EXPERIMENTAL ANALYSIS OF COP IN DOMESTIC REFRIGERATOR BY USING PHASE CHANGE MATERIALS

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Abstract: Preservation of food, medicine for a prolong period in a country like India has become difficult due to additional power cuts. To overcome this problem thermal energy storages like phase change materials can be used. PCM'S had extensive variety of uses in refrigeration and air conditioning. Phase change materials (PCM's) have an excellent advantage of constant temperature in course of absorbing or releasing the energy. A U-shaped PCM box which is comprised of aluminium sheet of 5mm thickness is used to contain the PCM, which is fabricated to the evaporator of domestic refrigerator. During the running time of compressor, the PCM acts as a slab and Heat is absorbed when the material changes its state from solid to liquid. Then phase change material improves heat transfer rate in the evaporator. During low demand the PCM stores the energy. The heat is absorbed by the PCM when the compressor is in OFF period and produces more effective cooling to the refrigerator cabin during off cycle and allows permits a few long periods of ceaseless activity without powersupply.PCM's used are water, sodium chloride (NaCl), sodium sulphate(Na2SO4).

Key words: R-134a, COP-Coefficient of performance, phase change materials.

1. INTRODUCTION

A phase change material is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy as this is the main advantage of PCM in this research. Heat is absorbed or released when the material changes its stage from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage units. Phase Change Materials are items that store and discharge thermal energy during the processes of melting and freezing. Phase Change Materials release large amounts of energy upon freezing in the form of latent heat but absorb equal amounts of energy from the immediate environment upon melting. This enables thermal energy storage; heat or coolness being stored from one process or period of time and used at a later point in time or transferred to a different location. PCMs can also be used to provide thermal barriers or insulation, particularly useful for industry sectors such as temperature controlled transport.Interestingly, the simplest, cheapest and most effective Phase Change Material is water/ice. Unfortunately, its freezing point of 0^{oC} blocks it from the majority of energy storage applications.Notwithstanding, various elective Phase Change Materials have been recognized and built up that stop and dissolve like water/ice, but at temperatures from the cryogenic range to several 100^0 c.Thermal Energy Storage is theis the transitory stockpiling of high or low temperature vitality for later utilize. It crosses over barrier between energy requirement and energy use.The PCMs used in this research were water, sodium chloride (Nacl), sodium sulphate (Na_2SO_4).The PCMs are called eutectic PCMs eutectic PCM ($NaCl.Na_2SO_4.10H_2O$) with highest latent heat of fusion 286 kJ/kg has shown the better results for improvement of COP. Basically the PCMsused are called eutectic PCMs in this work are called eutectic PCM's possess the following advantages.

- Eutectics have sharp melting point similar to pure substance.
- Volumetric storage density is slightly above organic compounds.
- Extra water standard can be utilized to maintain a strategic distance from stage change corruption, including dissolving the anhydrous salt amid liquefying to result in a thickening of the fluid material with the goal that it melts to a gel shape.

Thermal properties for water:

- Freezing temperature - 0 °C
- Boiling temperature - 100 °C
- Latent heat of fusion - 334 kJ/kg
- Latent heat of evaporation - 2257 kJ/kg
- Critical temperature - 380 °C - 386 °C
- Critical pressure - 221.2 bar, 22.1 MPa (MN/m^2)
- Maximum density at 4 °C - 1000 kg/m^3, 1.940 slugs/ft^3

Thermal properties for sodium chloride (NaCl):

- Freezing temperature = - 5°C

- Boiling temperature–108.7°C
- Latent heat of fusion - 254 kJ/kg

Thermal properties for sodium sulphate (Na_2SO_4):

- Freezing point 32°C (when it is mixed with NaCl is 18 °C)
- Boiling temperature–100°C
- Latent heat of fusion - 252 kJ/kg (when it is mixed with water and NaCl 286kJ/kg)

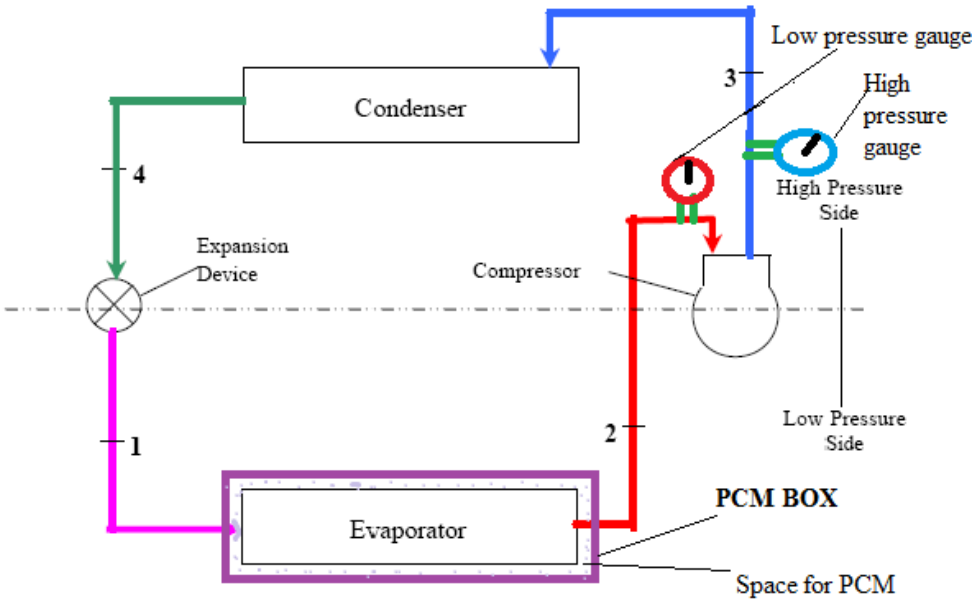


Fig 1. layout of VCRS system with PCM box

Generally, the vapour compression cooling system consists of a condenser, associate growth valve, associate evaporator, and a mechanical device. The vapour compression cooling system consists of 4 processes as such below.

(1-2) compressing refrigerant in hermitically sealed compressor isentropically,

(2-3) condensation at constant pressure in the condenser,

(3-4) isenthalpic expansion of refrigerant in the expansion valve,

(4-1) evaporation at constant pressure in evaporator.

Here,

h_1 is the enthalpy at compressor inlet in kJ/kg,

h_2 is the enthalpy at compressor outlet in kJ/kg,

h_3 is the enthalpy at the condenser exit in kJ/kg,

h_4 is the enthalpy at the inlet of evaporator in kJ/kg

And, $h_3=h_4$, since the process (3-4) is an isenthalpic

Net refrigeration effect (NRE) = $h_1 - h_4$d in kJ/kg

Mass flow rate of working fluid (m_f) =210/NRE in kJ/min

Compressor work (W_c) = $h_2 – h_1$ in kJ/kg

Heat equivalent for compressor work per TR (Q_e) = m_f (h2 – h_1) in kJ/min

Power of compressor (P_c) = Q_e/60 in kW

Coefficient of performance (COP) = (h1 –h_4) / (h2 –h_1) or NRE / W_C

Heat rejected by the condenser (Q_r) = $h_2 – h_3$ in kJ/kg

2. RESEARCH METHOD

Experimental apparatus and procedure:

Firstly choose the VCR system of a 175L capability. A conventional house hold refrigerator is used in the modified form with PCM box located behind the evaporator cabinet to carry out the necessary experiments. The experimental set up has been comprised with a refrigerator, pressure gauge, thermocouple, phase change material box. A U-Shaped box is fabricated and is fitted with in the evaporator cabin to withhold the phase change material. It is fitted so that is completely in contact with the evaporator coils. The box is made of aluminium sheet with a thickness of 5mm.In the present work PCM's selected were water, standard NaCl solution, Na_2SO_4solution PCM solution is prepared by mixing 58.4 gm of PCM powder and l litre of water. And

in case of mixing 3 PCM solutions 29.2gms of PCM powder is taken with 1litre of water. shaking the mixture well for few minutes makes the powder to dissolve completely in water.The volume of the PCM taken in this work is 200ml.

Test procedures:

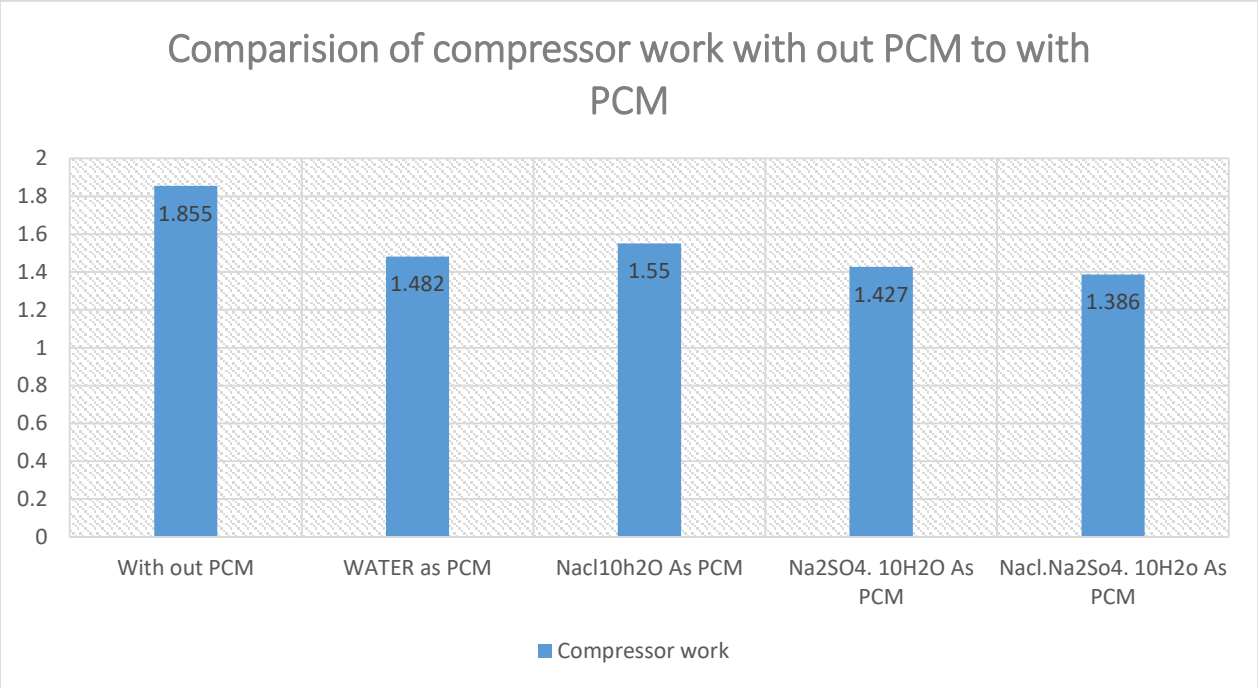
The type of PCMs used are eutectic PCMs. A eutectic is a melting composition of two or more components, each of which melts and freezes congruently, forming a mixture of the component crystals during crystallization. The refrigeration system experimentation was carried out with

1. Normal VCR system without using PCM with R134a as refrigerant.
2 .VCR System with using eutectic PCM (Nacl.$10H_2o$) with R134a as refrigerant.
3. VCR system with using eutectic PCM (Na_2SO_4.$10H_2O$) with R134a as refrigerant.
4. VCR system with using eutectic PCM (Nacl.Na_2SO_4.$10H_2O$) with R134a as refrigerant

Experiments are tried all cases and also the values of pressures and temperatures are tabulated and calculations are done.

3. RESULTS AND DISCUSSION

Experiments are conducted on175L capacity refrigerator. Here the PCMs were used in the chamber built manually and which surrounds the evaporator chamber of the refrigerator so the heat transfer rate in evaporator increases and will improve the COP of the refrigerator. For a particular phase until the PCM melts completely the desired temperature of the product can be maintain during the off cycle of the compressor which ultimately increase the OFF period



3.1Comparison of compressor work without PCM to with PCM:

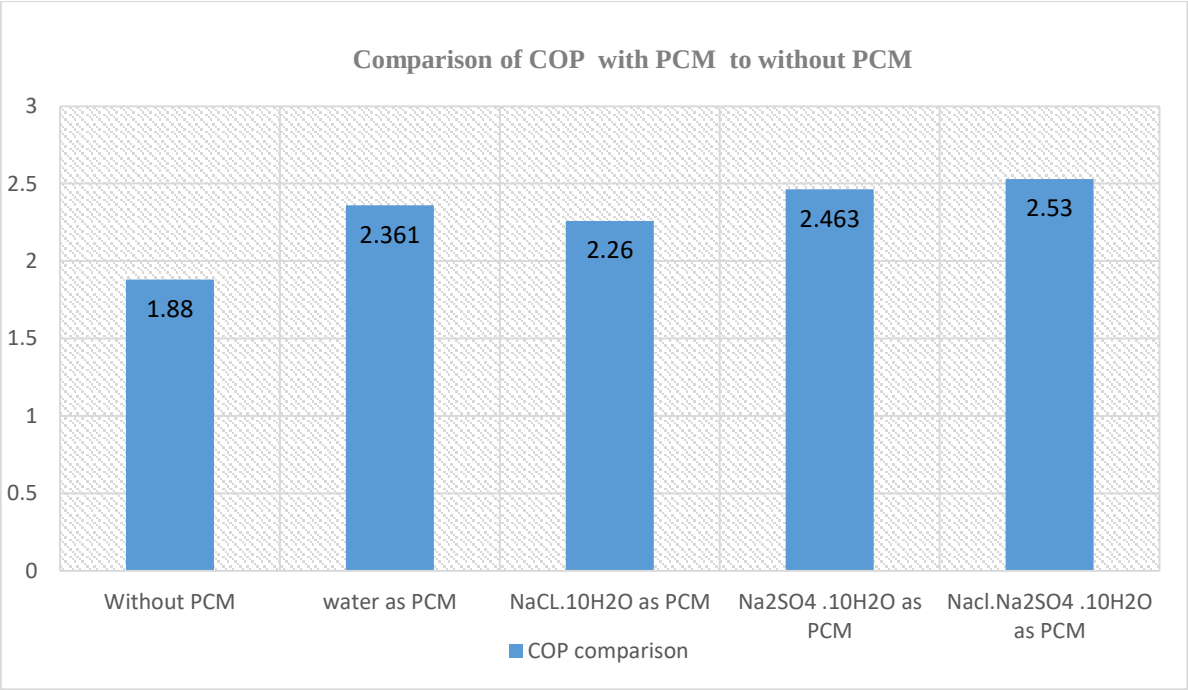
From fig, compressor work of the vapour compression refrigeration system by comparing to with and without PCM

1. When compared to without PCM to Nacl.10H2O as eutectic PCM the compressor work has been reduced to19.3%

2. When compared to without PCM to Na2so4.10H2O as eutectic PCM the compressor work has been reduced to 30.2%

3. When compared to without PCM to Nacl. Na2so4.10H2O as eutectic PCM the compressor work has been reduced to 34%

4. When compared to without PCM to water as PCM the compressor work has been reduced to 25.1%



3.2 Comparison of COP to with PCM and without PCM:

From fig, Comparison of COP to with PCM without PCM

1. When compared to without PCM to Nacl.10H2O as eutectic PCM the COP has been increased 20.2%
2. When compared to without PCM to Na2so4.10H2O as eutectic PCM the COP has been increased 30.8%
3. When compared to without PCM to Nacl.Na2so4.10H2O as eutectic PCM the COP has been increased 34.5%
4. When compared to without PCM to water as PCM the COP has been increased 25.5%

4.CONCLUSION

Use of phase changing materials is useful and can considerably contribute to society in saving energy. Due to its appreciable thermo physical properties it has various uses. Use of phase change materials will save electricity and additionally improve the quality of food in terms of hygiene by reducing the fluctuations of temperatures with in the evaporator section. it has observed that the PCM (Nacl.Na2SO4 .10H2O) has shown better results in improving COP and reducing compressor work. With This eutectic PCM solution it has been observed that there is 34.5 % improvement of COP and 34% reduction of compressor work. Bottom-line we can conclude that phase changing materials are indeed helpful serving elements within the refrigeration industry.

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