Design of a Prototype Air Conditioning System in Four Wheeler Using Suspension System

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Abstract: *Nowadays people are using fuel efficient cars for travel purpose. But the efficiency of the engine is affected by the use of air conditioning systems in the present day cars. To improve the overall efficiency of the engine, alternate ways of methods are thought to run the air conditioning unit of the cars or four wheelers. In cars kinetic energy is continuously produced from the suspension system. The present analysis aims to utilize this kinetic energy to run the air conditioning unit. The kinetic energy developed in the suspension can be used to compress the air by using a pneumatic cylinder. The air is then stored in an air storage tank. The regulated air is diverted into the heat exchanger which is filled with water or the Phase change material (PCM). When the air passes through the heat exchanger heat is transferred from hot body to cold body using the principles of heat transfer. This method is used to cool the internal area of the car. This system will improve the overall efficiency of the car and also reduces the pollution.*

Keywords: Air conditioning, Heat transfer, Heat exchanger, PCM, Vehicle Suspension.

I. INTRODUCTION

Air conditioning, which is used for both private and industrial purposes, is a moisture and heat regulation process in air suiting our comfort level and also for many manufacturing jobs. In AC's the air is distributed to the target area by means of a fan and the conditioning capacity varies widely from cooling a small bedroom to a large commercial building. Basically, AC's use main product as air, generally called as free air or a chemical desiccant that sets the required temperature by eliminating the moisture content in air. New generation air conditioning systems are equipped with dehumidification cycle which adds up to the efficiency of air conditioner. In this process, the fan shuts off when the needed temperature is obtained for stopping the additional removal of temperature. The compression cycle starts again when the rise in temperature is detected. When the compressor is set to work continuously, there forms some amount of ice. To defrost this part, the fan has to run without the compressor being active. And sometimes inner coil temperature is used to keep track of compressor performance. Elizabeth Palermo in their blog [1] "Who Invented Air Conditioning?" said that the first free air concept was shown in Ancient Egypt, where the markers or the sticks with nib points are hung to a casement opening. The nibs absorbed some amount of water from the air making it cooler than outside. Further advancements like use of cisterns and wind towers took place in medieval Persia. Palermo also added that an experiment was conducted by Benjamin Franklin and John Hadley, two chemistry professors for Cambridge University, in the mid-18th century. We can obtain cool air after compressing and liquefying ammonia and letting it evaporate. This was discovered by an English scientist with a hand given by Michael Faraday in 1820. After about two decades, John Gorrie used a compressor to supply cold air for his patients in his hospital. Eventually he used the technology to create ice and hoped it could provide enough cooling for an entire building which was mentioned by Bernard Nagengast [2] A History of Comfort

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Cooling Using Ice. Willis H. Carrier After graduating from Cornell University and experimented with air conditioning to find a solution Sackett-Wilhelms Lithographing while he worked at Buffalo Forge Company.

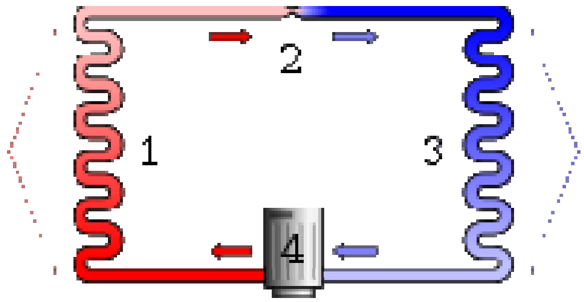

Figure 1: Air conditioning cycle: 1) Condensing coil 2) Expansion valve 3) Evaporator 4) Compressor

The first air conditioner was technically put to work on 17 July 1902 according to Global Cooling: In the refrigeration cycle shown in Fig. 1, the heat is transported from the passenger compartment to the environment. A refrigerator is an example of such a system, as it transports the heat out of the interior and into the ambient environment [3]. Charles Gates was the person to own a first ever home which has built-in air conditioning system in 1914. Further analysis has revealed that air conditioning will be a primary feature for homes, especially in warmer climate, this was also discussed by Elizabeth Palermo. So, David St. Pierre DuBose designed a ductwork for his home and made it the first home with centralized air conditioning system. Carrier with his knowledge of heating an object by air sent through hot coil and modified it with cold coils to get desired output. Which controlled even the moisture and further case, humidity also. The other type of air cooling is free air cooling, where a coolant is used, which works basically as a heat sink, i.e., absorbing the heat form the air when they are made to have a contact. Generally, the coolant is water or water-glycol mixture. The clarification was supportive in 'An investigation into using free cooling and community heating to reduce data centre energy consumption' [4] written by Gina Posladek.

The first fully developed air conditioning set is equipped in a car manufactured by Packard. And the manufacturer of this system was "Bishop and Babcock Weather Conditioner", who also added heater to it, which was described by Dennis Adler in his book [5] “Packard”. But the reasons like over used trunk space, manually turning off the blower after required cooling effect is obtained and non-reliability of the system made it a failure. Chrysler being the first production car company to offer an AC variant in its Imperial model. With the gaining technology advancements, rival companies have also emerged in order to compete with the former company. Air temp is one of the inventions from Chrysler company which offered preset temperature control in the AC system in 1953. This system was great success as it avoided reuse of overworked air in the vehicle cabin and acquiring fresh air from small ducts placed the bottom of window with a filter attached to it. The conventional air conditioning cycle in the automobiles is discussed by Nishanth Agarwal et.al [6]. In this traditional system of air conditioning that is being followed for many years, a belt-driven compressor is used to compress the refrigerant from low pressure liquid to high pressure gas with high temperature. When this gas passes through the condenser, it changes its state to liquid. Filter driers are used to filter the impurities and then the refrigerant is sent into the expansion valve. Here the high-pressure liquid is converted into low pressure liquid. Next in the chain is the evaporator wherein the liquid refrigerant is exposed to the air from outside and the actual heat transfer process takes place. From this stage the air is directly sent into the cabin of the car using a blower.

R Farrington et.al in their paper [7] explained about the effects of the air conditioning on the performance of the vehicle as well as on the environment due to the emissions and refrigerants used. On an average with the increase of 1000W of power on the battery in electric vehicles, the range of the vehicle (in this case Kilometers) reduced by 27 Kilometers. Now-a-days, air conditioning in cars is becoming a necessity than luxury and hence alternative methods should be developed for better performance of cars and for better environment. This study aims in developing an air conditioning system that does not depend on the engine power and relies on the suspension system of a car. Suspension system and air conditioning units are both important and independent units in an automobile. As we know that the compressor of AC system uses additional energy for its action and the mileage goes down when using it, a consideration of replacing it has made. Not losing its basic element, which is cooling the air in vehicle cabin, the efficiency of the vehicle can be increased by this integration. The kinetic energy from the suspensions of the vehicle is used to provide the conditioned air into the cabin. This method includes the usage of pneumatic cylinder, air storage tank, heat exchanger, water, phase change material and a fan/blower. The method is expected to decrease significant amount of fuel consumption and helps in the increase of mileage of the vehicles. The system follows second law of thermodynamics, conduction and convection modes of heat transfer as basic working principle. Second law of thermodynamics states that heat transfer takes place from hot body to cold body unless external forces act upon it. In this case, the hot body will be air and cold body will be the coolant (i.e., water or PCM).

II. EXPERIMENTAL SETUP

Figure 2 shows the block diagram of the experimental setup used in the present study. The components are used to in this work are Vehicle base & Spring, Pneumatic cylinder, Spring loaded valve (NRV), Air storage tank, Ball valve, Heat exchanger, Phase Change Material, Pressure gauge and Pressure relief valve. Fig 3. Shows the assembled working model. The phase change material used in this work is savE® OM21. It is an organic chemical based PCM having nominal freezing temperature of 21^{0}C and melting temperature of 21^{0}C.

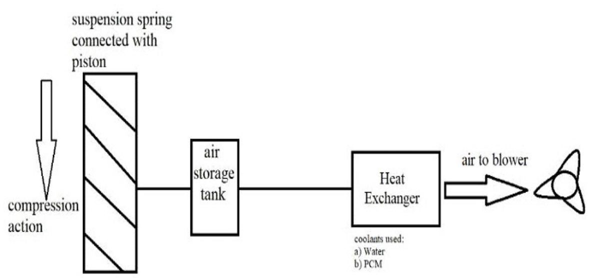

Figure 2: Block diagram of the setup

Figure 3: Assembled working model

III. SIMULATION ANALYSIS

A steady state analysis has been carried out for the safety factor, stress concentration, displacement and temperature effects on the equipment using Catia software as shown in Fig. 4 (a). A load of 500 N is applied on the top of vehicle base and springs as shown in Fig 4.3. On total, the minimum factor of safety is maintained on the L-pipe and the maximum factor of safety is maintained on Air storage tank, Heat exchanger and pneumatic cylinder. With the same conditions, Von Mises stress analysis is carried out and a maximum stress of 146.7 MPa on the pipe in between air storage tank and heat exchanger and minimum of 0.001 MPa on the bottom part of the spring was observed as shown in Fig 4(b). With the same study conditions, The Fig 4 (c) shows the displacement analysis with maximum deflection on the springs. The system is completely safe with the applied load with negligible displacement. Considering the room temperature is 300C, after passing through pneumatic cylinder the temperature raised to 340C and after reaching a stable state the temperature reduced to 330C in the air storage tank. After passing through the Heat exchanger the air temperature reduced to 230C. From Fig 4(d), the analysis shows that the assembly is safe for the applied temperatures.

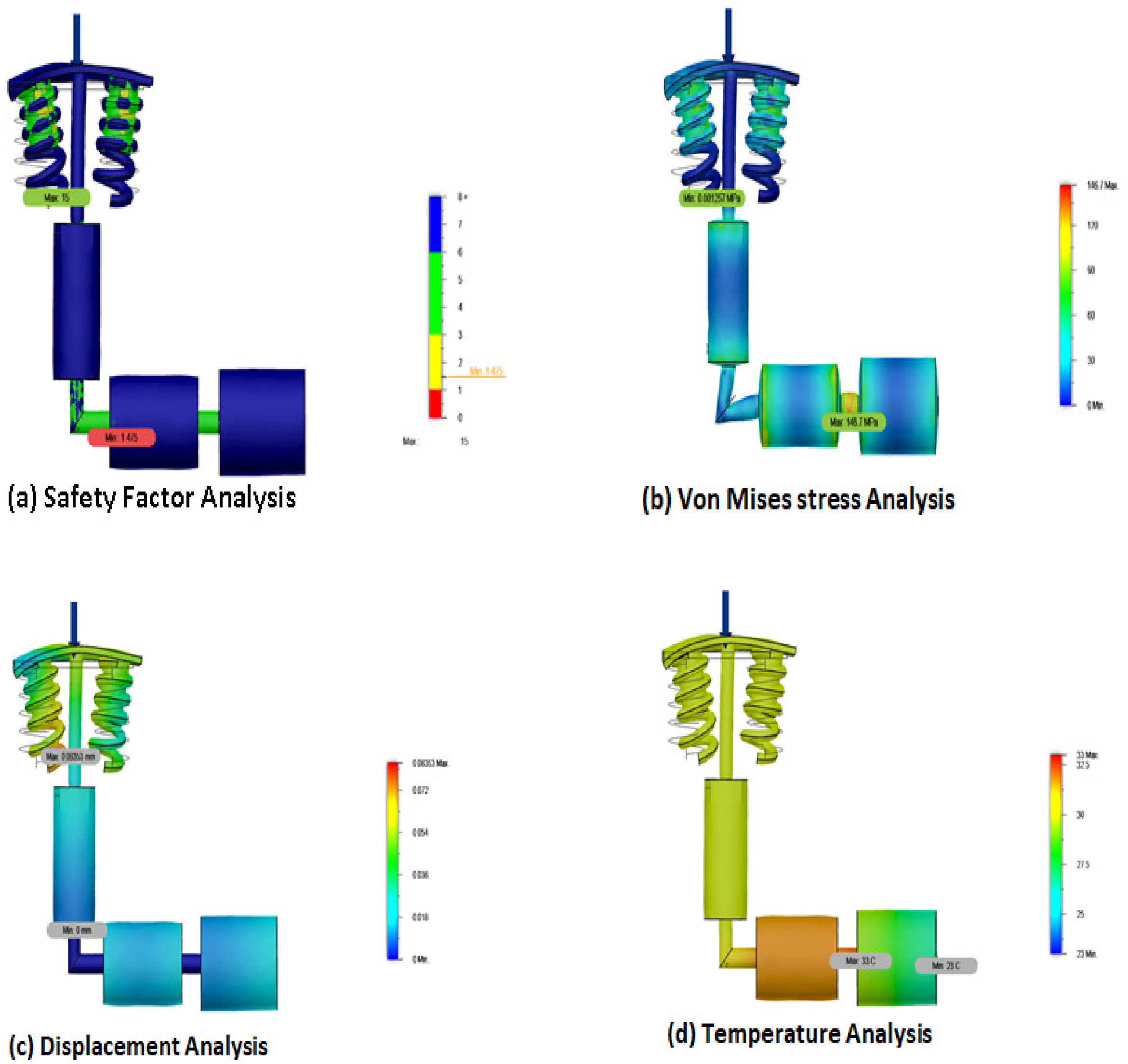

Figure 4: Analysis using Catia Software

IV. TESTING AND RESULTS

The working model is tested using two different coolants i.e Water and Phase Change Material (PCM) in Heat exchanger. The temperature sensors are used to measure the temperatures at four different points in the model. The inlet and outlet temperatures are tabulated in Table 1 and 3. The effectiveness is calculated for both the coolants and shown in Table 2 and 4. From the readings it is observed the following.

(i) The PCM has greater effectiveness when compared to water.
(ii) On an average the temperature of air got down by 8^0C degrees as PCM as coolant and 6^0C for water as coolant.
(iii) On an average the coefficient of performance is almost equal (i.e., 4.2 for PCM and 4.4 for water)
(iv) PCM cooled the air with greater effectiveness when compared to water

The Figures 5 and 6 shows the Comparison of effectiveness and COP between water and PCM as coolants.

Table1: Inlet and outlet Temperature as water as coolant

Readings	Water inlet temperature (W1)	Water outlet temperature (W2)	Air inlet temperature (A1)	Air outlet temperature (A2)
1	10	11	30	25
2	13	14	33	27
3	10	14	31	25
4	10	12	32	26
5	10	14	33	26

Table 2: Comparison of effectiveness as Water as coolant

Readings	Effectiveness of water as coolant	Effectiveness of PCM as coolant
1	0.25	0.5
2	0.3	0.66
3	0.28	0.51
4	0.27	0.4
5	0.3	0.62

Table 3: Inlet and outlet Temperature as PCM as coolant

Readings	PCM initial temperature (W1)	PCM final temperature (W2)	Air inlet temperature (A1)	Air outlet temperature (A2)
1	17	18	31	24
2	18	18	33	23
3	18	20	27	22.5
4	20	21	29	25.5
5	21	22	30	24.5

Table 4: Comparison of effectiveness as PCM as coolant

Readings	COP of Water as coolant	COP of PCM as coolant
1	5	3.42
2	4.5	2.3
3	4.166	5
4	4.33	5.66
5	3.7	3.76

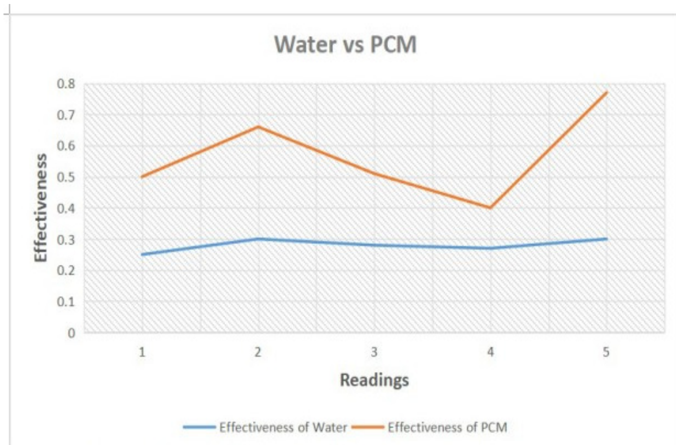

Figure 5. Effectiveness for different temperature

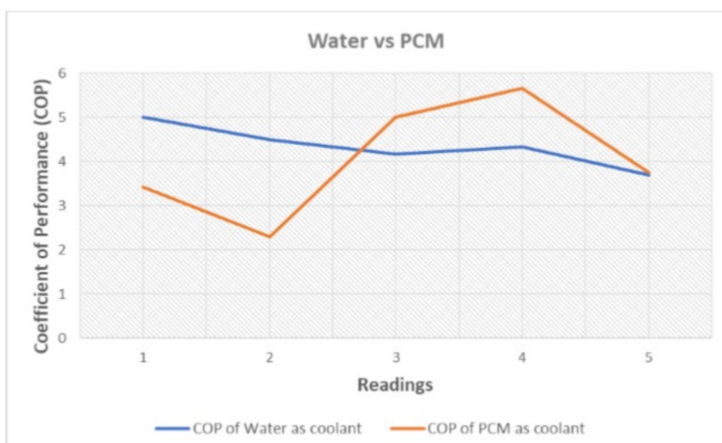

Figure 6. COP for different readings

V. LIMITATION AND FUTURE SCOPE

In the present study only a Prototype is designed and analyzed. It can be developed in the Full scale to increase overall efficiency of the vehicle by using the energy stored in the suspension system.

VI. CONCLUSIONS

The Phase change material (PCM) has greater effectiveness when compared to water in giving the better cooling effect. On an average the temperature of air in the given space is reduced by 8°C degrees when PCM is used as coolant and reduced the air temperature by 6°C for when water is used as coolant. On an average the coefficient of performance is almost equal (4.2 for PCM and 4.4 for water). PCM cooled the air with greater effectiveness when compared to water.

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