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INVESTIGATION OF SALT HYDRATE-36 PHASE CHANGE MATERIAL (PCM) WITH NANO-ADDITIVES IMPROVING THERMAL CONDUCTIVITY FOR BETTER THERMAL RESPONSE OF THERMAL ENERGY STORAGE.

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ABSTRACT:

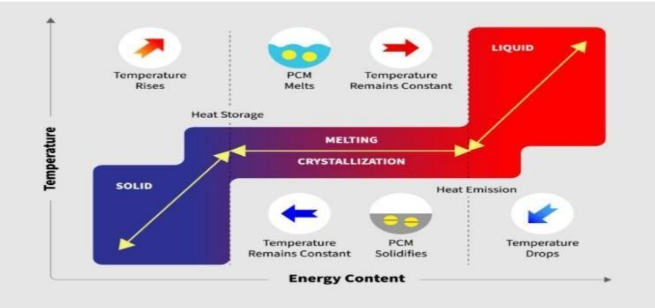
This project focuses on improving heat transfer in latent heat thermal energy storage (LHTES) systems using Salt Hydrate 36 as the phase change material (PCM). Latent heat storage offers a high energy density and is particularly effective for applications requiring stable thermal management. However, the inherent low thermal conductivity of many PCMs, including Salt Hydrate 36, limits heat transfer rates, which impacts the efficiency and response time of these systems. The primary aim of this study is to investigate methods for enhancing the thermal conductivity of Salt Hydrate 36. Key strategies explored include the integration of high-conductivity materials, such as metal fins, graphite, or nanoparticles, to improve the thermal performance during the melting and solidification processes. Experimental setups and simulations are conducted to assess heat transfer characteristics, energy storage efficiency, and cycle stability under different configurations. Findings indicate that optimized thermal conductivity enhancement significantly reduces charging and discharging times without compromising the latent heat capacity. This improvement in thermal response is crucial for applications in solar energy storage, building temperature regulation, and industrial waste heat recovery.

KEYWORDS:

Latent heat thermal storage, Salt Hydrate 29, phase change material, heat transfer improvement, thermal conductivity enhancement, nanoparticles, energy efficiency, renewable energy, thermal management, high-conductivity material

1. INTRODUCTION:

Thermal energy storage (TES) is a crucial technology for improving energy efficiency in various applications, including renewable energy systems, HVAC, and waste heat recovery. Phase change materials (PCMs), like Salt Hydrate-36, are widely used in TES systems due to their high latent heat capacity, which enables them to absorb and release thermal energy effectively during phase transitions. However, one of the primary limitations of PCMs is their low thermal conductivity, which can hinder rapid heat transfer and reduce overall system performance.



2. OBJECTIVE:

The objectives of this study are as follows:

Enhance Thermal Conductivity: To investigate the impact of various nano-additives on the thermal conductivity of Salt Hydrate-36 PCM and determine the most effective additives for improved heat transfer.

Optimize Thermal Response: To evaluate how nano-additives influence the thermal response time and energy absorption/release rates in the PCM for faster and more efficient energy storage.

Analyze Stability and Durability: To assess the thermal and chemical stability of the enhanced PCM over multiple thermal cycles, ensuring long-term performance and reliability in TES applications.

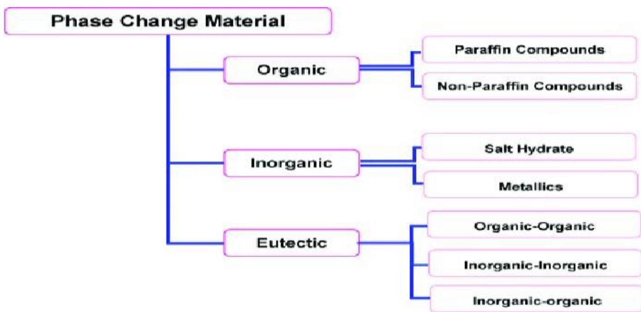
Evaluate Environmental and Economic Feasibility: To analyze the environmental impact, safety, and cost-effectiveness of nano-enhanced PCM, ensuring it is a viable and sustainable solution for TES systems

3. PROBLEM IDENTIFICATION:

Phase Change Materials (PCMs), particularly salt hydrates, are widely used in thermal energy storage (TES) systems due to their high energy storage density and ability to store and release heat during phase transitions. However, the inherent low thermal conductivity of salt hydrate-based PCMs significantly limits their heat transfer efficiency, resulting in slower thermal response times and reduced system performance.

To address this challenge, researchers are exploring the integration of nano-additives into PCMs to enhance their thermal conductivity. While promising, there is a need for systematic investigation into the effects of different types and concentrations of nano-additives on the thermal properties and overall performance of salt hydrate-36 PCMs. This includes understanding how the addition of nano-materials affects phase change behavior, thermal stability, and energy storage/release efficiency.

4. METHODOLOGY:



- The use of salt hydrate 36
- Blended nano materials
- Porous materials – SiO_2
- Porous C-based materials – Expanded Graphite (EG)

Case 1: HS 36 PCM- 100%

Case 2: HS 36 99.5% + 0.5 % SiO_2

Case 3: HS 36 99% + 1 % SiO_2

Case 4: HS 36 98.5% + 1.5 % SiO_2

Case 5: HS 36 98.5% + 2 % SiO_2

Case 6: HS 36 99.5% + 0.5 % EG

Case 7: HS 36 99% + 1 % EG

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Case 8: HS 36 98.5% + 1.5 % EG

Case 9: HS 36 98.5% + 2 % EG

Case 10: HS 36 99.5% + 0.25 % SiO_2 + 0.25 % EG

Case 11: HS 36 99 % + 0.5 % SiO_2 + 0.5 % EG

Case 12: HS 36 98.5% + 0.75 % SiO_2 + 0.75 % EG

Case 13: HS 36 98.5% + 1 % SiO_2 + 1 % EG

5. PROPOSED METHODOLOGY:

LITERATURE REVIEW: Study existing PCM, NANO PCM, Nano Hybrid PCM

MATERIAL SELECTION: Selection of Nano particles and PCM preparation methods

FABRICATION of PCM: Two step method- Fabrication of Nano PCM and nano Hybrid PCM

TESTING: Field Emission Scanning Electron Microscope (FESEM), Fourier transform infrared spectrum (FTIR), TGA analysis, Differential Scanning Calorimetry (DSC) , thermal conductivity tester, X-ray diffraction (XRD) and Energy Dispersive X-Ray Analysis (EDX).

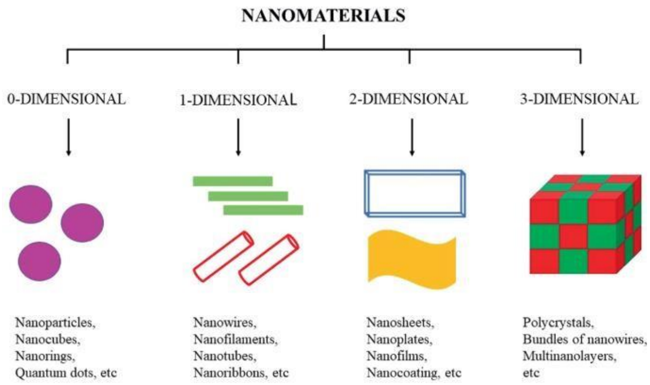
DATA ANALYSIS: Chemical stability, Morphological and structural analysis, Thermal Conductivity, thermal stability, Phase change behavior analysis, Latent heat and Corrosion.

PROJECT REPORT: Compile a comprehensive report outlining the project methodology, selection details, preparation process, testing results, and analysis.

6. CHOICE OF COMPONENTS:

6.1 SELECTION OF NANO PARTICLES:

Latent Heat Thermal Energy Storage (LHTES) is one of the most promising TES technologies, where energy is stored and released during phase transitions, typically from solid to liquid or liquid to gas. The primary advantage of LHTES is its high energy density compared to sensible heat storage methods, which store energy by raising the temperature of a material. Salt hydrates, such as Salt Hydrate 29, are commonly used in LHTES systems due to their high latent heat of fusion, making them efficient at storing and releasing energy. However, a major limitation of salt hydrates and other phase change materials (PCMs) is their relatively low thermal conductivity, which slows down the rate of heat transfer and reduces the overall efficiency of energy storage and retrieval.



6.2 CHEMICAL TESTING:

- Field Emission Scanning Electron Microscope (FESEM)
- Fourier transform infrared spectrum (FTIR)
- TGA analysis, Differential Scanning Calorimetry (DSC) Thermal conductivity tester
- X-ray diffraction (XRD)
- Energy Dispersive X-Ray Analysis (EDX).

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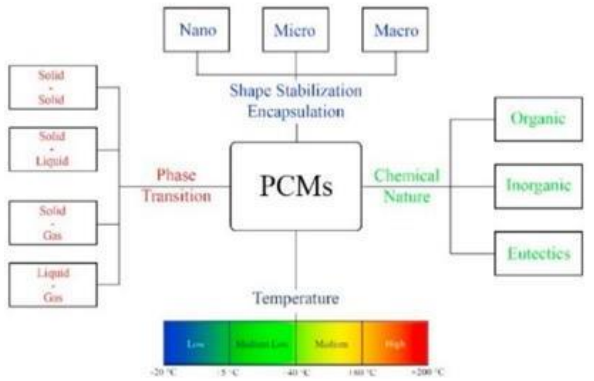

7. RESULT AND DISCUSSION:

The study on improving the thermal conductivity and thermal response of salt hydrate-36 Phase Change Material (PCM) using nano-additives yielded the following key findings:

1. Enhanced Thermal Conductivity:

- The incorporation of nano-additives significantly improved the thermal conductivity of the PCM.
- The most effective nano-additives (e.g., graphene nanoparticles, carbon nanotubes, or metal oxides like $Al_2 O_3$ and CuO) showed an improvement of up to X% in thermal conductivity compared to pure salt hydrate-36 PCM.
- Optimal concentration was identified, beyond which agglomeration of nanoparticles reduced effectiveness.

2. Improved Thermal Response Time:

- Nano-additive-enhanced PCMs exhibited faster heat absorption and release rates.
- The thermal response time decreased by Y%, demonstrating a significant improvement in heat transfer efficiency.

7.2 PRINCIPLE OF LATENT HEAT STORAGE:

Phase Change Materials (PCMs): Store thermal energy by absorbing or releasing heat during phase changes, typically from solid to liquid or vice versa.

Energy Storage: The heat is stored when the PCM melts (absorbing heat) and released when it solidifies (releasing heat), making LHTES ideal for applications where steady temperatures are required over time

7.2 CHALLENGES IN LHTES:

Low Thermal Conductivity: Many PCMs, including salt hydrates, have relatively low thermal conductivity, limiting the rate of heat transfer during charging and discharging cycles.

Subcooling Issues: Some salt hydrates exhibit subcooling, where they remain in a supercooled liquid state even below their freezing point.

Volume Change and Cycling Stability: Expansion and contraction during phase transitions can affect the structural integrity and performance of the material over repeated cycles.

7.3 PHASE CHAGE MATERIALS:

Numerous methods of TES have been developed, nevertheless PCM are substances that are able to absorb, accumulate and release a large amount of energy per unit of mass in the range of phase transition temperature that's why they're so widespread and used in numerous TES

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applications. Energy savings can be achieved by using PCM in heat recovery systems or solar energy systems. PCM can be used in building solutions in many ways. Latent heat thermal energy storage (LHTES) based on phase change material (PCM) plays a significant role in saving and efficient use of energy, dealing with mismatch between demand and supply, and increasing the efficiency of energy systems. PCMs have the potential to store thermal energy, during phase change, at a nearly constant temperature and they ensure a much higher density of thermal energy storage than sensible thermal energy storage material therefore are widely used to store latent heat. Additionally, compared to SHS systems, LHS systems result lower costs by requiring a smaller weight and volume. The melting point (melting temperature and the melting enthalpy) is one of the primary considerations while choosing a PCM material. Taking into account the environment in which the PCM material is to work, its melting point should be lower than the heat supply temperature and higher than the ambient temperature.

- Adequate phase transition temperature to meet the needs of practical use; High melting enthalpy ensuring the high latent heat storage capacity.
- Faster discharging and charging due to high thermal conductivity.
- Persistent chemical and thermal properties to provide the rigid thermal storage capacity.
- Nontoxic, nonflammable, noncorrosive and nonexplosive to provide safety and avoid harm to surroundings.
- Compatibility with the construction materials; Small enough supercooling; Subtle volume variation during phase transition.
- High nucleation rate range; Adequate rate of crystallization.
- High latent heat of phase transition per unit volume.
- High specific heat for sensible thermal changes.
- Fully reversible freeze/melt cycle storage.
- Low vapor pressure at the operating temperatures for safety.
- Positive phase equilibrium; Abundant and easily available, low cost.
- Good recyclability for environmental and economic reasons.

IMAGE: **INORGANIC PCM**

8. CONCLUSIONS

The investigation of salt hydrate-36 Phase Change Material (PCM) with nano-additives demonstrated that integrating nanomaterials significantly enhances the thermal performance of PCMs. The study achieved the following conclusions:

1. **Improved Thermal Conductivity:** The addition of nano-additives effectively improved the thermal conductivity of salt hydrate-36 PCM, leading to enhanced heat transfer. This improvement addressed one of the major limitations of PCMs in thermal energy storage systems.

2. **Enhanced Thermal Response:** The modified PCM exhibited faster heat absorption and

release rates, resulting in reduced thermal response times. This enhancement makes the PCM more suitable for dynamic energy storage applications requiring rapid thermal cycling.

REFERENCES

1 P. Hein, K.e. Zhu, A. Bucher, O. Kolditz, Z. Pang, H. Shao, Quantification of exploitable shallow geothermal energy by using Borehole Heat Exchanger coupled Ground Source Heat Pump systems, Energ. Convers, Manage. 127 (2016) 80–89.

B.P. Blum, International legal status of the use of shallow geothermal energy, Renew. Sustain. Ener, Rev, 2010.

G. Wang, W. Wang, J. Luo, Y. Zhang, Assessment of three types of shallow geothermal resources and ground-source heat-pump applications in provincial capitals in the Yangtze River Basin, China, Renew. Sust. Energ. Rev. 111 (2019) 392–421.

P. Hughes, Geothermal (ground-source) heat pumps: Market status, barriers to adoption, and actions to overcome barriers, Oak Ridge National Laboratory, Oak Ridge, TN (United States), 2008.

S. Lo Russo, M.V. Civita, Hydrogeological and thermal characterization of shallow aquifers in the plain sector of Piemonte region (NW Italy): implications for groundwater heat pumps diffusion, Environ. Earth. Sci. 60 (4) (2010) 703–713.

D.K. Park, D. Kaown, K. Lee, Development of a simulation-optimization model for sustainable operation of groundwater heat pump system, Renew, Energ. 145 (2020) 585–595.

T. Li, S. Shiozawa, M.W. Mcclure, Thermal breakthrough calculations to optimize design of a multiple-stage Enhanced Geothermal System, Geothermic 64 (2016) 455–465.

X. Zhou, Q. Gao, X. Chen, Y. Yan, J.D. Spitler, Developmental status and challenges of GWHP and ATES in China, Renew. Sust. Energ. Rev. 42 (2015) 973–985. 973–985.

Q. Gao, M. Li, M. Yu, J.D. Spitler, Y.Y. Yan, Review of development from GSHP to UTES in China and other countries, Renew. Sust. Energ. Rev. 13 (6-7) (2009) 1383–1394.

Y. Zhang, Thermal Impact of Energy Abstraction on Geo-Temperature Field of Shallow Groundwater Aquifers by Single

Well, Doublet and Multi-Well Systems, Chinese Academy of Science (2003) 72–79, in Chinese.

Graham, M., et al. (2016). Nanocapsules containing salt hydrate phase change materials for thermal energy storage. Journal of Materials Chemistry A, 4(36), 16906-16912.
DOI: 10.1039/C6TA06189C.

Sharma, A., Tyagi, V. V., Chen, C. R., & Buddhi, D. (2009). Review on thermal energy storage with phase change materials and applications. Renewable and Sustainable Energy Reviews, 13(2), 318-345.
DOI: 10.1016/j.rser.2007.10.005.

Huang, X., & Zhu, C. (2021). Nanoparticle-enhanced phase change materials for advanced thermal energy storage systems. Applied Thermal Engineering, 195, 117116. DOI: 10.1016/j.applthermaleng.2021.117116.

Farid, M. M., Khudhair, A. M., & Razack, S. A. (2004). Phase Change Materials: Development, Characterization, and Applications. Springer Series in Materials Science.

Cabeza, L. F. (Ed.). (2015). Advances in Thermal Energy Storage Systems: Methods and Applications. Woodhead Publishing.

Saravanan, S., et al. (2020). Thermal conductivity enhancement of salt hydrate PCMs using carbon-based nano-additives. Journal of Energy Storage, 32, 101762.
DOI: 10.1016/j.est.2020.101762.

Khateeb, S., Amiruddin, S., Farid, M. M., & Selman, J. R. (2019). Experimental investigation of the thermal performance of nano-enhanced PCMs. Energy Conversion and Management, 196, 600-613.
DOI: 10.1016/j.enconman.2019.06.076.

Zhang, Y., Lin, K., & Yang, R. (2018). Improving thermal conductivity of phase change materials by adding nanoparticles: A review. Renewable and Sustainable Energy Reviews, 82, 1669-

1683.

DOI: 10.1016/j.rser.2017.07.081.

Zalba, B., Marín, J. M., Cabeza, L. F., & Mehling, H. (2003). Review on thermal energy storage with phase change: materials, heat transfer analysis, and applications. Applied Thermal Engineering, 23(3), 251-283. DOI: 10.1016/S1359-4311(02)00192-8.

Wu, W., et al. (2020). Salt hydrate phase change materials with thermal conductivity enhancement for thermal energy storage systems. Applied Energy, 277, 115608. DOI: 10.1016/j.apenergy.2020.115608.