International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V70I4P223
Volume 70 Issue 4, 272-277, April 2022

Original Article

Enhancement of the Performance of Automobile Refrigeration System by using a Cellulose Pad

Zaid Ali Hussein [1], Haider L Aneed [2], Moayed Ahmed Hameed [3]

[1,2,3]*Mechanical Power Technical Engineering (Refrigeration and Air Conditioning) Department, Dijlah University College.*

[1]zaid.alihuss@duc.edu.iq

Received: 26 February 2022 Revised: 16 April 2022 Accepted: 19 April 2022 Published: 26 April 2022

Abstract *- The automobile refrigeration system's performance and power-saving coefficient were evaluated experimentally in this study. The pad made of cellulose and water recirculated system is used for cooling the atmospheric air before passing the condenser and radiator of an automobile. The study was done on this case with and without using the cellulose pad. It measured the temperatures and pressures, and then the coefficient of performance and power saving have calculated at the peak period time (at 11 am, 12 am, and 1 pm). The discharge temperature also decreases when the use of a cellulose pad. The results illustrate the benefits of adding a cellulose pad up to the condenser and radiator of an automobile, the coefficient of performance has increased by about (27%) the isentropic efficiency of the compressor by about (10%) and the temperature reduction of the discharge temperature of the refrigerant about (13%).*

Keywords *– Cellulose pad, Evaporative cooling, Automobile refrigeration system.*

1. Introduction

In hot, dry climates, increasing vapor compression system cooling efficiency through evaporative processes is critical for minimizing energy consumption and peak demand. Evaporative condensers, notably in automobiles and vehicles, enhance efficiency by reducing the temperature of the condensing environment from the external dry bulb temperature to near the exterior wet-bulb temperature. While driving or parking in the blazing sun, heat enters a car in various ways.

The following are some of these sources [1]:
as shown in Fig. 1 are ambient air heat gain – sunlight heat gain - engine heat gain - road heat gain – transmission heat gain - exhaust heat gain.

Together with other heat sources of the environment, all of these heat gains increase the air temperature inside the vehicle. Summer temperatures in the Middle East may reach 40-45°C, and occasionally considerably higher, and the air inside the car left in the scorching sun with the closed windows can be between 65-70°C. The AC compressor works continuously in this condition, using more power and reducing the COP [2]. As a result, to lower the condenser temperature and pressure, The ambient air temperature must be lowered before going through the condenser coil.

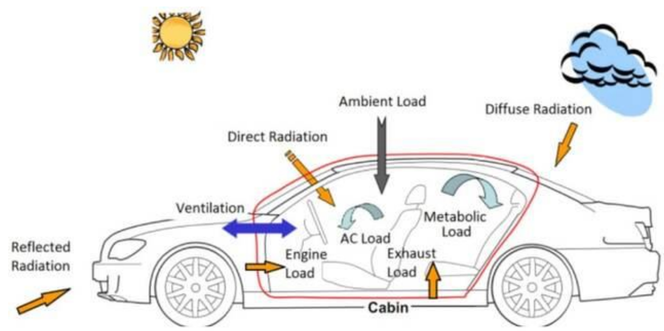

Fig. 1 Heat load on vehicles

As seen in Fig. 2, the researcher improved the performance of a vapor compression cooling system in [3]. Using an evaporative cooler effect, a condenser combined with a direct evaporative cooling system improves the process and boosts energy efficiency. It is possible to lower power consumption by 46% while increasing the performance coefficient (COP) by roughly 12%.

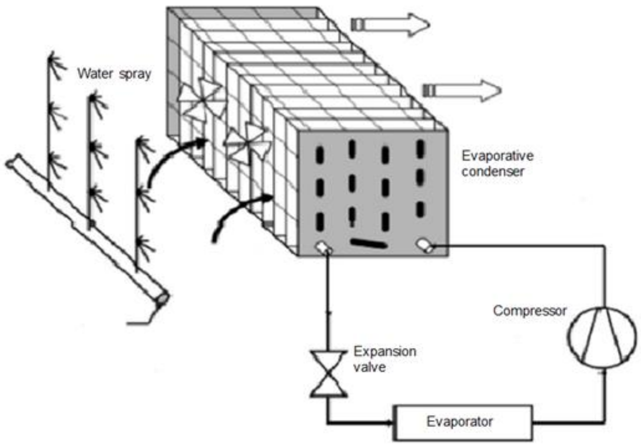

Fig. 2 Compression system with evaporative condenser

[4] Investigated the efficiency spray chamber of an air-cooled heat exchanger in wet conditions. The experimental results show that as the volume of spraying water grows, so does the cooling efficiency, the amount of the heat rejected, and the density of spraying, while the condenser's air flow decreases. Furthermore, when the input air velocity increases, the cooling effectiveness of the pads in Fig. 3 diminishes [5].

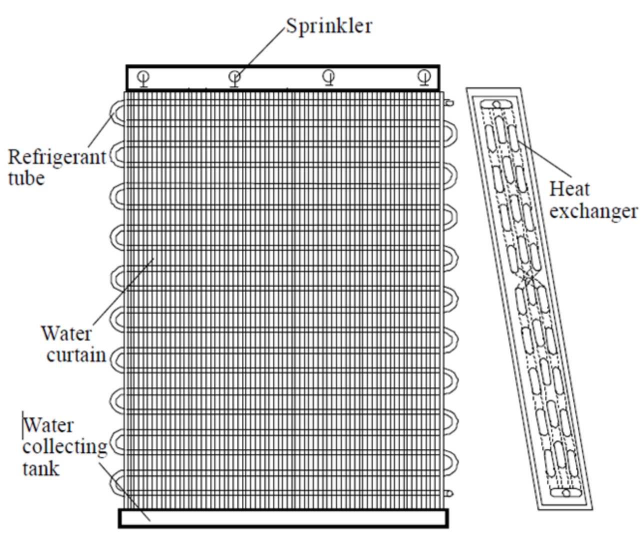

Fig. 3 Schematic diagram of the spray system on the condenser

The air-conditioning condenser's temperature and pressure have dramatically increased as in [6] the locations where the weather is quite hot (50 to 60°C); some of the air-side adjustments include spray water above the condenser, wet Pads before the condenser is used, and a water vapor nozzle in the condenser airflow to decrease the air temperature which reduces the condenser temperature. According to the results, spray water modification for improved condenser performance is the most effective method for enhancing COP. The COP of the spray water system rises by 44.5 percent and 102.1 percent for the air-refrigerant and water-refrigerant evaporators, respectively, as compared to a system with no changes.

2. System description

The vehicle engine powers the automobile's air conditioning system through a ribbed or V-ribbed belt [7]. It compresses and transfers the refrigerant throughout the system. The refrigerant is drawn in from the evaporator as a low-pressure, low-temperature gas, as shown in Fig. 4, which is compressed and transmitted to the condenser as a high-temperature, high-pressure gas. The hot refrigerant gas enters the condenser from the top and transmits heat through the pipe and fins to the environment. The condenser at the bottom connection is liquid due to the refrigerant cooling down.

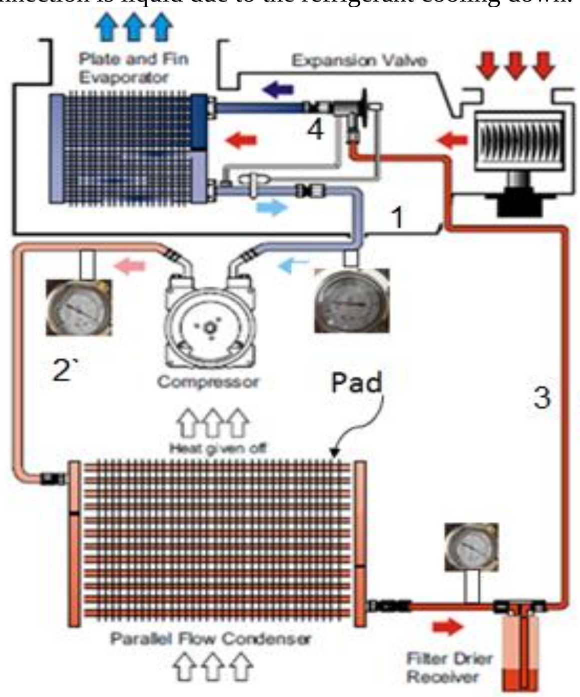

Fig. 4 automobile air-refrigeration system

Rigid Cooling Media is the newest and most efficient type of cooling media. This type of material has cooling effectiveness of up to 99 percent. The structure of this medium is remarkable in that it features 45-degree and 15-degree transverse flutes that alternate. The water (introduced over the top of the media) is carried to the front of the media by the 45-degree flutes, where it is forced back into the media by the approaching air, helping in the thorough wetting of the media. The 15-degree flutes allow air to pass through them. This medium comprises cellulose, wetting agents, and rigidifying saturates.

Fig. (5-a) Cellulose pad

Fig. (5-b) Cellulose pad installed in the car

The vapor-compression refrigeration cycle consists of four parts: the evaporator, the compressor, the condenser, and the expansion (or throttle) valve. The vapor-compression refrigeration cycle is the most often utilized compression refrigeration cycle. The refrigerant enters the compressor as a saturated or super-heated vapor and is cooled to the saturated liquid state in the condenser in the vapor-compression refrigeration system. When heat from the refrigerated region is absorbed, it is throttled to evaporator pressure and vaporizes. [8]. The standard vapor-compression system consists of four phases.

1-2 isentropic compression
1-2` real compression process
2`-3 Heat rejected at constant pressure
3-4 pressure decrease at constant enthalpy
4-1 Heat added at constant pressure

3. Governing equations

The practical basis for comparing the studied cases is the coefficient of performance (COP) and the amount of energy savings consumed by the system by applying the First Law Analysis of Vapour Compression System [9]

$$E_{in} = E_{out} \quad \dots\dots (1)$$

- Energy balance equation for compressor

$$\dot{m}\,.\,h_1 + w_{1-2} = \dot{m}.\,h_2 \quad \dots\dots (2)$$
$$w_{1-2} = \dot{m}.\,(h_2 - h_1) \quad \dots\dots (3)$$
$$\eta_{comp,isen} = \frac{h_2 - h_1}{h_2' - h_1} \times 100\% \quad \dots\dots (4)$$

Where $\eta_{comp,isen}$ is the isentropic efficiency of the compressor.

$$w_{1-2,actual} = \dot{m}.\,(h_2' - h_1) \quad \dots\dots (5)$$

Where $w_{1-2,actual}$ is the actual work consumption by the compressor.

- Energy balance equation for condenser

$$Q_{Cond} = \dot{m}.\,(h_2 - h_3) \quad \dots\dots (6)$$

- Energy balance equation for evaporator

$$Q_{Evap} = \dot{m}.\,(h_1 - h_4) \quad \dots\dots (7)$$

Where Q_{Evap} is refrigerating capacity of the compression system

- Energy balance in the expansion valve

$$h_3 = h_4 \quad \dots\dots (8)$$

The coefficient of performance (COP) can be determined by:

$$COP = \frac{Refrigeration\ Effect}{Compressor\ work} = \frac{h_1 - h_4}{h_2' - h_1} \quad \dots\dots (9)$$

4. Results and discussion

The data, Table 1; for refrigerant temperatures and pressures of the compression system were measured on the different days when the air-conditioner was operating with and without using a cellulose pad in the condenser and radiator. Each system was run under identical conditions to compare system performance. Temperatures and pressures were measured in the summer during the worst weather conditions in Baghdad, where the temperature reached 45 degrees Celsius and the relative humidity between 20 - 40 %, according to Fig. 6.

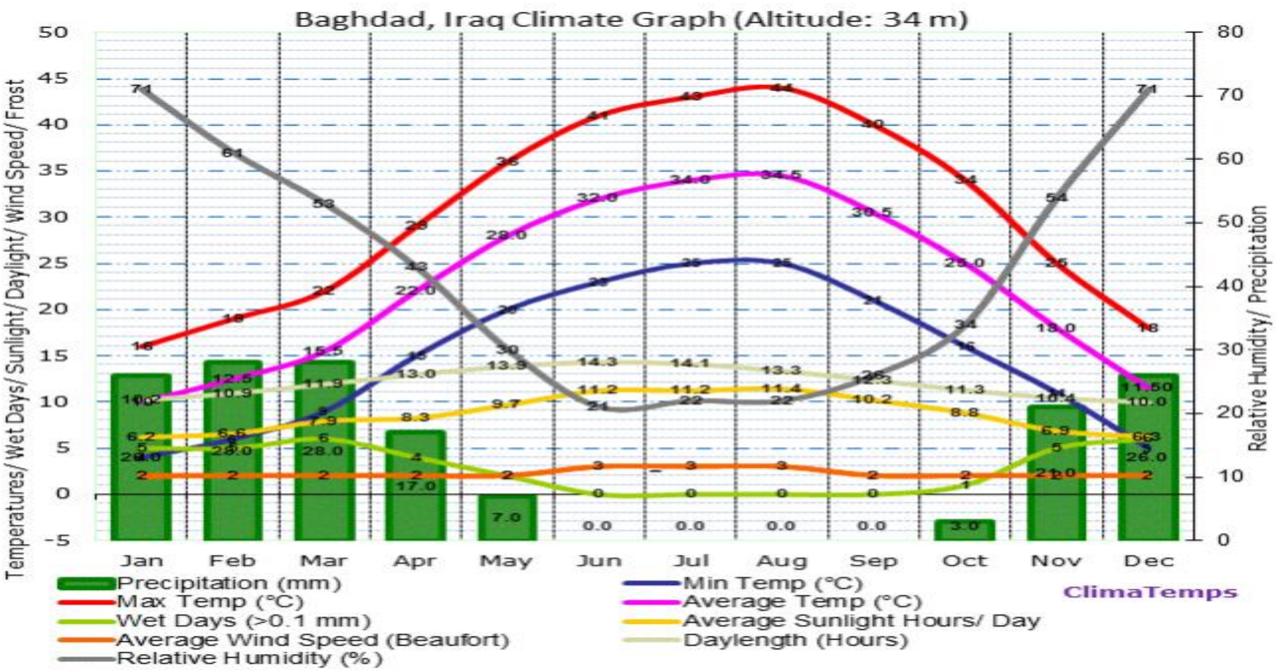

Fig. 6 Monthly average temperatures, precipitation, wet days, sunny hours, relative humidity, and wind velocity in Baghdad, Iraq. [10].

According to [11], VRT (Variable Refrigerant Temperature) and VAV (Variable Air Volume) technologies are both possible. The air conditioning is both energy-efficient and comfortable.

Table 1. The results at the peak of the solar irradiance with and without the use of a cellulose pad

Hour	COP) with pad	COP) without pad	Compressor efficiency) with pad	Compressor efficiency) without pad	Discharge temperature without pad	Discharge temperature with pad
11:00 am		2.557		67.3 %	76	
11:30 am	3.312		74.1%			67
12:00 pm		2.641		68.1 %	78	
12:30 pm	3.333		75.5%			69
1:00 pm		2.653		69.3 %	79	
1:30 pm	3.354		77%			70

Fig. 7, Fig. 8, and Fig. 9 show the effect of the evaporative cooling of the air entering the condenser of the automobile cooling system, and these results are due to the following reasons: -

1. The cooling process for air entering the condenser of the automobile cooling system led to a decrease in the condensing pressure and finally decreased the compressor's work. This led to increasing the coefficient of performance of the cooling system [12].

2. Lowering the condenser pressure also resulted in subcooling the refrigerant liquid, which increased the evaporator's refrigeration effect and, as a result, the system's coefficient of performance. [13].

3. The temperature of the discharge in the actual system without using a cellulosic pad is high, necessitating the designers to increase the size of the condenser to be sufficiently heat rejected. This high temperature negatively affects the engine's performance, especially in the summer, when the engine requires a cooling process that is greater than necessary and when cooling is used. The cellulose pad for evaporative cooling has reduced the amount of gasoline required to circulate the cooling water pump. This method (evaporative cooling) indirectly improves the life of plastic engine parts and lowers the advanced combustion phenomena caused by high temperatures [14].

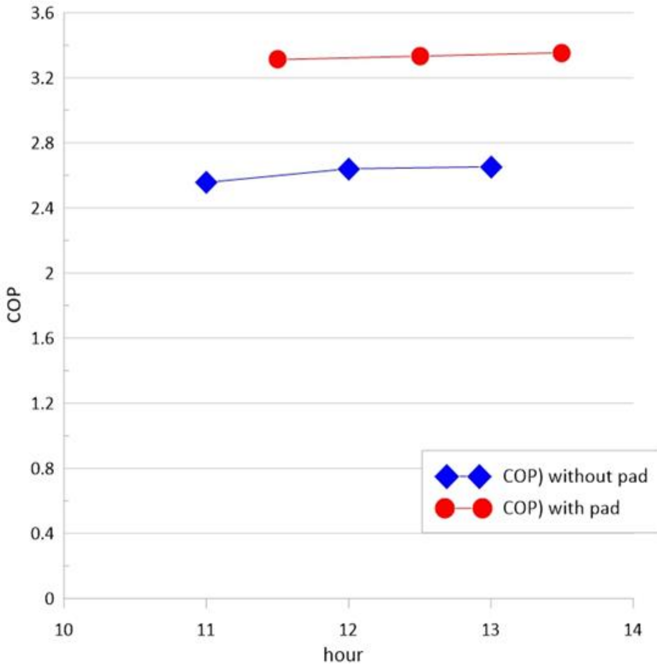

Fig. 7 The relationship between the coefficient of performance and the high-temperature peak period

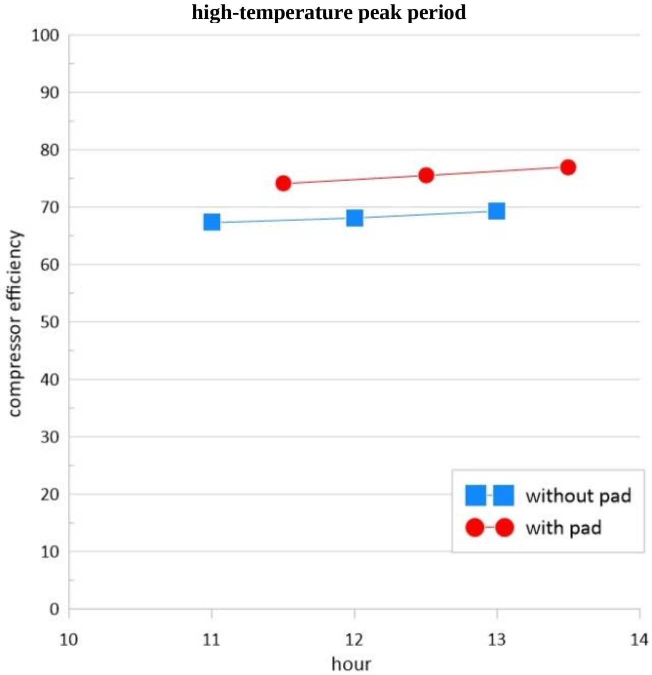

Fig. 8 The relationship between the isentropic efficiency and the high-temperature peak period

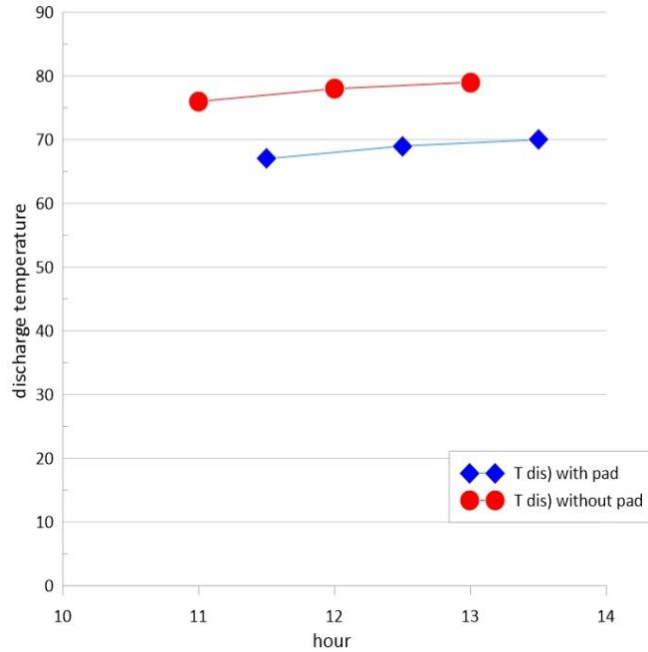

Fig. 9 The relationship between the discharge temperature and the high-temperature peak period

5. Conclusion

The use of a wetted pad before the condenser of the automobile led to:

1. A 13% reduction in discharge temperature extends the life of plastic engine parts and reduces the advanced combustion phenomena induced by high temperatures.

2. Increasing the isentropic efficiency of the compressor by 10% means the power consumption is saved.

3. The coefficient of performance increased by 27%.

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