ECOLOGICAL AND FREE COLD PRODUCTION IN VEHICLES

[1]S.DHIMDI, [2]L.MARTORANA, [3]J.MFULU, [4]A.LAKNIZI, [5]A.BENABDELLAH

[1,2,3]IEPSCF-Uccle (Belgium)
[4,5]International university of Rabat(Morocco)
E-mail: Said.dhimdi@iepscf-uccle.be,

Abstract - Most vehicles are equipped with air conditioning systems to ensure comfort as well as the traffic safety. The current auto air conditioning system relies exclusively on conventional refrigeration cycle using mechanical compression. In the conventional system, the compressor driven by the motor shaft is the most expensive and vulnerable part of the vehicle. Indeed, its lifetime is limited due to the parts fatigue and the bearing problems, thus, it requires a continuous monitoring and maintenance. Even without any failure of the compressor, the mechanical power (between 4 and 16 bar) requires extra fuel consumption and causes a loss of vehicle power. In this paper we will present an innovative and ecologic automobile air conditioning system. The originality of this system is to provide the compression using only the excess of motor heat. Thus, the fuel consumption will be reduced, which has a positive impact on the environment.

Index Terms - Ecologic Automotive, Efficient Air-Conditioning, Thermodynamic Compressor

I. INTRODUCTION

To ensure comfort and safety for automotive drivers we use air conditioning system. The conventional system uses a belt driven compressor that consumes fuel and produce greenhouse gases.
According to [1] running the air conditioning system increase the fuel consumption of about 3.1 liters/100km (+31 %) and the emissions increases to about 48% in terms of NOx and 68% in terms of particles for both petrol and diesel vehicles. In addition, the conventional system is based on the mechanical compression concept that requires care and monitoring which increases the maintenance cost. For this reason many research projects are launched, where the main purpose is to improve and limit the impact of the actual system either by changing the refrigerant with low GWP refrigerant using CO2, HFO-1234yf and the mixture HFC-161 + HFC-134a [2, 3] or by the energy management to limit the fuel consumption [4]. Furthermore, other researches propose another technologies like absorption, adsorption cooling system [5, 6], and the ejector compression [7].
The main novelty in the proposed systems is to replace the belt driven compressor, by using heat exchanger to compress fluid refrigerant. The current compression process is thermally energized by capturing heat losses from motor. The heat losses in the automobile engine through the exhaust gases and cooling water represent almost 35% of the thermal energy generated from combustion.
In this work we will use cooling hot water to compress refrigerant inside a small container in an isochoric process.

II. CONVENTIONAL AND THE PROPOSED

A. Conventional system

The conventional system is a reverse Rankine vapor compression system , which is composed of: compressor, condenser, evaporator, expansion device and some auxiliaries components like thermostat and pressostat that help a better control the system.
The system has many inconveniencies:

- The fuel consumption and the corresponding greenhouse gas emissions.
- High cost.
- Failure rate very high compared to other system components (lack of lubrication, drive belt, etc.)
- The COP (coefficient of performance) doesn't exceed 4

B. Innovative system

The innovative system looks like the conventional one, it contains a condenser on the high- pressure side and an evaporator at low pressure side. The only difference lies in the compression part. In the conventional one, the compression transformation is performed by a mechanical compressor, while in the innovative one the compression transformation is obtained by a subsystem consisting of thermodynamic compressor and a small circulator (Fig. 1).

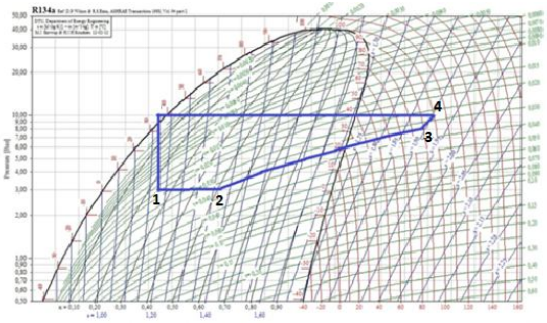


Fig.1 Refrigeration cycle of the innovative system on P-h diagram using R134A fluid

The thermodynamic compression transformation is represented, in the diagram, by the Transformation 2-3. For the circulator transformation 3-4, there are two

possibilities electrically or driven by exhaust gases via a turbine.
According to the above figure, the cycle coefficient of performance (COP) is more than 6.

III. MATHEMATICAL MODEL OF THE THERMODYNAMIC COMPRESSOR

The thermodynamic compressor is a cylindrical container immersed in the cooling water at 90 °C.
From the energy balance on the thermodynamic compressor, we obtain the following equation of the heat delivered to a system

The initial two phases fluid in the cylinder receive two kind of energy, latent and the sensible.

$$dE_{diphasique}(T) = h_{ev}(T).dm_L + m_g(T)C_v(T)dT \quad (1)$$

$$m_g(T) = x(T).M \quad \text{and} \quad M = m_g + m_L$$

$$dE_{diphasique}(T) = M.h_{ev}(T).dx + M.x.C_v(T).dT \quad (2)$$

$$dE_{sensible}(T) = MC_v(T)dT$$

Where m_g and m_L are respectively the mass of the gas and the liquid in the cylinder, while the h_{ev} is the evaporation heat of the liquid. C_v is the volume specific heat Following the enthalpy diagram in Fig. 1 and along the first part of the transformation2-3, the value of x(T), C_v(T) and h_{ev} are interpolated. We note than x(T) is the gas mass fraction.

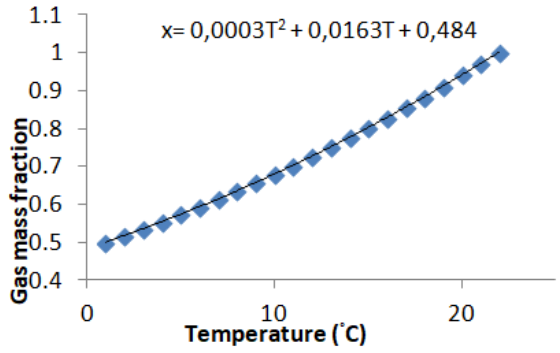


Fig. 2 Gas mass fraction vs temperature

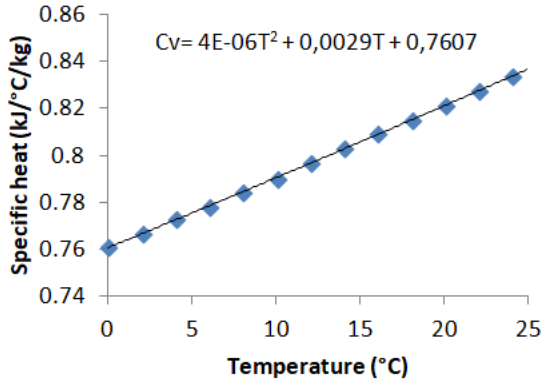


Fig.3 Volume specific heat function of temperature

Finally, the energy conservation in the two phases transformation (Fig.1) must satisfy the following law:

$$\frac{dE_{diphasique}(T)}{dt} = U.A.(T_\infty - T(t))$$

T_∞ is the hot water temperature fixed at 90 °C,
U is the overall heat transfer coefficient,
A is the geometrical exchange area

$$\frac{1}{U.A} = \frac{1}{h_i \pi D_i L} + \frac{\ln(\frac{D_o}{D_i})}{2\pi KL} + \frac{1}{h_o \pi D_o L}$$

We note that h_i, which is the inner convection coefficient responsible of the phase change, is very higher than the h_o the outer convection coefficient. Thus, the inner thermal resistance can be neglected.
Eckert and Jackson developed the following correlation to calculate the Nusselt number in the natural convection using Grashof and Prandtl number for vertical cylinder, h_o could be developed from the following traditional correlations:

$$Nu_L = 0.555(Gr_L \Pr)^{1/4} \quad Pour Gr_L \Pr \langle 10^9$$

$$Nu_L = 0.021(Gr_L \Pr)^{2/5} \quad Pour Gr_L \Pr \rangle 10^9$$

Using numerical values, we obtain the following evolution form

$$(e_5T^5 + e_4T^4 + e_3T^3 + e_2T^2 + e_1T + e_0).\frac{dT}{dt} = 57.(90 - T(t))$$

$$e_5 = -8,60E-11$$
$$e_4 = -1,02E-08$$
$$e_3 = -1,01E-06$$
$$e_2 = -2,00E-04$$
$$e_1 = 1,20E-01$$
$$e_0 = 3,57E+00$$

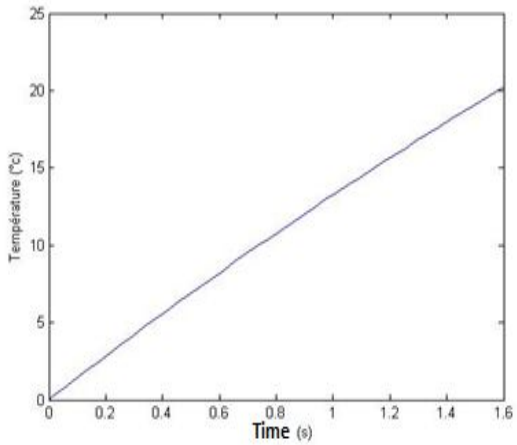


Fig.4 Temperature evolution during the two phases state

When all the fluid is evaporated, it will receive more energy (in the sensible form) until its temperature will be equal the one of the water (90 °C)

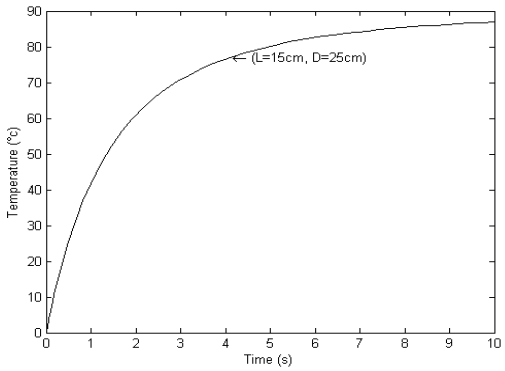


Fig .5 The refrigerant temperature during the whole compression stage

IV. THE EXPERIMENTAL PART

From the P-h diagram of the new cycle (shown in Fig. 1), the new compression method will cause modification in the system components sizes, especially the evaporator and the condenser.

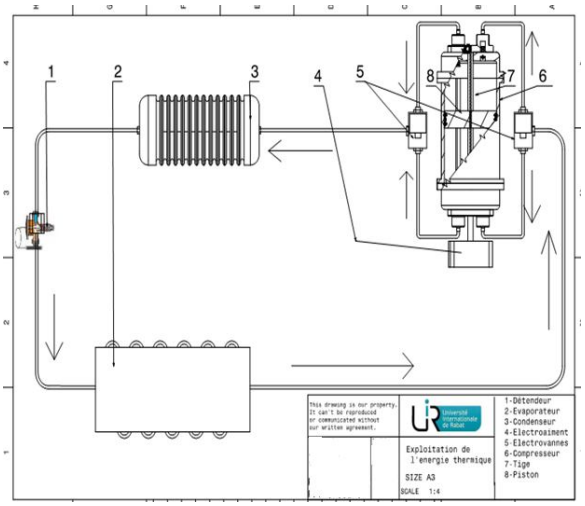


Fig.6 Refrigeration circuit of innovative system

The thermodynamic compressor (cylinder) is connected to refrigeration circuit by four pipes and many non-return valves that ensure the desired flow direction (see Fig. 6).

These pipes are attached to the thermodynamic compressor by a clamping. The translation of the piston (circulator) within the thermodynamic compressor ensures the circulation of the fluid and it is controlled by pressure switches.

CONCLUSION

In this paper, we presented an innovative and ecologic automobile air conditioning system. The Mechanical compression was replaced by the thermodynamic compression using only the excess of motor heat. Thus, the fuel consumption will be reduced, and the gas leak is minimized which has a positive impact on the environment.

The compression time cycle is reasonable, and the driver and the passengers comfort is not affected.

The experimental cycle time is the double of the calculated one, this is because the thermal resistance between the fluid and the inner cylinder surface was neglected during the theoretical study.

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