SIMULATION OF PERFORMANCE OF AIR CONDITIONING SYSTEM

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ABSTRACT

This thesis represents the simulation of performance of air conditioning system in the vehicle. The objective of this thesis is to analyze the relationship of performance of a car air-conditioning system and with variable speed of the compressor. The thesis describes the fundamental of air-conditioning system, the way the system works and brief explanation of each component involved in air-conditioning system. The simulation was done using Matlab Software to obtain the important parameters and data. The COP indicate the performance drop due to higher speed of the compressor. The speed of compressor affects the displacement volume of the refrigerant than affected the mass flow rate of the refrigerant and remain constant. Thus the cause of the mass flow rate make the cooling capacity slightly decrease when the speed of the compressor increases but for the power input of the compressor increases due to the increasing of the compressor speed. However the simulation does not consider the mass of the refrigerant. If the mass of the refrigerant is being considered it would give a better result for the simulation of the performance of the air conditioning system.

ABSTRAK

Tesis ini hanya merupakan simulasi prestasi sistem penghawa dingin di dalam kenderaan itu. Objektif tesis ini adalah untuk menganalisis hubungan prestasi sistem penghawa dingin kereta dan dengan kelajuan kompresor yang berbeza. Tesis menerangkan asas sistem penghawa dingin, sistem kerja dan penerangan ringkas setiap komponen yang terlibat dalam sistem penghawa dingin. Simulasi itu dilakukan menggunakan Perisian Matlab untuk mendapatkan parameter dan data yang penting. COP yang menunjukkan penurunan prestasi disebabkan kelajuan yang lebih tinggi kompresor. Kelajuan pemampat menjejaskan jumlah sesaran penyejuk daripada memberi kesan kepada kadar aliran jisim bahan penyejuk dan kekal malar. Oleh itu, menyebabkan kadar aliran jisim membuat kapasiti penyejukan sedikit menurun apabila kelajuan kompresor bertambah tetapi untuk kuasa masukan kompresor meningkat disebabkan peningkatan kelajuan kompresor. Walau bagaimanapun, simulasi ini tidak mengambil kira jisim bahan pendingin. Jika jisim bahan pendingin turut dipertimbangkan, ia akan memberikan hasil yang lebih baik untuk simulasi prestasi sistem penghawa dingin.

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LIST OF SYMBOL

A_0	Minimum flow area across TXV orifice
COP	Coefficient of performance
DV	Displacement volume
h_1	Enthalpy at point 1
h_2	Enthalpy at point 2
h_3	Enthalpy at point 3
h_s	Enthalpy suction of compressor
h_d	Enthalpy discharge of compressor
h_e	Enthalpy inlet of evaporator
k	Ratio of ideal gas specific heat for R-134a
m	Mass flow rate of the refrigerant
m_{leak}	Mass flow rate of leakage
n	Speed of compressor
np	Polytropic exponent
F_{leak}	Leakage force
P_1	Pressure at point 1
P_2	Pressure at point 2
P_4	Pressure at point 4
P_{low}	Pressure at low side
P_{high}	Pressure at high side
P_s	Pressure suction of compressor
P_d	Pressure discharge of compressor
Q_{low}	Heat transfer at low side

Q_{high}	Heat transfer at high side
Q	Cooling capacity at evaporator
T_{low}	Temperature at low side
T_{high}	Temperature at high side
T_s	Temperature suction of compressor
T_d	Temperature discharge of compressor
v_s	Specific volume suction of compressor
w_c	Work done by the compressor
W	Power input of compressor
W_{shaft}	Work done by the shaft
W_{comp}	Work done by the compressor
W_s	Work done at the suction of compressor
W_d	Work done at the discharge of compressor
η_m	Mechanical efficiency
η_v	Volumetric efficiency
ΔP_s	Pressure drop at suction compressor
ΔP_d	Pressure drop at discharge compressor
ε_{cv}	Clearance volume fraction

LIST OF ABREVIATION

MFCV	Mass flow compensation valve
FOV	Fixed orifice valve
TXV	Thermostatic expansion valve
SAE	Society of Automotive Engineers

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The air conditioner is functioning as the mechanism to transfer heat from a vehicle to the surrounding. Due to this system it helps to maintain the low temperature condition in the vehicle to prevent from high temperature condition.

In this project, it focuses on to do the simulation of the performance of an air-conditioning system in car using Mathlab software. The simulation include in the modeling of the various components of the system, namely, the fan coil unit and the refrigeration unit. All the data will get from the simulation and will be calculated automatically in the software. The purpose of the calculation is to get the performance of an air-conditioning system in the car. The coefficient of performance, heat absorbs within evaporator and the work done by compressor are measured and analyzed with the variation of compressor speed and period of time.

Generally the functions of the air-conditioner are:-

i Temperature control

Air-conditioner controls the temperature inside the passenger compartment by adjusting the measurement device, according to the passenger needs.

ii Air circulation control

The air-conditioner will absorb air inside passenger compartment, filter it and blow back inside passenger compartment.

iii Humidity control

Air-conditioner controls the humidity inside the passenger compartment to make sure humidity level is in comfort state.

iv Air purification

Air-conditioner filters air, from dust and bacteria, either from passenger compartment or outside car before it is blown back inside passenger compartment.

1.2 PROBLEM STATEMENT

The performance of the air-conditioning system can be described as to define the efficiency of the system. The high efficiency of the system acquired low in power consumption but high in its performance. For air-conditioner, high performance can be achieved when the compressor consumes a low power but evaporator can absorb more heat from the passenger compartment.

Important data to measure the system’s performance are temperature, pressure, total flow rate and humidity for every component. All of this data are used to complete the calculation to determine the system’s performance using computerize calculation or manual calculation.

1.3 OBJECTIVE OF PROJECT

The objective of the project is to analyze the relationship between performance of air-conditioning system and speed of compressor by manipulates the variable of compressor speed through time.

1.4 SCOPE OF PROJECT

The scopes of this project are:

i Simulate the performance of the air-conditioning system using computer software.

ii To analyze power input, W cooling capacity, Q and coefficient of performance, COP of the air-conditioning system due to the speeds of the compressor.

iii Range of compressor speed is between 1500 rpm until 5250 rpm.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

This chapter will be discussing about literature review of air conditioning system. The literature review including about the theory of air conditioning system, the basic function of each component of car air conditioner and mathematical model of the performance of air conditioning system.

2.2 AUTOMOTIVE AIR CONDITIONING SYSTEM

The automotive air conditioning system used the process that's been described in earlier subtopic to move heat from the passenger compartment to the condenser and then to the ambient air moving through the condenser. However the heating system used the reverse of the process that's been described in earlier subtopic to move heat from the engine’s cooling system to the passenger compartment.

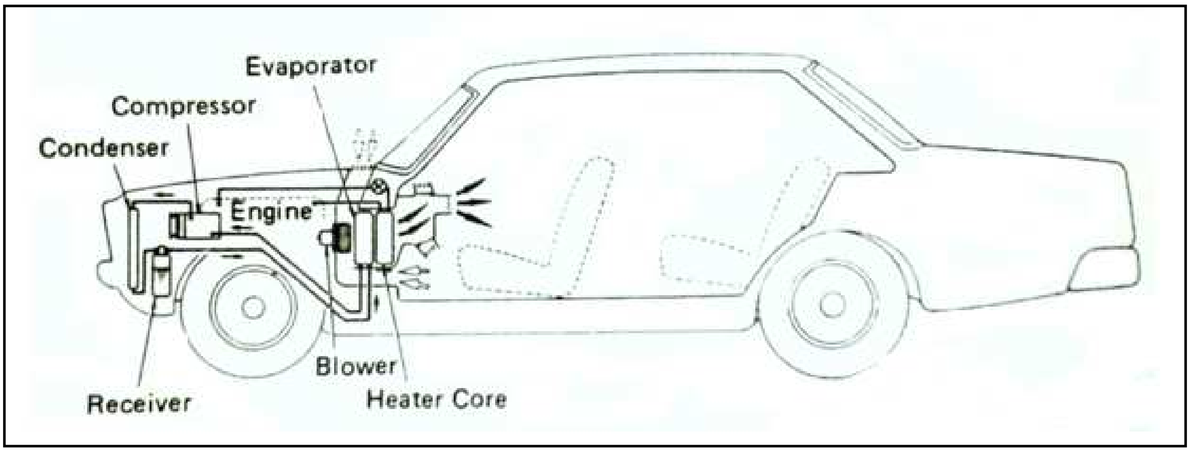

Figure 2.1: Air is circulated through the air conditioning and heating system and the car to either add or remove heat

Source: Birch, T.W, 2003

Automotive air conditioning system is depending on which type of flow control or expansion device is used. Air conditioning system can be easily divided into two parts which are the low side, with its low pressure and temperature, and the high side, with its high pressure and temperature (Birch T.W, 2003).

2.2.1 Low Side Operation

When the air conditioning system is in full operation, the goal of most systems is to maintain an evaporator temperature just above the freezing point of water, 0^oC. This temperature produces the greatest heat exchange without ice formation on the evaporator fin.

The cold temperature in the evaporator is produced by boiling the refrigerant. The refrigerant which is R-12 and R-134a have very low boiling point, well below 0^oF, and then when a liquid boils, it absorbs a large amount of heat, the latent heat of vaporization. To produce cooling, liquid refrigerant must enter the evaporator, and it must boil inside the evaporator. The amount of heat an evaporator absorbs is directly related to the amount of liquid refrigerant that boils inside it.

Warren, F, 2004 state that a properly operating evaporator has a temperature just above 32^{o}F, and refrigerant pressure is directly related to temperature because the refrigerant is a saturated vapor. An evaporator that has a low pressure but the temperature is too warm is called starved which mean the refrigerant that entering the evaporator does not enough to produce the desire cooling effect. If the pressure is higher than normal this mean that the evaporator is having flood which is the refrigerant that enter the evaporator is too much.

Major component in the low side is the evaporator and the expansion device. The evaporator is the heat exchanger that absorbs heat from the passenger compartment. The low side begins at the refrigerant expansion or flow metering devices, which produce a pressure drop. The low side end of the compressor, which causes the pressure to increase.

2.2.2 High Side Operation

The high side of an air conditioning system takes the low-pressure vapor from the evaporator and return high-pressure liquid to the expansion device. To do this, the compressor must raise the pressure and concentrate the heat so that the vapor temperature is above ambient (Warren, F. 2004). This causes heat to flow from the refrigerant to the air passing through the condenser. Removing the heat from the saturated vapor causes it to change state, to a liquid.

Major component in high side is the compressor and the condenser. The condenser, like the evaporator, is a heat exchanger. The high side begins at the compressor and ends at the expansion device.

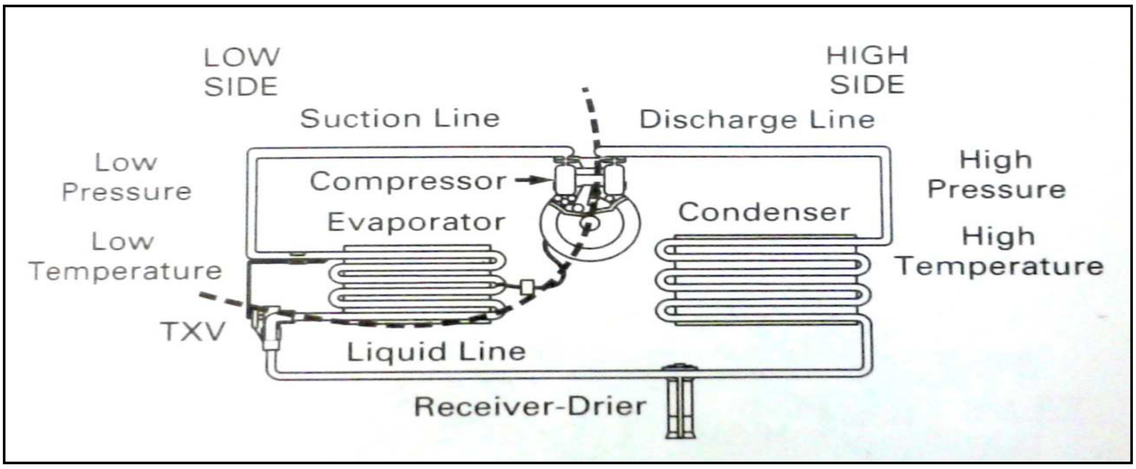

Figure 2.2: The high and the low side of the air conditioning system are divided by the compressor

Source: Warren, F. 2004

2.3 AUTOMOTIVE AIR CONDITIONING COMPONENT

In an air conditioning system, there are four major components that run the system from one process to another process. These components are compressor, condenser, expansion device and evaporator. In automotive applications, one component must be added to the air conditioning system which is receiver drier to make sure the refrigerant that flow to the expansion device fully in vapor phase each component in the automotive air conditioning system will be discussed in the next section of this chapter.

2.3.1 Compressor

The function of the compressor is to compress and circulate the superheated refrigerant vapor around a closed loop system (any liquid or dirt will damage the compressor) (Rajoli, N.M.M. 2008). Compressor varies in design, weight, size, rotational speed and direction, and displacement. Some compressors are variable displacement and some are fixed. The compressor uses about 80% of the energy required to operate an air conditioning system (Rajoli, N.M.M. 2008). This means that the compressor used in the system will determine the overall efficiency of the system.

Figure 2.3: Automotive air conditioning compressor

Source: Rajoli, N.M.M. 2008

Operation:-

In automotive air conditioning, the compressor as shown in Fig. 2.5 is driven by an engine driven pulley system. At the front of the compressor is a magnetic clutch which when given power engages the compressor. The compressor draws in refrigerant vapor from the suction side which is the outlet of the accumulator (fixed orifice valve system) or the outlet of the evaporator (expansion valve system)(Rajoli, N.M.M. 2008).

Types of Compressor:-

In book of Automotive Heating and Air Conditioning written by Birch, T.W. 2003 stated that there are three types of compressor which are :-

i Rotary
ii Reciprocating
iii Oscillating

2.3.2 Condenser

The function of the condenser is to act as a heat exchanger to dispel the heat energy contained in the refrigerant (Birch, T.W, 2003). Superheated vapor enters the condenser at the top and the subcooled liquid leaves the condenser at the bottom.

The pressure and temperature have been raised by the compressor. There is a need to lower the temperature to change it back into liquid enabling it to act as a cooler again in the system. To accomplish this, the refrigerant flows into the condenser as a vapor and gives off to the surrounding area and most of the refrigerant (depending on the system load) condenses back into liquid which then flows into the receiver or drier.

In automotive applications, the condenser as shown in Fig. 2.6 is located at the front of the vehicle (in front of the radiator) where strong air flow through its core can be achieved when the vehicle is in motion. To aid the removal of heat when the vehicle is stationary of at low speed, the condenser is fitted with a single or double fan system.

Figure 2.4: Automotive air conditioning condenser

Source: Rajoli, N.M.M. 2008

2.3.3 Expansion Device

To control the amount of refrigerant volume flowing through the evaporator, a metering device as shown in Fig. 2.7 must be used. S had been stated by Birch, T.W. 2003 in his book that the function of metering device is as follows:

i To separate the high pressure and the low pressure side of the system.

ii To meter the volume of refrigerant and hence the cooling capacity of the evaporator.

iii To ensure that the superheated refrigerant exiting the evaporator.

Currently there are two main categories of metering device used which are:

i Thermostatic Expansion Valve (TXV)

ii Fixed Orifice Valve (FOV)

Figure 2.5: Automotive air conditioning thermostatic expansion valve (TXV)

Source: Rajoli, N.M.M. 2008

2.3.4 Evaporator

The evaporator as shown in Fig. 2.8 is very similar in construction to a condenser. The function of an evaporator is to provide a large surface area to allow the warm often humid air to flow through it releasing its heat energy to the refrigerant inside (Birch, T.W, 2003).

The ideal temperature of the evaporator is 32^0F. The refrigerant by this time will have a large pressure and temperature drop coming through the expansion/fixed orifice tube valve causing it to want to boil and just requiring the heat energy to do so. The evaporator absorbs the heat energy from the air flowing over its surface. The energy is transferred and the refrigerant reached saturation point. At this point the refrigerant can still absorb a small amount of heat energy. The refrigerant will do so and become superheated. The superheated refrigerant will then flow to the compressor (TXV system) or the accumulator (FOV system) (Birch, T.W, 2003).

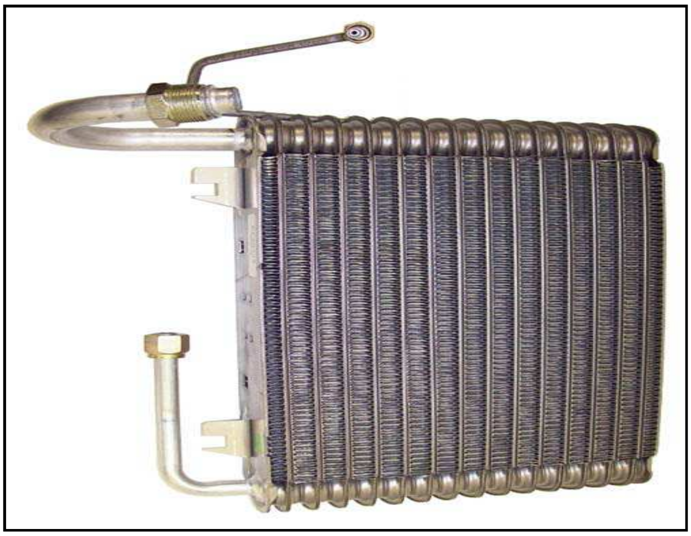

Figure 2.6: Automotive air conditioning evaporator

Source: Rajoli, N.M.M. 2008

In automotive applications, evaporator is located inside the heater box in the vehicle. The benefit of the evaporator is dehumidification. S warmer air travels through the aluminum fins of the cooler evaporator coil, the moisture contained in the air condenses on its surface. Dust and pollen passing through stick to its wet surfaces and drain off to the outside. On humid days you may have been this as water dripping from the bottom of your vehicle. Rest assured this is perfectly normal.