Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 12, Issue 12 December 2023

The Integration of Renewable Energy Sources in Vehicle HVAC System

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***Abstract*— The rapid growth of the automotive industry, coupled with increasing environmental concerns, has driven a significant shift towards renewable energy sources in vehicle engineering. Vehicle Heating, Ventilation, and Air Conditioning (HVAC) systems play a key role in providing comfort and safety to occupants, but they also consume a significant amount of energy. Integrating renewable energy sources into these systems can reduce energy consumption and decrease the environmental impact of vehicles by reducing their carbon footprint. Heating, ventilation, and air conditioning (HVAC) technology is employed to enhance indoor and automotive ambient comfort. HVAC systems are essential for maintaining a comfortable temperature and climate inside vehicle cabins. Vehicle HVAC (Heating, Ventilation, and Air Conditioning) systems play a vital role in ensuring passenger comfort, safety, and overall vehicle performance. This paper provides a comprehensive overview of Renewable Energy Vehicle's Heating, Ventilation, and Air Conditioning (HVAC) systems, highlighting their importance in reducing greenhouse gas emissions, enhancing energy efficiency, and improving overall driving experience. The paper explores various renewable energy sources, such as solar power, and waste heat recovery to employ absorption refrigeration system that can be integrated into vehicle HVAC systems.**

***Keywords*—** Air Conditioning, Environmental impact, HVAC, Passenger Comfort, Ventilation, Renewable Energy Sources

I. INTRODUCTION

Vehicle HVAC (Heating, Ventilation, and Air Conditioning) systems play a crucial role in providing comfort and safety to occupants, but they also consume a significant amount of energy. Integrating renewable energy sources into these systems can reduce energy consumption and minimize the carbon footprint of vehicles.

In the conventional operation of vehicle air conditioning, the system comprises four primary components: the compressor, condenser, expansion valve, and evaporator. The compressor functions as a pump, powered by a belt connected to the engine's crankshaft. It draws the refrigerant in as a low-pressure gas. Once inside the compressor, the gas undergoes a significant pressure increase, typically reaching levels between 250 to 400 psi, and is then directed to the condenser.

The refrigerant enters the condenser as a high-pressure gas, and during this process, heat is generated. However, the airflow through the condenser's fins and tubes cools the refrigerant down, causing it to transition from a high-pressure gas to a high-pressure liquid state, a process known as condensation.

Within the receiver-dryer, desiccants are employed to eliminate any moisture that might have entered the system. Allowing moisture to persist within the system can result in adverse reactions with internal metal components and mix with the system's lubrication oil, leading to the formation of acids and sludge buildup, ultimately resulting in premature failure of the air conditioning system [1].

The high-pressure liquid refrigerant proceeds from the receiver-dryer through the expansion valve, where it undergoes expansion, thereby reducing its pressure. This lowered pressure facilitates the refrigerant's movement into the evaporator. In the evaporator coil, the refrigerant enters as a cold, low-pressure liquid. As warm cabin air is blown across the evaporator and the refrigerant flows through its coil, heat is absorbed from the air, as well as moisture. This heat transfer causes the air to cool directly before being vented into the cabin.

Initially in a liquid state, the refrigerant in the evaporator transforms into vapor as it absorbs heat. The evaporator maintains a constant temperature and pressure. The refrigerant operates as a working fluid, carrying out the heat transfer process by cycling through the air conditioning system, absorbing heat when it becomes a gas and releasing heat when it turns into a liquid [2].

An ideal refrigerant should possess several key characteristics as shown in Table.1.

Table I. An Ideal Refrigerant Properties

S. No.	An Ideal Refrigerant Properties
1	Zero ozone-depleting potential (ODP)
2	Low global warming potential
3	Low boiling point
4	High critical pressure and temperature point
5	Miscibility with oil while remaining chemically stable
6	Non-toxic, non-flammable
7	Non-corrosive to metal, rubber, and plastics
8	Affordability in terms of production, usage, and disposal

The Tetrafluoroethene, HFC-134a (R134a) is the current choice for air conditioners due to its ease of evaporation and liquefaction, chemical stability, and non-degenerative properties. It is also notable for having zero ozone-depleting potential since it lacks chlorine. However, it does contribute to global warming. Fig.1 provides an illustration of the cycle of a vehicle's air conditioning system.

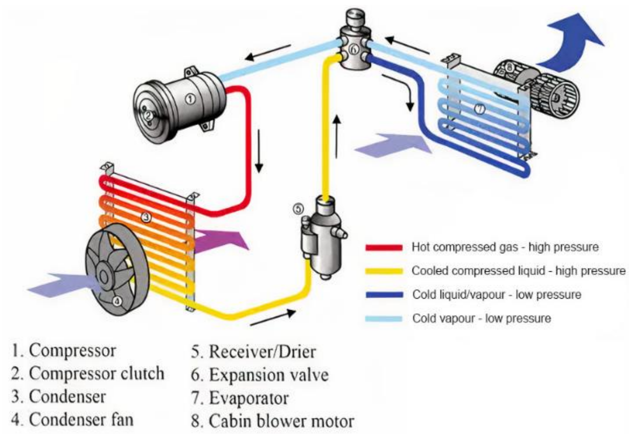

Fig. 1. Vehicle's air conditioning system.

The operation of a vehicle's air conditioning system consumes fuel, which constitutes an additional factor contributing to increased pollution and the exacerbation of global warming.
The fuel consumption of a vehicle's air conditioning system can vary depending on various factors, including the vehicle's make and model, the efficiency of the air conditioning system, the outside temperature, and how often and at what settings the air conditioning is used.
Generally, using the air conditioning in a vehicle can increase fuel consumption because it places an additional load on the engine.
As a rough estimate, using the air conditioning can increase fuel consumption by as much as 10% or more, especially when driving in stop-and-go city traffic.
Air conditioning systems in vehicles represent the most substantial auxiliary power loads in contemporary automobiles. The AC energy consumption for a standard vehicle use 8.7 liters per 100 kilometers. The air conditioning compressor can add a peak power load of 5-6 kilowatts on the vehicle's engine. The addition of the AC compressor load to the engine significantly reduces the vehicle's fuel efficiency. The effect is even larger in high fuel economy vehicles [3].
The research findings indicated that the United States annually consumes 27 billion liters of gasoline for the purpose of air conditioning vehicles. This quantity is equivalent to 6% of the country's total petroleum consumption or 10% of the crude oil imported into the United States [4].
The utilization of renewable energy sources in vehicle HVAC systems offers a wide range of benefits, from reducing environmental impact, enhanced air quality to promoting energy efficiency, and the promotion of long-term sustainability. As renewable energy technologies continue to advance, their integration into vehicle HVAC systems is becoming increasingly important for a more sustainable and environmentally responsible transportation sector.
Consequently, there are environmental and economic advantages associated with the utilization of renewable energy [5].
The components and operation of renewable energy-integrated HVAC systems, focusing on key elements and their functions. The solar heating elements are integrated into the vehicle's design to capture and convert solar energy into heat. Typically, these systems consist of solar panels or collectors mounted on the vehicle's exterior surfaces. The captured solar energy is then used to heat a heat-transfer fluid (usually a coolant or refrigerant) that circulates through a heat exchanger to warm the air in the cabin and the absorption cooling system is employed to generate cabin cooling by utilizing the same energy source.

Thermoelectric generators can also be employed to harness waste heat from the vehicle's powertrain or other sources. These generators convert temperature differentials into electrical energy, which can be used for heating purposes. Thermoelectric heating is particularly effective in hybrid and electric vehicles.

Renewable energy-integrated HVAC systems like absorption air conditioning system often include improved air circulation mechanisms to distribute conditioned air more efficiently throughout the cabin.

Air quality is crucial for passenger comfort and health. These systems may incorporate advanced air filtration and purification technologies to remove pollutants and allergens from the incoming air. Solar and waste heat-based systems can operate ventilation components, ensuring continuous air quality improvements.

solar energy or waste heat can power absorption system that provide cooling. This system use heat energy to drive a cooling process, providing air conditioning without the need for a conventional compressor-driven system.

Some renewable energy-integrated HVAC systems employ innovative cooling technologies that reduce or eliminate the need for energy-intensive compressors. These systems may rely on thermoelectric cooling or evaporative cooling methods, which can be driven by renewable energy sources.

Renewable energy-integrated HVAC systems require sophisticated energy management and control systems. These systems continuously monitor energy generation, battery state of charge, cabin temperature, and other relevant parameters to optimize HVAC operation. Machine learning and predictive algorithms are often used to make real-time adjustments.

Many renewable energy-integrated HVAC systems incorporate energy storage solutions, such as lithium-ion batteries, to store excess energy generated by renewable sources. These batteries can provide power during periods of low renewable energy production or when the vehicle is stationary.

The driver and passengers typically have control over the HVAC system through a user-friendly interface. This interface allows occupants to set their preferred temperature, fan speed, and other settings, while the integrated control system ensures that energy-efficient strategies are followed to meet these preferences.

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The limitations of vapour compression refrigeration system as the environmental aspects of use of refrigerants gives rise to developed system of vapour absorption refrigeration system. The vapor absorption refrigeration system operates based on the utilization of low-grade heat energy, while the vapor compression refrigeration system relies on mechanical energy [6]. Absorption cooling systems offer a viable alternative to traditional vapor compression refrigeration systems. This transition not only relieves the vehicle engine's compressor workload but also results in significant energy savings. The substantial waste heat generated by the engine proves more than sufficient to power a absorption system, effectively maintaining ideal temperature conditions within the vehicle's cabins.

II. VEHICLE ABSORPTION REFRIGERATION SYSTEM

The vapor absorption refrigeration system, one of the oldest refrigeration methods, utilizes secondary low-grade heat energy rather than primary mechanical energy. This system operates based on the principle of absorption, where water serves as the refrigerant, and lithium bromide (LiBr) functions as the absorbent [7].

The absorption system is ideally suited to harness waste heat energy from the vehicle's engine or exhaust, as well as alternative heat sources like solar energy. Instead of a compressor, the system employs a generator and an absorber to increase the cooling agent's temperature and pressure. The system comprises several essential components, including the absorber, pump, generator, condenser, expander (expansion valve), and evaporator.

In the generator, heat is supplied to the strong solution, causing an increase in both the temperature and pressure of the cooling agent. The high-pressure refrigerant vapours from the generator enter the condenser. The condenser has a cooling medium to cool the hot vapours of the refrigerant. Here the refrigerant vapours get converted into the high-pressure saturated liquid refrigerant by removing latent heat energy.

Expansion valve is located between the condenser & evaporator. After the condenser, the high-pressure liquid refrigerant enters the expansion valve. Here the high-pressure liquid refrigerant is converted into a mixture of low-pressure and low temperature refrigerant (liquid + vapour) due to expansion process.

The evaporator is located in the enclosed space in the vehicle cabin where cooling is carried out. In the evaporator, the low-pressure liquid refrigerant absorbs the latent heat in the enclosed space to provide a cooling effect. As the latent heat of evaporation is absorbed by the cooling agent converts its phase from liquid to gaseous form. The fumes of cooling agent mix with the week fluid solution present in the absorber.

The strong solution from the absorber is pumped to the generator and the cycle repeats. Fig. 2 illustrate the typical vapour absorption refrigeration system [8].

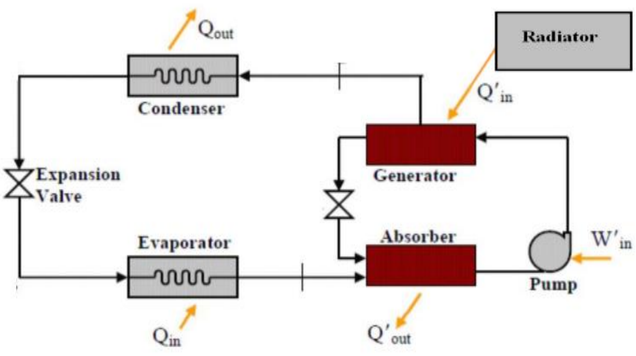

Fig. 2. Vehicle's vapour absorption refrigeration system

Before utilizing absorption cooling systems as a renewable energy source in vehicles, it's advisable to optimize the vehicle's heat load during the design of its air conditioning and ventilation systems. This optimization can lead to a reduced capacity requirement for the absorption system. Which will help in minimizing the capacity of absorption system.

Using high-performance insulation, advanced thermal wind screens, energy-efficient side window glass, smart ventilation practices, energy-saving lighting, and adhering to energy standards like ASHRAE 62.1, ASHRAE 62.2 [9], ASHRAE 55, or similar standards guidelines can significantly reduce the demand for cooling in the air conditioning and ventilation system of vehicles [10].

III.CONCLUSION

Vehicle Heating, Ventilation, and Air Conditioning (HVAC) systems are essential for ensuring occupant comfort and safety, but they also consume a considerable amount of energy.

The Vehicle air conditioning system consumed fuel which is about 8.7 liters per 100 kilometers depending on size. This not only contributes to increased pollution and global warming but also results in a significant reduction in the vehicle's fuel efficiency.

Using renewable energy sources in vehicle HVAC systems has many advantages, including reducing environmental impact, improving air quality, increasing energy efficiency, and promoting long-term sustainability.

The various renewable energy sources, including solar power and waste heat recovery, can be harnessed to implement an absorption refrigeration system that can be integrated into vehicle HVAC systems.

Absorption refrigeration systems is secondary energy renewal source which utilize heat energy to provide cooling. The heat energy, which may come from renewable or vehicle's engine or exhaust. This system is energy-efficient and environmentally friendly compared to traditional vapor compression refrigeration systems.

Successful implementation of an absorption cooling system in a vehicle requires careful planning, engineering, and consideration of safety, environmental, and efficiency factors.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 12, Issue 12 December 2023

IV. REFERENCES

[1] "How Car Air Conditioning Works," [Online]. Available: https://myjackfrost.com.au/car-air-conditioning/how-car-air-conditioning-works/. [Accessed: Oct. 9, 2023].

[2] "HVAC System for Cars and Automotive Vehicles," [Online]. Available: https://www.cedengineering.com/userfiles. [Accessed: Oct. 9, 2023].

[3] K. Shete, "Influence of Automotive Air Conditioning load on Fuel Economy of IC Engine Vehicles," International Journal of Scientific & Engineering Research (IJSER), vol. 6, no. 8, pp. 1367, Aug. 2015. ISSN: 2229-5518.

[4] V. H. Johnson, "Fuel Used for Vehicle Air Conditioning: A State by-State Thermal Comfort Approach," in SAE Technical Paper, SAE International, Detroit, MI, 2002, paper 2002-01-1957.

[5] "Local Renewable Energy Benefits and Resources," [Online]. Available: https://www.epa.gov/statelocalenergy/local-renewable-energy-benefits-and-resources. [Accessed: Oct. 11, 2023].

[6] P. V. Patwardhan and A. A. Patil, "Review of Recent Advancements in Vapour Absorption Refrigeration System," Int. J. Eng. Scientific Innov., vol. 10, no. 6, pp. 14-18, Jun. 2021.

[7] "How Do Absorption Chillers Work?" Online. Available: https://www.thermaxglobal.com/how-do-absorption-chillers-work. [Accessed: Oct. 12, 2023].

[8] "Water-Lithium-Bromide Vapor Absorption Refrigeration System," Online. Available: https://www.brighthubengineering.com/hvac/66301-water-lithium-bromide-vapor-absorption-refrigeration-system. [Accessed: Oct. 13, 2023].

[9] ANSI/ASHRAE/IESNA, "Standard 62.1 & 62.2, SI edn. Ventilation for Acceptable Indoor Air Quality," ASHRAE, Atlanta, USA, 2019.

[10] ANSI/ASHRAE/IESNA, "Standard 55, SI edn. Ventilation for Acceptable Indoor Air Quality," ASHRAE, Atlanta, USA, 2020.