Engineering Universe for Scientific Research and Management
ISSN (Online): 2319-3069
Vol. XV Issue IX
Sep 2023

A Review on optimization of refrigeration system using phase change material to enhancing the performance by simulation tool

Mrs. Priyanka Jhavar[1], Anzar Nawazish[2], Mr.Sachin Baraskar[3]
Associate Professor, Mechanical Department, SSSUTMS, Sehore, M.P., India[1]
Research Scholar, Mechanical Department, SSSUTMS, Sehore, M.P., India[2]
Assistant Professor, Mechanical Department, SSSUTMS, Sehore, M.P., India[3]

Abstract

Among the renewable energy sources, solar energy has been utilized more adequately due to its wide availability and being a reliable source of energy source. Solar cooling and refrigeration have emerged as a basic need for human comfort along with food conservation. However, since renewable energy sources are time-dependent, there are problems that occur due to the mismatch of energy supply and energy demand. Hence to resolve the issues, thermal energy storage techniques can be used which stores the energy and provides uninterrupted energy based on the requirement. Phase change materials can be used for this purpose since PCM has better capacity in terms of storing energy and isothermal behaviour during both charging and discharging processes. By observing the results obtained from the analysis that under the same operating conditions and time, the D-mannitol has stored the higher energy as compared to the hydroquinone. From these obtained results it can be suggested that the D-mannitol is the best suited as the PCM for the thermal energy storage process. For the ease of the computational analysis, it can be considered an individual unit for analysis where we can dub that each and every unit that will work similarly and further reducing the computational load there which we are charging for the PCM for about 4000 sec in both cases and they are compared to both the PCMs for a maximum energy storage.

Keywords: Thermal Energy Storage, Phase Change Material, Refrigeration Performance Optimization.

1. Introduction

Nowadays energy is required for each & every household and industrial work, a choice can be made amongst primary energy sources like fuels that provide energy without any conversion process and secondary sources like electricity which obtained by primary sources. Further, the non-renewable and renewable sources can be differentiated as per their properties. The increase in Energy demand majorly comes from developing countries like India and China were energy- consuming activities like manufacturing, production, research, services and transportation increases by considerable difference year by year. That also increases the difference between the amount of energy consumption and energy production defined as Energy Gap. A major percentage of consumption is by the household and industrial heating and cooling procedure. To bridge this energy gap research is required on the design and implementation of efficient systems for heating and cooling.

2. Vapor Compression Refrigeration System

As of late, the term cooling and refrigerant framework were commonly used to characterize the status and extravagance of a person. It has turned into a basic issue because of the changing ecological conditions and has turned into a pre- requisite of individual everyday life. By and large, in tropical and sub-tropical areas, the warmth exchanges and cooling of nourishment and different materials through refrigeration is a basic element for the cutting edge improvement and dismal of the individual . The term refrigeration can be expressed as the counterfeit improvement and age of chilly according to the prerequisite and day by day needs of humankind. The use of refrigeration is reached out to various applications, for example, handling of sustenance and palatable things, transportation and conservation, cooling according to the forlorn, use of cooling in business and modern applications, fabricating units, generation of vitality, social insurance, etc. The procedure of refrigeration was presented a long time back by a celebrated known researcher Frenchman Ferdinand Carre in the year 1859 . Refrigerant utilized for the procedure is a water smelling salts ingestion framework and it was industrially brought into the market in the year 1875 with alkali as a working liquid.
Thermal Energy Storage (TES) is characterized as the transitory holding of warm vitality with high temperature properties. Vitality requests fluctuate on day by day, week after week and occasional bases. These requests can be coordinated with the assistance of TES

frameworks that work synergistically, and manages the capacity of vitality by cooling, warming, dissolving, cementing or vaporizing material and the warm vitality ends up accessible when the procedure is turned around [54]. TES is a noteworthy innovation in frameworks including sustainable power sources and in addition other vitality assets as it can make their activity increasingly productive, especially by spanning the period between periods when vitality is gathered and periods when it is required. That is, TES is useful for adjusting between the free market activities of vitality.

Thermal Energy Storage systems filled the energy gap between demand and consumption along with the improvement in the efficiency and performance of refrigeration systems. With the result of the saving in fuel, the system becomes more effective in terms of cost analysis as it decreases the energy loss during the procedure. Thermal energy storage techniques used effectively in human life up to the great extent till the beginning of life development stages. The use of different stones, bricks and iron materials to maintain the thermal comfort in the house is a typical example of the same. With the development of industries, thermal energy storage becomes a by product. The use of steam and hot water is one of example relates to Thermal Energy Storage techniques.

2.1 Objective

The significant advantages of Thermal Energy Storage (TES) systems include little energy loss during the storing operation, higher energy densities and the possibility of attaining more compact systems. In order to enhance the knowledge of the engineering and scientific characteristics of thermo chemical TES systems further research is necessary. The performance and implementation of these system scan be analysed and improved only by conducting such studies. Thermo chemical material forms a significant component of such systems. The selections of thermo chemical materials are affected by their availability, cost, durability, energy density, degradation, and cyclic behaviour. Further studies are required on the topics of design factors, safety, size, efficiency, maintenance, economics and installation. Along with these broad analyses of these systems is carried out with the main focus on the selection of PCM and its Encapsulation Procedure. Such analyses can help in the optimization and improvement of design. It can be hoped that it will be fruitful in terms of new findings and experimental results.

3. Literature Review

Boda et al. (2022) said that Phase change materials (PCM) are idle warmth storage materials. While changing its phase from strong to fluid and fluid to strong a thermal (Heat) vitality exchange happens, this is known as a change in state, or phase. To begin with, these strong fluid PCMs acts like customary storage materials and their temperature ascends to what they retain warm vitality. Far-fetched traditional storage materials, PCM retains and discharge warm at almost to a steady temperature. PCMs stores five to fourteen times warm (vitality) per unit volume more than sensible warmth storage materials, for example, shake, sand, rock, water, or brick work and so forth. Countless change materials are to dissolve with warmth of combination in any required range .

Rasta et al. (2021) studied the role of vegetable oil in water based phase change materials for medium temperature refrigeration. Blends of water with little sum vegetable oil expansion were picked as applicants of the PCM that were thought to be appropriate for medium temperature refrigeration application with temperature scope of items between 1 ° C and +5 ° C. The PCM competitors were tried tentatively through DSC and T-history strategy. The outcomes demonstrated that esters of vegetable oils assumed critical part on the solvency of the vegetable oil in water.

Gasia et al. (2017) in their experiment used the cycling stability is concentrated to identify changes in the thermos-physical and chemical properties of the PCM after a specific number of softening and solidifying cycles. In this investigation, the cycling stability tests were separated in two stages. The sixteen PCMs were subjected to finish cycling tests amid 100 cycles. Once the PCM experienced the required number of cycles, the thermos-physical and chemical properties were assessed. The cycling stability changes typically begin amid the primary thermal cycles because of thermal debasement or after numerous cycles because of thermal pressure. To evaluate the cycling stability and quantify the variation of the thermos-physical and chemical properties of all the PCMs, different measurement points were established

According to Silval et al. (2017), it has been verbalized that the microencapsulation is a process of active substance. These substances are extremely coated by some capsules. It has been even said that the microencapsulation has become a new technology in the cosmetic industry. Even in the agrochemical industry, the food industry, the pharmaceutical industry uses various flavours, oils, microorganism and some acids. The correct choice of wall materials is the main reason for the success of this technology. The capsule wall materials, en capsulation method, core release forms are found in the review of some microencapsulation aspects. It has

been found that the encapsulation method has been improving its effectiveness. It even reduces the dose of the additives of the components. The interaction between the core of the wall and the wall materials are termed as a main factor that affects the release rates. The volatility if the core, the size of the various particles, its velocity grade and the various rations between the wall material and the core of the walls are considered as some other factors that influence the additional release. It has been found that the various diffusions occur mainly because of the wall that interacts among the microcapsule walls. It is even said that the release rate has been governed by various chemical properties. The wall material and the core of the wall are such property that rates the government.

According to Hu et al. (2017), the microencapsulation was said to be soughed out as a cleaner substitute for the carbon papers. This technology has some technology has captured some various interest with some scientific communities. These substances are extremely coated by some capsules. It has even said that these industries have made rapid progress in the past few decades. The capsule wall materials, encapsulation method, core release forms are found in the review of some microencapsulation aspects. This has happened because of the tremendous demand for advanced molecular structures. It has been even verbalized that the microencapsulation is a very tiny liquid particle or a solid material or a very tiny drop that is coated or surrounded with a continuous film of polymeric material. The volatility if the core, the size of the various particles, its velocity grade and the various rations between the wall material and the core of the walls are considered as some other factors that influence the additional release. The wall material and the core of the wall are such property that rates the government. This polymeric material will turn as isolation from the external environment and it is mainly used for controlled release, protection and as core compatibility .

According to Gharibzahedi et al. (2018), the various effects of the process that are involved in the microencapsulation process are been involved in the quality and the efficiency of the products. These products produced the innovation of some microcapsule. It has been found that the development of the various spherical particles had a smoother surface that could show an excellent encapsulation yield and in the efficiency on the microencapsulation. The microencapsulation was said to be soughed out as a cleaner substitute for the carbon papers. This technology has some technology has captured some various interest with some scientific communities. Even in the agrochemical industry, food industry, pharmaceutical industry uses the various flavours, oils, microorganism and some acids and it is even termed that the microencapsulation is a process of active substance. The microencapsulation is said to be utilized as a technique to fortification. This technique is used as a fortification and as a control that could release some functional foods. The fatty acids, minerals, vitamins, antioxidants are some functional foods.

Bland et al. (2017) said that most structures are worked with the goal of them having an administration life of between 50– 100 years. It is discovered that a house incorporated with PCMs impregnated with the divider sheets can spare around 4 GJ of energy consistently which compares to around 15% lessening in energy costs yearly. With a normal establishment cost, around £5000, and a yearly energy sparing of £202.65 this implies a perfect PCM framework required introduced into a private building will require an administration life of no less than 25 years to make it suitable. One overpowering issue with the utilization of PCMs incorporated with building materials is that there is next to zero approach to perform nosy support on the PCM framework. This implies once the PCM has quit being successful in any building, it is very hard to supplant the PCM without performing any special ruinous methods to get to it. condenser used in air conditioning purposes. In the research work, heat transfer is investigated for finding the optimum material and refrigerant in vapor compression refrigeration system. The materials used for tubing are Copper and Aluminum alloy 1100 and for fins are Al 1050, and Al1100. The refriger¬ants options considered by the researchers are R-12, R-22, and R-134A. For this purpose, 3D model is developed on Pro/Engineer and analysis is done in ANSYS.

Diwan and Sahu 2016 In the research work, design of shell and tube type heat exchanger with helical baffle is accomplished with the help of modeling software CATIA, and analysis software ANSYS. With the help of ANSYS, study of flow and temperature fields is conducted inside the shell. The highlighted heat exchanger consists of 27 tubes, a shell of length 5,490 mm, and diameter 540 mm. The helix angle of baffle varies from 0o to 20o. Simulation of the device shows the variation of temperature and heat flux throughout the surface. Simulation also shows that the flow pattern in the shell side of the heat exchanger using continuous type of baffles tends to be rotational, and helical, based on the geometry of the baffles, which, in turn, gives rise to significant increase in heat transfer coefficient per unit pressure drop in the condenser. Engineering Universe for scientific Research and management.

Sai Krishna et al. 2013 In the research work, researchers advocate the superiority of plate heat exchangers by stating that for many industrial applications, plate heat exchangers are superior over other types. Present research work aims at designing an optimal plate type of heat exchanger used in refrigeration purposes. The research work contains, both, theoretical as well as simulation analysis for a parallel flow type of heat exchanger. The working fluids used are CO2¸and R134a. On theoretical part, researchers find very less pressure drop. In the next stage of the research, CFD analysis on ANSYS software is carried out on the basis of investigated inlet conditions like mass flow rate, and temperatures and pressures of cold and hot fluids. In ANSYS, design of a multi-pass plate heat exchanger is optimized with the help of variables like number of passes for hot and cold streams, number of plates, type of plates, and size of plates. The selection of suitable material is accomplished on the basis of thermal ageing of materials, temperature stresses, and failure modes, previously reported by other researchers. In the research work, the researchers has also formulated some basic equations regarding, heat transfer, overall heat transfer coefficient, and pressure drop.

Yadav et al. 2015 Present research work is devoted to modeling and simulation of a house hold refrigerator. In the research work, the vapor compression refrigeration system consisting of evaporator, compressor, condenser, and expansion device is modeled using 3D modeling software Pro-E wild fire 5, and thermal analysis is performed on different parts of the modeled system with the help of ANSYS 14. In the research work, refrigerants used are HCFC, HFC-152A, and 404R, also, the commonly used tube material copper is replaced with A, and, Al6061.

4. Conclusion

An investigation into the energy storage framework has been completed for cooling and warming remains and is being considered for the waste warmth recuperation, energy age, building energy protection, and cooling. Based on the observation of the heat properties of PCM, the PCM is sufficiently helpful in increasing the energy storage property of the system. The phase change process using the heat limit procedure, demonstrated that the main parameters of the framework are based on the MEPCM layer thickness, cooling water temperature, and other MEPCM properties. PCM is arranged into three categories depending on their system as natural, inorganic, and eutectic mixes. The phase change temperature extended in terms of the enthalpy change is the essential warm properties of the phase change slurries. Such parameters can recognize the heat storage limit and their potential applications. Contrasted with the customary liquids, a MEPCM can display the high estimation rate as per the evident explicit heat limit amid the stage change process. Inside the potential MEPCMs, paraffin has the favourable position of speaking to little thickness variety between the active and fluid stages. The ability to store or discharge thermal vitality from MEPCM firmly relies upon the warmth stockpiling limit, warm conductivity, the liquefying temperature of the MEPCM, and the extreme condition that it is present. Found to be a better capacity in terms of storing energy and isothermal behaviour during both charging and discharging processes.

5. Future Scope

Energy storage capacity depends on the efficiency of the framework designed. Numerous investigations have been executed for the cold storage system in terms of its efficiency. The use of ice, such as the ice slurry is a blend of water (ice and fluid water) and a glycol. In the famous methods for cool stockpiling these days, PCM has clear favourable circumstances, utilizing PCM is intriguing because of the benefit of a high proportion between the measure of heat energy and temperature variation. In the flow explores, so as to all the more likely utilize the PCM exposed to the refrigeration framework, it is important to tackle a few issues, for example, novel technique PCM of microencapsulation (MEPCM) has been figured out. This study is based on the experimental study of household refrigeration works at moderate temperature range and development of high temperature thermal energy storage (TES) system with implementation of latent heat materials at small scale. The main purpose of designing the model of the TES system is based on the cooling effect and applications based on the cooling effect. However, during the solidification process in the test setup, scale presented high sub cooling, which is harmful to any real based applicative support and it was found to be much more impactful for the solar cooling application which requires the work to proceed within a narrow range of temperature.

Reference

[1] Adebayo, V., Abid, M., Adedeji, M., Dagbasi, M., & Bamisile, O., “Comparative thermodynamic performance analysis of a cascade refrigeration

system with new refrigerants paired with CO2", Applied Thermal Engineering, 116286, 2020.

[2] Agarwal, S., Arora, A., & Arora, B. B.," Thermodynamic performance analysis of dedicated mechanically subcooled vapour compression refrigeration system", Journal of Thermal Engineering, 5(4), 222-236, 2019.

[3] Agarwal, S., Arora, A., & Arora, B. B, "Exergy analysis of dedicated mechanically subcooled vapour compression refrigeration cycle using HFC-R134a, HFO-R1234ze and R1234yf", In Advances in Energy and Built Environment (pp. 23-42). Springer, Singapore, 2020.

[4] • Agrawal, N., & Bhattacharyya, S., "Studies on a two-stage transcritical carbon dioxide heat pump cycle with flash intercooling", Applied Thermal Engineering, 27(2-3), 299-305, 2007.

[5] Aktemur, C., & Öztürk, I. T. "Energy and exergy analysis of a subcritical cascade refrigeration system with internal heat exchangers using environmentally-friendly refrigerants", Journal of Energy Resources Technology, 1-33, 2020.

[6] Aktemur, C., Ozturk, I. T., & Cimsit, C, "Comparative energy and exergy analysis of a subcritical cascade refrigeration system using low global warming potential refrigerants", Applied Thermal Engineering, 116254, 2020.

[7] Alhamid, M. I., Syaka, D. R. & Nasruddin, "Exergy and energy analysis of a cascade refrigeration system using R744+ R170 for low temperature applications" International Journal of Mechanical & Mechatronics Engineering, 10(6), 1-8, 2010.

[8] Aminyavari, M., Najafi, B., Shirazi, A., & Rinaldi, F. "Exergetic, economic and environmental (3E) analyses, and multi-objective optimization of a CO2/NH3 cascade refrigeration system", Applied Thermal Engineering, 65(1-2), 42-50, 2014.

[9] Anjum, N., Gupta, D. K., Ansari, N.A., & Misra, R. S. "Thermodynamic Analysis of a Two Stage Vapour Compression Refrigeration System Utilizing the Waste Heat of the Intercooler for Water Heating", Journal of Fundamentals of Renewable Energy and Applications, 7, 1-6, 2017.