Bird. Thus started the age of the oil-flooded rotary sliding vane compressor produced by Alfred Bullows Ltd, and first mass produced by Whittaker Hall in 1952. Since then, developments have been made and continue to be made especially in the areas of increased operating pressure and increased flow.

(a) Mathematical Modeling and Computer Simulation

Maruyama (1982), reported on the "Capacity Control of Rotary Type Compressor for Automotive Air-Conditioners'. The journal is discussed about the