

Energy Efficient Automobile Air Conditioning System Through Effective Condenser Cooling



Rohith Thotakura, Lakshmi Supraja, S. Vineeth Raj, Anjali Damodaram, and M. Mohamed Musthafa

Abstract An air conditioning system was built in all deluxe vehicles. The air conditioning fit in vehicles will give higher fuel consumption because of power absorbed to run the compressor from engine output. The main drawback of reduction in mileage will be improved in this study by increasing the heat removal rate, thereby decreasing the compressor power absorption. This study was depicted with experimental test rig consists of various components such as compressor, condenser, evaporator, expansion device, and electric motor were put together. The modifications were made on the existing system viz., the compressor was run by an electric motor instead of engine power. Inbuilt condenser fan was replaced by an evaporative cooling method using exhaust fan was surrounded by a cooling pad. Cool water is supplied to the cooling pad using a pump. The test was conducted on conventional cooling and evaporative cooling methods to obtain a similar cooling effect. The result showed that a higher coefficient of performance (COP) for the evaporative cooling system compared to the conventional system due to an increase in heat removal rate.

Keywords Compressor · Condenser · Electric motor · Evaporative cooling · Heat removal rate · Performance

Nomenclature

CoP	Coefficient of performance
p-h	Pressure-enthalpy
Q	Heat removal rate (W)
rpm	Revolution per minute
VCR	Vapour compression refrigeration

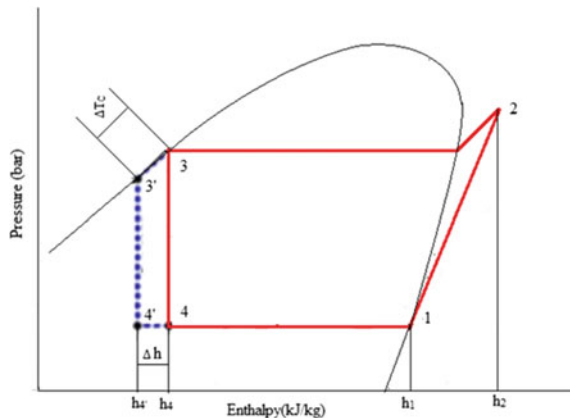
R. Thotakura (✉) · L. Supraja · S. V. Raj · A. Damodaram · M. M. Musthafa
School of Mechanical Engineering, SASTRA Deemed University, Thirumalaisamudram,
Thanjavur 613401, India
e-mail: rohiththotakura6997@gmail.com

1 Introduction

The air conditioning system in the vehicle refers to providing and maintaining desirable temperature and humidity for passenger comfort irrespective of external conditions. The working substance which is used in the air conditioning system to absorb and liberate the heat alternatively is called refrigerant. The name of refrigerant used is R134a [1]. An automobile air conditioning system works on the principle of vapour compression refrigeration (VCR) system [2]. In this system, a refrigerant R134a undergoes alternatively a change of phase from vapour to liquid and liquid to vapour during the working of the cycle. The refrigerant is circulated in a closed circuit through a compressor, condenser, expansion valve, and evaporator. The power required to run the compressor is given from engine power. It will increase fuel consumption and reduce the mileage of the vehicle by up to 35% [3]. The system should give a higher CoP in the working temperature range. This is necessary to reduce the running cost of the system in terms of reducing fuel consumption. The CoP is defined as the ratio of heat extracted from the cabin to the work done on the system [4]. The heat removal rate in the evaporator depends on the refrigerant temperature at the condenser exit. The evaporative cooling gives a decrease in exit temperature of refrigerant by additional removal of heat than the inbuilt air cooling condenser. Hence, CoP of the system increases for the same amount of compressor work [5]. This was understood from the p–h chart as shown in Fig. 1. In this Fig. 1, 3–3' is the decrease in exit temperature of the refrigerant in the condenser due to evaporative cooling, and 4–4' is corresponding to the increase in heat removal rate in the evaporator for the same compressor work of 1–2. Hence, the CoP of the system increases [6].

Many kinds of research [7] on VCR system are focussed to increase the CoP through either increase in heat removal rate (refrigeration effect) by subcooling or a decrease in compressor work input by superheating. Subcooling has a simple and more effective method rather than superheating [8]. Removing extra heat from the

Fig. 1 p–h chart of VCRS



condenser through any method allows a higher amount of heat absorption in the next stages of the cycle. Hence, the CoP of the system increases with the same compressor work. Subcooling by liquid-suction method has been used in the past years to achieve better performance of the system [9]. These methods necessitate the exact and optimised design of the heat exchanger. The research gap of improving performance on the air conditioning system is to be fulfilled in this study through evaporative cooling of the condenser.

2 Experimental Facility

2.1 Evaporative Cooler Setup

The evaporative cooler was fabricated as shown in Fig. 2, and it consists of exhaust fan runs at 1300 rpm, three cooling pad of size 60 cm × 40 cm and a water pump. The steel frame was fabricated in such a way that to accommodate the fan and cooling pads. A separate water pump was used to supply water over the cooling pads through the multi-drilled PVC pipe at a different flow rate such as 0.03, 0.07, 0.08, and 0.1 kg/s, and the corresponding reduction of atmospheric air temperature was measured and found 4 °C temperature reduction from 31 to 27 °C at 0.08 kg/s flowrate. The velocity of cooled air blow over the surface of the condenser was measured using an anemometer. The distance between the cooler and condenser was adjusted to obtain a maximum reduction in condenser surface temperature. At a gap of 20 cm, the maximum decrease in surface temperature of the condenser was attained at 5.5 m/s velocity of air blow.

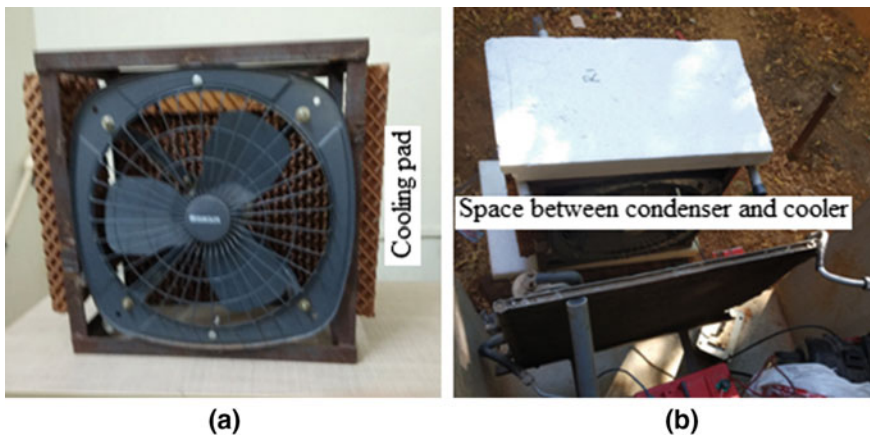


Fig. 2 a Fabricated evaporative cooler. b Distance between cooler fan and the condenser

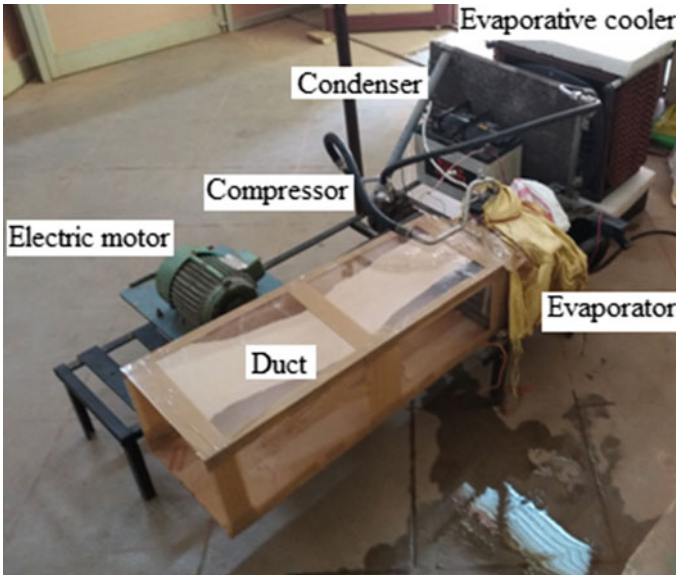


Fig. 3 Test rig setup

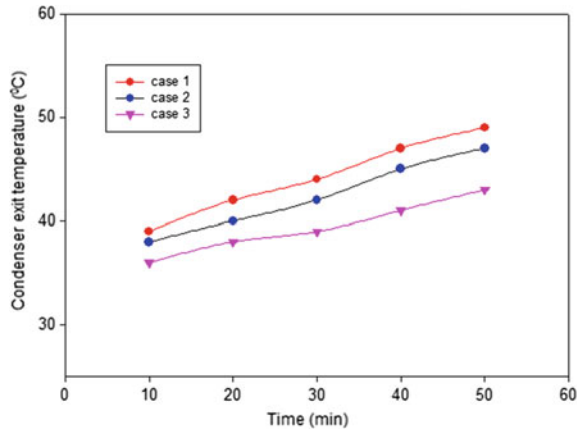
2.2 Test Rig Setup

The experiment test rig was fabricated as shown in Fig. 3 using Hyundai, i-10 variant car air conditioning parts. A 1.5 HP three-phase induction motor was attached to the test rig set up to drive the compressor through the belt and pulley assembly. The electric power consumption was measured using an energy metre. The evaporator is enclosed by a rectangular duct of size 25 cm × 18 cm and 80 cm made up of a 3 mm thick acrylic sheet to prevent heat loss to the surrounding. The inbuilt condenser fan was replaced by an evaporative cooler fan. The velocity of cooled air blows in the duct was measured as 0.5 m/s.

2.3 Experimental Tests

The experiment was conducted on the test rig at three various cases viz., 1. using inbuilt fan, 2. exhaust fan, and 3. evaporative cooler. During the test trial, the amount of heat removed from one kg of water in the aluminium jug which is kept inside the duct at a regular interval of 10 min was measured. Besides that suction and delivery pressure of compressor; condenser and evaporator inlet and exit temperatures; and energy metre readings were noted for CoP calculation.

Fig. 4 Condenser exit temperature with a running time



3 Results and Discussion

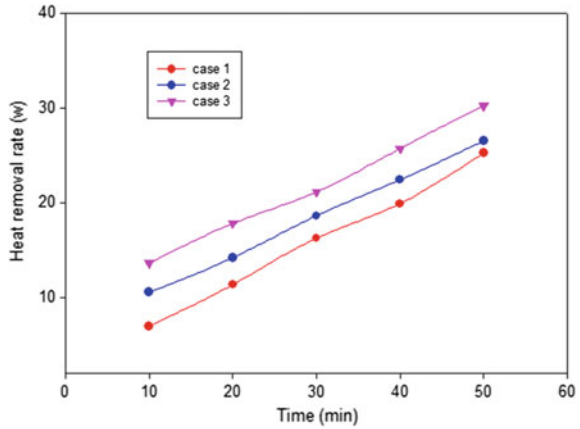
3.1 Condenser Exit Temperature

Figure 4 represents the exit temperature of the condenser against the running time of the system for the three cases. When running time increases, the exit temperature of the condenser increases in all trails. The increasing excess temperature for an entire test run was reduced in the case 2 and 3 compared to case 1. Most reduction in condenser exit temperature in case 3 was observed by blowing the cooled air over the entire surface of the condenser and placing the cooler at an optimised distance from the condenser. Trail 2 also reduces the exit temperature of the condenser to some extent compared to Trail 1 due to reduction of bypass volume of air blows over condenser surface even the exhaust fan speed (1300 rpm) is lower than inbuilt fan speed (1700 rpm).

3.2 Heat Removal Rate

Figure 5 illustrates the amount of heat removed with running time for three trails. The amount of heat removed from the water was calculated using the formula $m c_p \Delta T$. Where m is mass of water, c_p is the specific heat of water and ΔT is the decrease in temperature of the water after 10 min. An increasing trend of heat removal rate was observed in three cases. The more amount of heat was removed in case 3 followed with case 2 and case 1. It is evident from Graph 4; there is a small drop of exit temperature of condenser give more amount of heat removal rate in case 3 due to evaporative cooling.

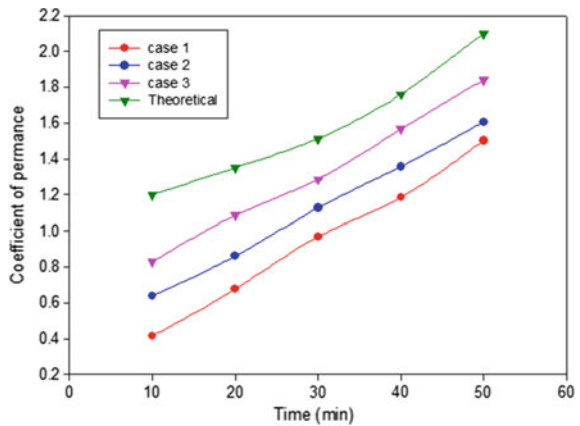
Fig. 5 Amount of heat removed with a running time



3.3 Coefficient of Performance

As explained in the introduction section, the higher CoP of the system reduces the running cost. The actual CoP of the three cases was calculated against the running time using the ratio between heat removal rate and electric power consumption for the motor. Theoretical CoP was also calculated using p-h chart of R134a and found that the actual CoP of three cases was lower than theoretical CoP. Figure 6 represents the comparison of the coefficient of performance with running time. From the calculation, the deviations of the power consumption of the compressor in the three trails are very small. Hence, work input was assumed as constant. But the variation of heat removal rate, the CoP has varied. The higher CoP was noted in case 3 during the test run due to more amount of heat was removed, it is evident from Graph 5.

Fig. 6 Coefficient of performance with a running time



4 Conclusion

Through experimental study, it was proved that the evaporative cooling process in the condenser increases the heat removal rate for the same compressor work which results in higher CoP of the system. The test results point out the following.

- Through the fabricated evaporative cooler reduce the atmospheric air temperature up to 4 °C
- By reducing the bypass of air blows over the condenser surface using an evaporative cooler increases the amount of heat removed rate up to 35%
- A 5 °C temperature drop of the liquid refrigerant at condenser exit due to evaporative cooler increases the CoP system up to 22.5%
- This method will put into operation in the vehicle reduces fuel consumption considerably.

Acknowledgements The authors thank SASTRA Deemed university provide amenities to this study for successful completion of work.

References

1. Boloji and Bukola Olalekan (2010) Effects of sub-cooling on the performance of R12 alternatives in a domestic refrigeration system. *Int Sci Technol* 15(1):12–19
2. Ashish Kumar P, Gupta RC (2013) Effect of sub cooling and super-heating on vapour compression refrigerant systems using R-22 alternative refrigerants. *Int J Emerg Trends Eng Develop* 1(3):521–531
3. Mohammed Sajid NK, Ram KS, Shafi KA (2012) Performance improvement of an air conditioning system using matrix heat exchanger. *Int J Eng Res Develop* 2(11):66–70
4. Poltker G, Predrag Hrnjak S (2012) Effect of condenser sub-cooling of the performance of vapour compression systems: experimental and numerical investigation. In: *International refrigeration and air conditioning conference*, Purdue
5. She X, Yonggao, Zhang X (2014) A proposed sub-cooling method for vapour compression refrigeration cycle based on expansion power recovery. *Int J Refrig* 43:50–61
6. Hajidavalloo E, Eghtedari H (2009) Performance improvement of air-cooled refrigeration system by using evaporatively cooled air condenser. *Int J Refrig* 33:982–988
7. Christian JL, Hermes (2014) Refrigerant charge reduction in vapour compression refrigeration cycle via liquid-to-suction heat exchanger. *Int J Refrig* 52:93–99
8. Upadhyay and Neeraj (2014) To study the effect of sub-cooling and diffuser on the coefficient of performance of vapour compression refrigeration system. *Int J Res Aeronaut Mech Eng* 2(6):40–44
9. Upadhyay N (2014) Analytical study of vapour compression refrigeration system using diffuser and sub-cooling. *J Mech Civil Eng* 11(3):92–97