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Research Article

Energy Efficient Car Air Conditioning System

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Abstract

This paper speaks about the existing car air conditioning challenges and probable solution for them. Problem statement is to design an air conditioning system for car in static and dynamic conditions using waste energy. Existing cooling systems provide air conditioning in the car while it's in the motion. There is a large amount of Heat energy entrapment when the car is in the static position. Existing cooling systems are motivated by the engine. This causes the reduced efficiency and less power available for driving the vehicle. So we have to consider some other sustainable energy source for air conditioning. There is considerable energy in vibrations at wheels. These vibrations are observed due to uneven roads and obstacles. These vibrations are treated with shock absorbing systems to make cars more comfortable. Existing car cooling systems need energy to circulate the fluid in the tube and for the forced convection at heat exchangers. There is a lot research has been done in the Energy extraction from Vibrations, but all of them are in the direction of converting the vibrations into the Electric energy.We can extract vibration energy to pressurize the A.C. refrigerant directly. This direct method will reduce the stages required and resulting in the increased overall efficiency of the system. This energy tapping method will lead to the dampening effect in the shock absorbing system. This will make the car more comfortable and vibration free.

Keywords: *Car air conditioning, Energy extraction from the Vibrations, Efficiency.*

1. Introduction

In conventional car air conditioning system, power is taken from the car engine itself. In sunny days, car cabin gets more heated up comparatively. Car needs to be cooled by a different manner to achieve the best possible air conditioning. Conventional systems are not able to continue working while engine is off. Car needs a continous air cooling so it is comfortable to sit in all the time. Shock absorbing systems used nowdays contain telescopic hydraulics companied with the springs. These shockabsorbers delay the time of impact but don't use vibration energy in any other manner. This is a waste and unwanted energy in consideration of the comfort of the vehicle. Vehicle should be more vibrationless to make it more comfortable. Shockabsorbers work on impulse phenomenon. Impulse is defined as force applied in unit time. Shockabsorbers increase the impact time to minimize the impact.

The forces due to the vibrations anyhow displace the car. If this energy is tapped out for any other uses we can certainly reduce the vibration amplitude. In car air conditioning, maximum energy is consumed to motivate the refrigerant. Our goal is to acquire the required pressure needed to circulate the refrigerant from the vibrations directly.

2. Problem Statement

To design a car air conditioning system using another source energy than that of the engine, which can work in static as well as the dynamic conditions.

3. Solution

Solution consists of following points

- Energy Extraction
- Energy Storage
- Energy Usage
- Governing

3.1 Energy Extraction

We are suggesting a design modification of shock absorber to accumulate the energy. By keeping conventional design intact, we are just trying to tap out the pressure energy from the shock absorber. Figure (2) shows the design of modified shock absorber. [A] from diagram(1) indicates the energy extraction

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assembly. As the piston moves due to the vibrational energy at the wheels, pressure in the piston will increase. This increased air pressure is tapped out by a pneumatic line, which leads to the cylinder. The pressure in the cylinder starts increasing due to continuous vibrations observed at the wheels.
A direction control valve (DCV) is provided after the piston to direct the pressurized air.

3.2 Energy Storage

[B] block from Diagram (1) shows cylinder which stores the accumulated air pressure. Energy tapped by continuous extraction, is stored in the cylinder for further use. The cylinder has two sections, divided by a slider, which has minimum friction. In left section, there is pressurized air and in right section, there is refrigerant which is to be motivated through the cooling lines. The cylinder has sensors to guage the pressures in these sections i.e. sec (a) and sec (b).

3.3 Energy Usage

In any air conditioning system, the energy is required to circulate the refrigerant and for the forced convection. The pressure energy stored in the cylinder is to be used for circulation. Figure (3) shows the arrangement of refrigerant lines, check valves, direction control valves (DCV) and flow control valve (FCV). Check valve encourages unidirectional flow. Flow control valve is introduced to control the flow in case of different cooling requirements. Car air conditioning provides heating as well as the cooling effects. In the heating effect direction of the flow is reversed to attain the desired heating effect.

3.4 Governing

All the valves (DCV and FCV) are solenoid controlled. They can run on the car battery. To govern all these valves, an automated system is provided i.e. Governing. Governer controls the valves for particular feedbacks and instructions. These feedbacks and instructions can be obtained by the pressure sensors and user selections.

If cylinder pressure reaches at the limit, DCV-1 will act by the governing system with pressure feedback.

DCV-2 and FCV will be acting on the instructions by user i.e. DCV-2 will change the direction of the flow if user wants heating effect and FCV will control the flow rate according to the cooling rate requirements.

4. Mathematical Justification

A. Design for shock absorber Piston

Assumptions:-
Gross weight of the car = 1800 kg.
Weight on one wheel = 450 kg.
Speed of the car = 40 km/hr
Engine power = 100 HP =76.4 Kw

Consider a compound spring and Hydraulic Shock absorber system. So we consider the 25% of total Force is taken by Spring and 75% of total force is taken by Hydraulic Piston system.
Now we assume the dimensions of the obstacle
L= 50 mm
H= 25mm

We know,

$$\text{Power} = \text{Force} \times \text{Velocity}$$
$$76.4 \times 10^3 = F \times \left(\frac{40\times 5}{18}\right)$$

$$F = 6.7\ \text{kN}$$

This is the total force on one wheel. So onsidering the 75% of the total force for the Piston- Cylinder arrangement, we get

$$F_1 = 1.77\ \text{kN}$$

Now , assumptions for Piston-Cylinder
diameter (d) = 0.07 m
height (h) = 0.1 m
area (a) = $3.8484 \times 10^{-3}\ m^2$
volume (v) = $3.8484 \times 10^{-4}\ m^3$

Now, Pressure
$$\text{pressure } (P_1) = \frac{F_1}{a}$$
$$\text{pressure } (P_1) = \frac{1.77\times 10^3}{3.8484\times 10^{-3}}$$
$$\text{pressure } (P_1) = 4.75\ \text{bar}$$

B. Design for Cylinder 2

Assumptions

diameter of cylinder (D) = 0.3 m
Length (L) = 0.1 m
Area (A) = $0.07068\ m^2$
Volume (V) = $0.07068\ m^3$
density of air (ρ_a) = $0.001225\ g/cm^3$
density of refrigerant (R − 134a)(ρ_r) = $0.00425\ g/cm^3$

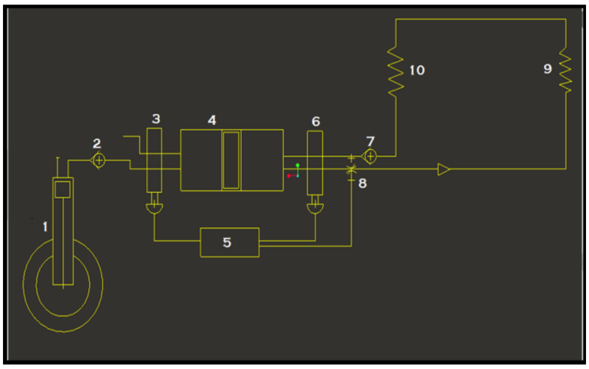

Figure 1: Block Diagram

Description

1 - Spring and Hydraulic hybrid Shock absorber system
2 - Check valve 1
3 - Direction control valve 1
4 - Cylinder for compressing the refrigerant R-134a
5 - Governing mechanism
6 - Directional control valve 2
7 - Check valve 2
8 - Flow control valve
9 - Heat Exchangers Cold junction
10 - Heat Exchangers Hot junction

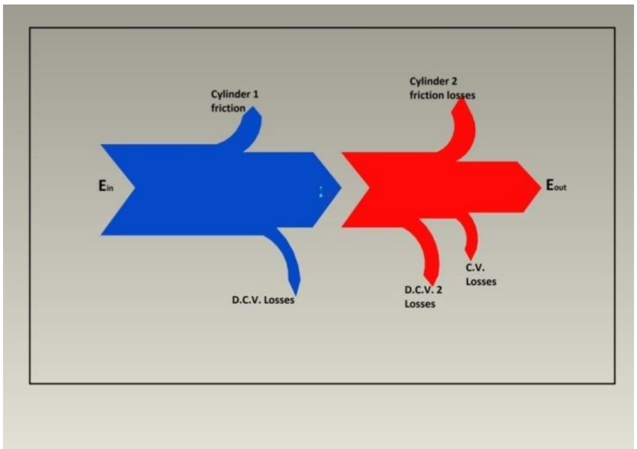

Figure 2: Sankey diagram of energy distributions in Car air conditioning system

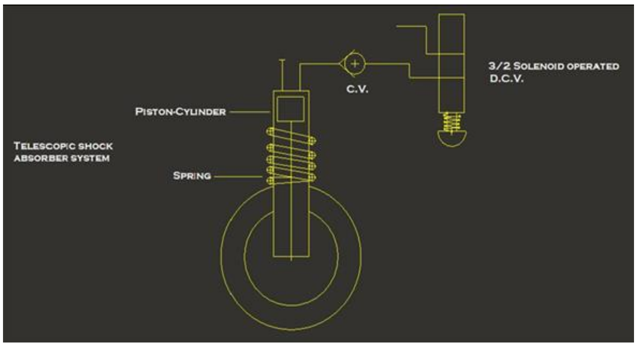

Figure 3: Energy Extraction

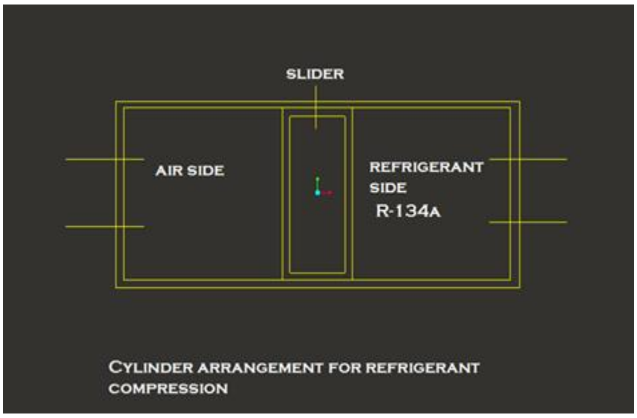

Figure 4: Energy Storage

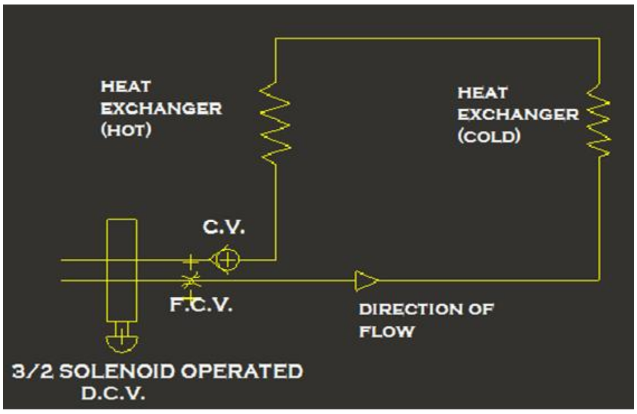

Figure 5: Energy Usage (Hydraulic Circuitry for Air-conditioning)

For the volume V_2 We know,

$$P_1/P_2 = \rho_a/\rho_r \quad (1)$$

$$X_1/X_2 = P_1/P_2 \quad (2)$$

From (1) & (2), we can say that,

$$X_1/X_2 = \rho_a/\rho_r \quad (3)$$

So,

$$X_1/X_2 = 0.001225/0.00425 \quad (4)$$

where,

X_1 & X_2 are length of air chamber and refrigerant chamber respectively.
Also for initial condition,

X_1+X_2 = total length of the cylinder = 1 m

After solving,

X_1 = 0.39 m
X_2 = 0.61 m

We can find volume of the cylinder (air side) from above values,

$V_1 = 0.02756\ m^3$

C. Design for Power requirement

Considering Boyles Law at Isothermal conditions;

$$nP_1V_1 = P_2V_2$$

where,

n = number of displacements of the piston (vibrations)
Work = force × displacement

Work = Pressure × area × displacement

$$Work = \left[n \times P_1 \times \left(\frac{V_1}{V_2}\right) \times area \times dispalcement\right]$$

$$Work = [n \times 468.80 \times dispalcement]$$

Now consider,

$$Power = {}^{Work}/_{time}$$

We assume the vibrations for 100 sec. So

$$Power = {}^{Work}/_{100}$$

We require 5 kW power,

$$Work = 5 \times 10^5 J$$

$$Work = 5 \times 10^5 = n \times 468.80 \times displacement$$

Let Displacement = 25 mm

So n = 42662.11 times displacements of 25 mm in 100 sec.

Conclusion

1. In this research paper we conclude that the vibration energy from the vehicle can be utilized for air conditioning system.
2. We calculated the number of vibrations required for the system to start working at assumed speed of the vehicle 40 km/hr.
3. The scope for improvement in this field demands the storage of this energy so that the air conditioning can be achieved even if the vehicle is in static position. The current research paper deals with the basic ideas of this very huge topic.
4. The current research paper however is successful in proving that this vibration energy is sufficient enough for actuation of the air conditioning system.

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