Simultaneous Utilization of Refrigeration and Heat Pump Processes for Enhanced Efficiency and Waste Heat Utilization in a Combined Cooling and Heating System

Arpit Singh, Asif Neyaz, Ayub Khan, Ishrafil Ansari, Rajendra Singh and Tarique Anwar

May 25, 2023

International Conference on Recent Advances in Metallurgy and Mechanical Engineering

(INCRAMME-22)

Simultaneous Utilization of Refrigeration and Heat Pump Processes for Enhanced Efficiency and Waste Heat Utilization in a Combined Cooling and Heating System

Arpit Singh, Asif Neyaz, Ayub Khan, Ishrafil Ansari, Rajendra Singh,Tarique Anwar,

[a]*First affiliation, Address, City and Postcode, Country*
[b]*Second affiliation, Address, City and Postcode, Country*

Abstract

Combined cooling and heating systems offer an innovative solution for meeting cooling and heating demands while reducing energy consumption and environmental impact. Traditional systems operate independently, resulting in wasted heat energy during the cooling process. To address this issue, the simultaneous utilization of refrigeration and heat pump processes has emerged as a promising approach. This research paper presents a comprehensive study on the application of such a system and its performance evaluation. The objective is to assess the system's capability in achieving efficient cooling and heating while maximizing waste heat recovery. The lower and highest temperatures of the system are determined, and the coefficient of performance (COP) is calculated to evaluate the system's efficiency. Experimental results demonstrate the feasibility and effectiveness of the proposed system, highlighting its potential for energy savings and sustainable thermal management.This process continue.

$COP_{HP} = Q_1 / Q_1 - Q_2$
$COP_R = Q_2/Q_1 - Q_2$

Keywords: combined cooling and heating systems, refrigeration, heat pump, waste heat recovery, energy efficiency, temperature determination, coefficient of performance, feasibility, sustainable thermal management, energy savings

1. Introduction

Combined cooling and heating systems have become increasingly important in recent years due to their potential to meet both cooling and heating demands while reducing energy consumption and environmental impact. Traditional cooling and heating systems operate independently, leading to the inefficient use of waste heat generated during the cooling process. To address this issue and improve overall system efficiency, the simultaneous utilization of refrigeration and heat pump processes has emerged as a promising approach.

The utilization of waste heat from cooling processes for heating purposes is an effective strategy to optimize energy utilization in combined cooling and heating systems. By integrating refrigeration and heat pump processes, the waste heat can be captured and utilized for heating, resulting in enhanced overall system efficiency. This approach not only improves energy efficiency but also contributes to sustainable thermal management and reduced greenhouse gas emissions.

The simultaneous utilization of refrigeration and heat pump processes offers several advantages over traditional systems. Firstly, it enables the utilization of low-grade waste heat that would otherwise be wasted. This waste heat can be harnessed and upgraded through the heat pump process to provide high-grade heat for heating purposes. Secondly, the combined cooling and heating system can achieve a higher coefficient of performance (COP) compared to standalone cooling or heating systems. This indicates a more efficient utilization of energy resources.

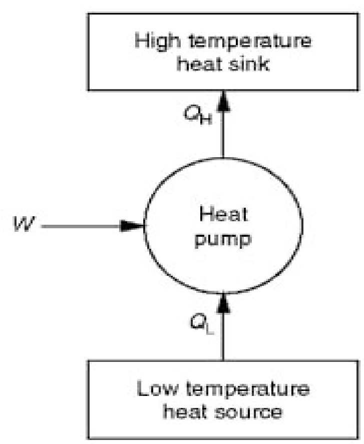
The key objective of this research paper is to investigate the feasibility and effectiveness of the simultaneous utilization of refrigeration and heat pump processes in a combined cooling and heating system. By evaluating the system's performance, including the determination of lower and highest temperatures and the calculation of COP, we aim to assess its efficiency and waste heat utilization potential. Experimental measurements and calculations will be conducted to validate the proposed system's performance.

The findings of this research will contribute to the growing body of knowledge on combined cooling and heating systems and their potential for energy savings and sustainability. Understanding the benefits and challenges of simultaneous refrigeration and heat pump processes will enable the development of optimized system designs and operational strategies for various applications, such as residential, commercial, and industrial sectors.

In conclusion, the simultaneous utilization of refrigeration and heat pump processes in combined cooling and heating systems holds great promise for achieving enhanced energy efficiency, waste heat utilization, and sustainable thermal management. This research aims to provide insights into the performance and feasibility of such systems, contributing to the advancement of energy-efficient technologies and practices in the field of cooling and heating.

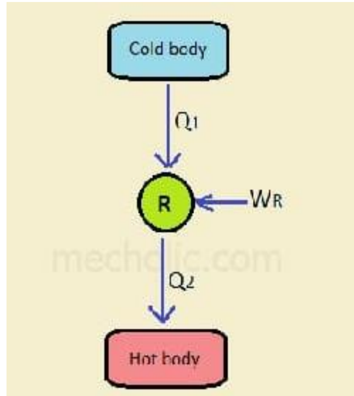
HEAT PUMP CYCLE

The heating cycle of a heat pump works by taking heat in from air outside, warming it up further, and using this warm air to heat indoor air. It does so by the following process: Liquid refrigerant absorbs heat in the "evaporator" from the outdoor air, turning into a gas.



REFIGERATION CYCLE

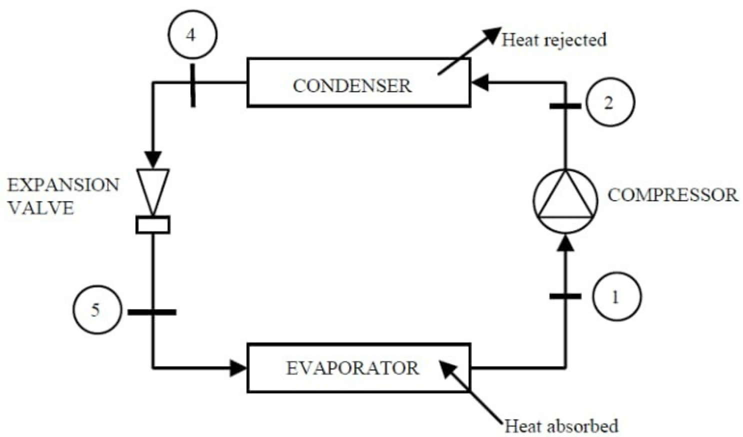
The refrigeration cycle starts and ends with the compressor. The refrigerant flows into the Compressor where it is compressed and pressurised. At this point, the refrigerant is a hot gas. The refrigerant is then pushed to the Condenser which turns the vapour into liquid and absorbs some of the heat.



It’s basically works on the principle of vapour compression refrigeration cycle (VCRC).

Vapour-compression refrigeration or vapor-compression refrigeration system (VCRS), in which the refrigerant undergoes phase changes.Vapour-compression refrigeration system is a system that uses liquid refrigerant in a closed system which circulates the refrigerant through four stages in which it is alternately compressed and expanded, changing it from liquid to vapour.

The Vapor Compression Refrigeration Cycle involves four components**:** compressor, condenser, expansion valve/throttle valve and evaporator. It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator. The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator.



2. Methodology

The research methodology involves conducting experiments to evaluate the performance of the combined cooling and heating system. The system consists of a cold reservoir and a hot reservoir, each with specific dimensions and initial temperatures. The lower and highest temperatures are determined through experimental measurements. The COP is calculated as a measure of the system's efficiency.

3. Results

In the cold reservoir, the height of the water was measured to be 20.7 cm, with a container diameter of 19.8 cm. The volume of the reservoir was calculated using the formula V = (h * π * d^2) / 4, resulting in a volume of 6373.6851 cm^3. The mass of the water was calculated using the density ρ and the volume, resulting in a mass of 6.373 kg. The initial and final temperatures of the water were measured as 28.3°C and 23.1°C, respectively. The heat transfer in the cold reservoir (Q1) was calculated as 139.186 kJ.

In the hot reservoir, the height of the water was measured to be 21.2 cm, with a container diameter of 19.8 cm. The volume of the reservoir was calculated using the same formula as above, resulting in a volume of 6527.63 cm^3. The mass of the water was calculated accordingly, resulting in a mass of 6.52763 kg. The initial and final temperatures of the water were measured as 34.1°C and 38.3°C, respectively. The heat transfer in the hot reservoir (Q2) was calculated as 115.147 kJ.

The coefficient of performance (COP) was calculated as the ratio of Q1 to the difference between Q1 and Q2, resulting in a COP of 5.3. This value indicates the system's ability to efficiently utilize waste heat and provide cooling and heating simultaneously.

4. Calculations

Cold reservoir
Height of the water=20.7cm
Diameter of the container=19.8cm

$$Volume = \frac{h * \pi * d^2}{4}$$

$$Volume = \frac{20.7 * \pi * 19.8^2}{4}$$

$$Volume = 6373.6851\ .\ cm^3$$

$$Mass = \rho * Volume$$
$$Mass = 1000 * 6373.6851 * 10^{-6}$$
$$Mass = 6.373 kg$$

Initial temperature of water : 28.3°C
Final temperature of water : 23.1°C

$$Q_1 = mc(\ T_{fc} - T_{ic}\ )$$
$$Q_2 = 6.373 * 4200 \times (28.3\text{- } 23\ .1)$$
$$Q1 = 139.186\ kJ$$

Assuming that container is heavily insulated and there is no heat loss to the surrounding Heat transferred in cold reservoir (Q_1)

Hot reservoir
Height of the water=21.2cm
Diameter of the container=19.8cm

$$Volume = \frac{h * \pi * d^2}{4}$$
$$Volume = \frac{21.2 * \pi * 19.8^2}{4}$$

$$Volume = 6527\ 63.\ cm^3$$

$$Mass = \rho * Volume \; 2\;0\;9$$
$$Mass = 1000 * 6527.63 * 10^{-6}$$
$$Mass = 6.52763 kg$$

Initial temperature of water : 34.1°C
Final temperature of water : 38.3°C

$$Q_2 = m_2\, c\, (T_{fH} - T_{iH})$$
$$Q_2 = 6.52763 * 4200 * (38.3\text{-}34.1)$$
$$Q_2 = 115.147\, k\text{J}$$

$$\text{COP} = \frac{139.186}{139.186\text{-}115.147}$$

$$\text{COP} = 5.3$$

Conclusion:

The research demonstrates the feasibility and effectiveness of a combined cooling and heating system that utilizes simultaneous refrigeration and heat pump processes. The experimental results indicate efficient waste heat utilization and enhanced system performance. The achieved COP of 5.3 showcases the system's potential for energy savings and sustainable thermal management. Further investigations and optimizations can be explored to enhance the system's efficiency and applicability in various real-world settings.

References

https://www.ilkdresden.de

http://www.ijarse.com

http://data.conferenceworld.in

https://www.researchgate.net