Design and Matching of Components for Air Conditioning in Non Air Conditioning Vehicle

C.Kannan[1] | M.Murugesan[2] | P.Prabakaran[3] | C.Sakthi[4] | K.Sambulingam[5]

[1](Department of Mechanical Engineering,Professor,Christ the king engineering college,karamadai,Coimbatore)

[2](Department of Mechanical Engineering,Professor,Christ the king engineering college,karamadai,Coimbatore)

[3](Department of Mechanical Engineering,Student,Christ the king engineering college,karamadai,Coimbatore-641104, India, Praba13895@gmail.com)

[4](Department of Mechanical Engineering,Student,Christ the king engineering college,karamadai,Coimbatore-641104, India, sakthi.crish@gmail.com)

[5](Department of Mechanical Engineering,Student,Christ the king engineering college,karamadai,Coimbatore-641104, India, samkrishnan05@gmail.com)

Abstract**—***In the present scenario the air conditioning for automotive is an essential requirement. In present day, the global warming rate increases rapidly due to the increased number of vehicles and industries. In order to provide a human comfort by controlling the temperature of cabin, the automotive air conditioning system is provided. The design of air conditioning system for automotive includes, various cooling load calculations such as metabolic load, radiation load, etc., While designing the air conditioning system for automotive, the fuel economy is an important factor which must to be considered. The fuel economy of vehicle can be increased by replacing the reciprocating compressor by rotary compressor. In this project, the design of air conditioning system is done for Maruti Suzuki 800 car.*

Keywords— Automotive, Air conditioning, Cooling loads, Fuel economy.

1. INTRODUCTION

Most of the automotive air conditioning system works based on the principle of vapour compression refrigeration (VCR) system while some others are works based on vapour absorption refrigeration (VAS) system. In the present, the air conditioning system for Maruti Suzuki 800 is designed based on the VCR system and the suitable compressor is selected, in order to demonstrate the fuel economy of engine. The cooling load calculations of air conditioning system are described briefly below. The various cooling loads involved are shown in the figure below.

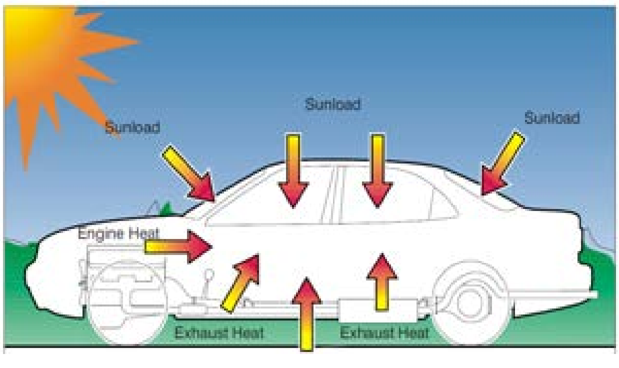

Fig1. Cooling loads employed in cars

2. COOLING LOAD CALCULATIONS

Metabolic load (QMet)

Metabolic load is the amount of heat generated due to the functions of human body. It can be calculated by

$$QMet = \sum Passenger*M*ADU$$

Where, M is the metabolic heat rate of human body. Generally it is given by for driver = 85 W/m2 and for sitting passenger = 55W /m2 (From tabulated values of ISO 8996 ASHRAE HANDBOOK OF FUNDAMENTALS2005). ADU is the body surface area.

Direct radiation load (QDir)

It is used to describe the solar radiation travelling on straight line from the sun down to the surface of the earth. It is given by

$$QDir = \sum Surfaces*S*\tau*IDir*Cos\Theta$$

Where, S is the surface area and τ is the transmissivity of the material and Θ is the angle between the surface normal and the position of sun and iDir is the direct radiation heat gain per unit area and is given by

$$IDir = A/ \exp (B/\sin\beta)$$

Where, β is the altitude angle and it can be calculated by

$$\sin\beta = \cos l \cos d + \sin l \sin d$$

Where, l is the latitude and d is the declination angle.

Diffuse radiation load (QDif)

It is used to describe the sun light that has been scattered by molecules and particles in the atmosphere but that has still made it down to the surface of earth. It can be calculated by

$$QDif = \sum Surfaces*S*\tau*IDif$$

Where, iDif is the diffuse radiation heat gain per unit area and is calculated by

$$IDif = C*IDir*(1+\cos\sum)/2$$

Where, C is the diffuse radiation factor and ∑is the surface tilt angle from horizontal surface.

Reflected radiation load (QRef)

Reflected radiation load is the part of the radiation load which is reflected by the ground and strikes the surface of the vehicle and is calculated by

$$QRef = \sum Surfaces*S*\tau*IRef$$

Where, iRef is the reflected radiation heat gain per unit area and is calculated by

$$IRef = \rho g*(IDir + IDif)*(1-\cos\sum)/2$$

Where, ρg is the ground reflective co-efficient

Ambient load (QAmb)

The exterior convection, conduction and interior convection causes the heat transfer between the ambient and the cabin. It is calculated by

$$QAmb = \sum Surfaces*S*U*(Ts-Ti)$$

Where, Ts is the average surface temperature, Ti is the average cabin temperature and U is the overall heat transfer co-efficient of surface and it can be calculated by

$$U = 1/ ((1/ho) + (\lambda/k) + (1/hi))$$

Where, λ is the thickness of the material, k is the thermal conductivity of the material and h is the heat transfer co-efficient.

$$h = 0.6+6.64\sqrt{V}$$

Where, V is the vehicle speed.

Exhaust load (QExh)

Because of the high heat of the exhaust gas some of the heat is transferred to the cabin through the cabin floor. It can be calculated by

$$QExh = S*U*(Texh-Ti)$$

Where, Texh is the exhaust temperature of the vehicle and is calculated by

$$Texh = 0.138RPM-17$$

Ventilation load (QVen)

The introduction of outdoor air for ventilation of conditioned space is necessary to supply the correct oxygen level inside the space to dilute the odours given by people. The heat added due to ventilation is given by,

$$QVen = mVen*(eo-ei)$$

Where, eoand ei are enthalpy of outside and inside air and is calculated by,

$$e = 1006T+ (2.501*106+1770T) X$$

Where, T is the air temperature and X is the humidity ratio.

AC load (QAC)

For summer season, the negative AC load is required for the cabin and is given by,

$$QAC = - (QMet+QDir+QDif+QRef+QAmb+QExh+QVen) - ((maCa+DTM) (Ti-TComf)/ tc)$$

Where, dtm is the deep thermal mass and tcomf is the comfort temperature and tcis the overall pull down time.

3. COMPRESSOR SELECTION

Compressor Selection Criteria for Automotive Air Conditioning System

While selecting the compressor for automotive air conditioning system the following factors should be considered. They are,

1. Power consumption
2. Maintenance
3. Initial cost
4. Refrigerating capacity required.

Types of Compressors used in Air Conditioning System

There are mainly three types of compressors are used in refrigerating system. They are

1. Reciprocating compressors
2. Rotary compressors
3. Centrifugal compressors

Comparison of Reciprocating and Rotary Compressors

Table1. Comparison of Reciprocating and Rotary Compressors

Type of compressor	Reciprocating	Rotary
Refrigerant	R134a	R134a
Power consumption	High	Low
Maintenance	High	Less
Initial cost	Less	High

Fuel Consumption While using Reciprocating and Rotary Compressors

For Reciprocating Compressor (SDH11 model)

Table2. SD5H11 model Reciprocating Compressor's specification

Compressor speed	2000rpm
Power consumption	2200watts
Refrigerating capacity	10263BTU/Hr

Brake Specific fuel consumption (BSFC)

TheBrake Specific fuel consumption of an engine while using the AC system can be calculated by,

$$BSFC = mf / (BP-P)$$

Where, mf is the mass of fuel consumed per hour, BP is the Brake Power of an engine and P is the power consumed by compressor.

For Rotary Vane Compressor (4912 model):

Table3. 4912 model Rotary Vane Compressor's specification

Compressor speed	1300rpm
Power consumption	2163watts
Refrigerating capacity	11000BTU/Hr

Brake Specific fuel consumption (Bsfc):

TheBrake Specific fuel consumption of an engine while using the AC system can be calculated by,

Bsfc = mf / (BP-P)

Where, mf is the mass of fuel consumed per hour, BP is the Brake Power of an engine and P is the power consumed by compressor.

4. RESULTS AND DISCUSSION

COOLING LOAD CALCULATIONS

The cooling load calculations for Maruthi Suzuki 800 car In summer season is

Table4.Cooling load calculations

Type of load	Loads in watts
Metabolic load	-595.096
Direct radiation load	-1883.876
Diffuse radiation load	-309.269
Reflected radiation load	-87.091
Ambient load	-208.031
Exhaust load	0
Ventilation load	-232.92
AC load	-3475.033

AC load (QAC)

QAC = -3475.033 watts = 0.99 TR ~ 1TR

= 12000 BTU/Hr.

The air conditioning system should produce the cooling load of 12000 BTU/Hr.

FUEL CONSUMPTION

Table5. Fuel consumption of vehicle while using reciprocating and rotary compressor

TYPE OF COMPRESSOR	RECIPROCATING	ROTARY VANE
RPM	2000	1300
Power consumption	2200 watts	2163 watts
Refrigeration capacity	10263 btu / hr	11000 btu / hr
Fuel economy	0.039367 kg / kw hr	0.039309 kg / kw hr

From the above table, it is obvious that the fuel economy of vehicle while using the rotary vane compressor is high compared to the reciprocating type compressor, since it is a best option to use a rotary vane type of compressor.

CO-EFFICIENT OF PERFORMANCE

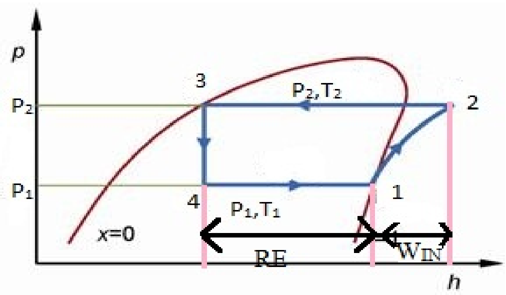

Fig.2. Ph diagram

(COP) AC = Refrigeration effect/ Work input

= (h1-h4)/ (h2-h1)

Table 6 COP of reciprocating and rotary vane compressor

	Reciprocating	Rotary vane
COP	3.9	3.3

MASS FLOW RATE OF REFRIGERANT (mRef)

For rotary vane compressor

mRef = Total tonnage capacity in (KJ / min) / Refrigeration effect

= (1.5*3.5*60) / (387.48-256.35)

mRef = 2.402 kg / min

PSYCHROMETRIC CHART

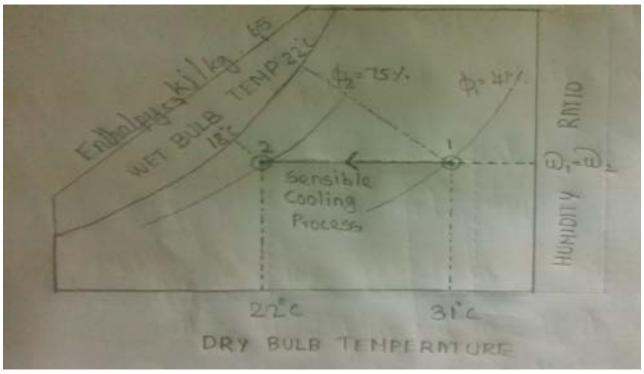

Fig.3. Psychrometric chart for sensible cooling process

Bypass factor (BPF)

BPF = Temperature difference between coil and exit air / Temperature difference between coil and entering air

$= (T_C - T_2) / (T_C - T_1)$

= (18-22) / (18-31)

BPF = 0.3

5. CONCLUSION

Based on test results, the summarized conclusion is given below,

1. For warm summer condition, a negative AC load of - 12000 BTU/Hr is required to produce a comfort cooling condition.
2. The increased fuel economy and easy maintenance is obtained by replacing the reciprocating compressor by rotary vane compressor.
3. From the calculations of co-efficient of performance, the $(COP)_{AC}$ of rotary vane compressor is nearly equal to the $(COP)_{AC}$ of reciprocating compressor. But, by using the rotary vane compressor the life of the compressor is increased by 50% and also the noise and vibrations are less.

REFERENCES

[1] OumSaad Abdulsalam, Budi Santoso, Dwi Aries“Cooling Load Calculation and Thermal Modeling for Vehicle by MATLAB” International journal of Innovative Research in Science and Technology. Vol. 4, Issue 5, May 2015
[2] Md Shahid Imam, Dr.M.Shameer Basha, Dr.Md.Azizuddin, Dr. K.Vijaya Kumar Reddy “DESIGN OF AIR CONDITIONING SYSTEM IN AUTOMOBILE”International journal of Innovative Research in Science and Technology. Vol. 2, Issue 12, December 2013.
[3] Shan K. Wang “HANDBOOK OR AIR CONDITIONING AND REFRIGERATION” TATA MC GRAW HILL, Second edition.
[4] P.L.Ballaney “REFRIGERATION AND AIR CONDITIONING” khanna publishers.
[5] C.P.Arora “REFRIGERATION AND AIR CONDITIONING” Second edition.
[6] SANDEN SD COMPRESSOR PRODUCT CATALOGUE.