International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Impact of Molten Salt as Phase Change Material in Heat Transfer Fluid

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Abstract:
molten salts are a novel heat transfer system whose potential is just beginning to be realized. This paper discusses in detail about molten salt as a phase change material.

Keywords: PCM-Phase Change Material

Introduction

The extensive dependency on fossil fuel for energy requirement brings huge environmental hazards. Large amount of carbon di oxide are released during the combustion of fossil fuels. The released carbon di oxide trap heat in atmosphere causing global warming. Already the average global temperature has increased by 1°C. Warming above 1.5°C may causes further rise in sea level, extreme weather condition, loss of biodiversity and species extinction, food scarcity, worsening health and poverty for millions of people worldwide. This situation focus on the need of effective utilization of renewable energy. Of various renewable sources solar energy brings the main attention due to several reasons. This may be due to the facts that solar energy is safer, environment friendly, pollution free and much more. It is estimated that we have a steady and limitless supply of solar energy for another 5 billion years. In one hour, the earth's atmosphere receives enough sunlight to power the electricity needs of every human being on earth for a year. The challenging question is that how can we entrap this energy more effectively even though we have many methods. This scenario bring the attention of researchers on phase change materials for solar energy entrapment.

Phase Change Materials

A phase change material is defined as a substance which either absorbs or releases sufficient energy at phase transition to provide useful heat or cooling. Usually the transition will be from one of the two fundamental states of matter. Ie from solid state to liquid state or from liquid state to solid state. The phase transition can be between non-classical states of matter such as the conformity of crystals, where the material goes from conforming to one crystalline structure to conforming to another, which may be a higher or lower energy state.
The energy released or absorbed by phase transition from solid to liquid, or vice versa, the heat of fusion is generally much higher than the sensible heat. Ice, for example, requires 333.55 J/g to melt, but

then water will rise one degree further with the addition of just 4.18 J/g. Water/ice is therefore a very useful phase change material and has been used to store winter cold to cool buildings in summer .
By melting and solidifying at the phase change temperature , a PCM is capable of storing and releasing large amounts of energy compared to sensible heat storage. Heat is absorbed or released when the material changes from solid to liquid and vice versa or when the internal structure of the material changes; PCMs are accordingly referred to as latent heat storage materials.

Types of Phase Change Materials

Even though many types of phase change materials are available the main types are (a) Organic (b) Inorganic (c) Eutectic. Organic phase change materials are further subdivided into another two.(1) Paraffin Compounds (2) Non Paraffin Compounds. Inorganic phase change materials are sub divided into Salt hydrates and Metalic. Further more Eutectic phase change materials are divided into (1) Organic-Organic (2) Inorganic – Inorganic (3) Inorganic – Organic.

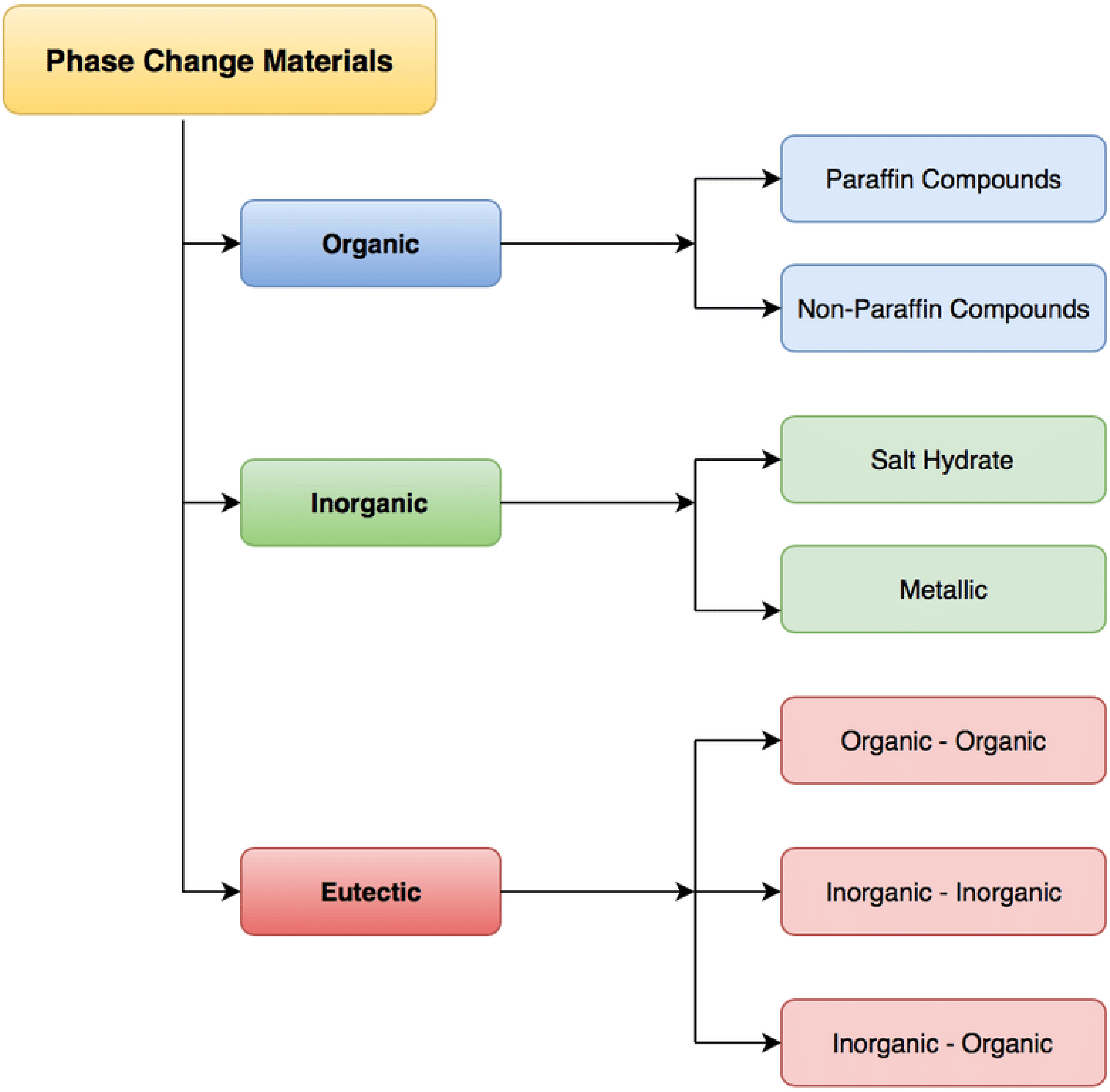

Fig (a) Types of Phase Change Materials

Organic phase change materials are those which are having carbon containing materials derived either from petroleum, from plants or from animals. Inorganic phase change materials are salt hydrates, which generally either use natural salts from the sea or from mineral deposits or are by-products of other processes.

Applications of Phase change materials

Industrial applications of Phase change materials spread across widely in modern era. Some of the major applications of phase change materials are listed below.

- Thermal energy storage
- Solar cooking
- Cold Energy Battery
- Conditioning of buildings, such as 'ice-storage'
- Cooling of heat and electrical engines
- Cooling: food, beverages, coffee, wine, milk products, green houses
- Medical applications: transportation of blood, operating tables, hot-cold therapies, treatment of birth asphyxia.
- Human body cooling under bulky clothing or costumes.
- Waste heat recovery.
- Off-peak power utilization: Heating hot water and Cooling.
- Heat pump systems
- Passive storage in bioclimatic building/architecture (HDPE, paraffin).
- Smoothing exothermic temperature peaks in chemical reactions.
- Solar power plants.
- Spacecraft thermal systems.
- Thermal comfort in vehicles.
- Thermal protection of electronic devices.
- Thermal protection of food: transport, hotel trade, ice-cream, etc.
- Textiles used in clothing
- Computer cooling
- Turbine Inlet Chilling with thermal energy storage

Molten Salt as Phase Change Material

Molten salts are a phase change material that is commonly used for thermal energy storage. These are usually termed as fused salts or melted salts. Molten salts are solid at room temperature and atmospheric pressure but it may change to a liquid when thermal energy is transferred to the storage medium. As phase change materials, molten salts have a higher latent heat capacity than conventional materials, and minimal temperature changes are needed to increase their heat capacity. It has a wide range of applications like high-temperature process heating, heat treating and annealing of steel, and thermal storage in solar thermal power plants etc. Usually these salts are composed of fluoride, chloride, and nitrate salts. For pure molten salts the phase change temperatures ranges from 150 °C to 500 °C. Molten salts are typically made up of 60% sodium nitrate and 40% potassium nitrate, and the salts melt at approximately 220°C. Molten salts are often used with concentrating solar power plants to store thermal energy for electricity generation.

[1] Manila Chieruzzi et.al studied the thermal properties of potassium nitrate phase change material mixed with silicon di oxide, Aluminum di oxide and a mixture of silicon di oxide and aluminum di oxide nanofluids. Each nanofluid was prepared in water solution, sonicated, and evaporated. The results obtained show that the addition of 1.0 wt.% of nanoparticles to the base salt increases the specific heat of about 5–10 % in solid phase and of 6 % in liquid phase. Also it reveals that the addition of silica nanoparticles has significant potential for enhancing the thermal storage characteristics of KNO_3. The phase-change temperature of potassium nitrate was lowered up to 3 °C, and the latent heat was increased to 12 % with the addition of silica nanoparticles. [2] Dongmei Han et.al analyzed the thermal properties of ternary chloride salts ($MgCl_2$:KCl:NaCl with 51:22:27 molar ratio) mixed with Al_2O_3, CuO, and ZnO nanoparticles. They measured the thermal properties of both base salts and base salts with various nanoparticle mixtures. The results showed that the melting temperature of the composite phase change materials was very close to that of the base salt. The thermal conductivity of the composite phase change material doped with Al_2O_3 nanoparticles showed the most obvious enhancement, which increased by more than 48%, compared to that of the base salt. Al_2O_3 nanoparticles could be considered as an optimal additive to improve the thermal conductivity of chloride salts. Also it is noted that composite phase change materials with Al_2O_3 has an excellent thermal stability. [3] Jianfeng Lu et.al developed Comprehensive transient and two-dimensional numerical model to study energy storage performance of molten salt thermocline thermal storage system with packed phase change bed in solar thermal power. The results declares that the packed phase change bed can remarkably increase the effective discharging energy and discharging efficiency. [4] Heqing Tian et.al designed a new highly thermal conductive composite phase change material by blending magnesium (Mg) particles with eutectic ternary carbonate salt (Li_2CO_3-Na_2CO_3-K_2CO_3) and used as heat transfer fluid and/or thermal energy storage medium in advanced high-temperature concentrating solar power plants. The thermo-physical properties of the composite systems were measured. Experimental results indicated that Mg particles dispersed in the molten salts with dendritic structure. The melting temperature of the composite phase change material had negligible change compared to pure carbonate salt, and the phase change enthalpy reached up to 160 J/g. The effective thermal conductivity was 1.93 W/(m K) for 2 wt% of Mg, which was enhanced by 45.11% compared to pure ternary carbonate salts. The upper limit working temperature of the composite phase change material was measured to be 725 C in argon atmosphere. The wide working temperature range (DT = 325 C) indicated its great thermal stability and high capacity of energy storage. [5] Yifeng Jiang et.al formulated eutectic Na_2CO_3–NaCl molten salt as a new high temperature phase change material for solar thermal energy storage. The composition of the eutectic binary salt was determined with the aid of FactSage software and its thermophysical properties were investigated using a Simultaneous Thermal Analyzer (STA) and X-Ray Diffraction (XRD). The Simultaneous Thermal Analyzer results exhibit that the melting point of the eutectic salt is 637.0 °C and its heat of fusion is 283.3 J/g whereas its specific heat is a function of temperature, which all are in agreement with the theoretical values determined by the FactSage software. The thermal stability analysis indicates that the eutectic molten salt has good thermal stability without weight loss in a CO_2 environment at temperatures below 700 °C, compared with 0.51% weight loss in a N_2 atmosphere. The study reveals that that the eutectic Na_2CO_3–NaCl salt is a promising high temperature phase change material when used in a CO_2 environment or encapsulation. [6] Ming Liu et.al explores the use of a eutectic NaCl-Na_2CO_3 salt as a reliable high temperature phase change material. The PCM has been thermally cycled up to 1000 times. Its thermophysical properties have been measured before and after it has been subjected to the thermal

cycling and its corrosion behavior has been investigated. This eutectic salt shows good thermal stability without degradation after cycling 1000 times between 600 and 650 °C. The corrosion rate on stainless steel 316 (SS316) increases linearly up to 350 cycles, and thereafter it stabilizes at 70 mg/cm2. [7] Limin Zhong et.al synthesized three kinds of porous heterogeneous composite phase change materials from expanded graphite and binary molten salts (LiNO3–KCl, LiNO3–NaNO3 and LiNO3–NaCl) through solution impregnation method. Binary molten salt content in the composite phase change materials was calculated to be between 77.8% and 81.5% and high encapsulation efficiency was calculated to be between 72.8% and 78.8%. The thermal conductivity of binary molten salts was enhanced by 4.9–6.9 times after impregnation with EG. SEM photographs showed that the prepared composites were more homogeneous in comparison to other salt/EG composites prepared by infiltration or compression. Phase change properties of the porous heterogeneous composite phase change materials showed great thermal stability, which was maintained after 100 cycles. [8] Yinsheng Yu et.al established the physical model of NaCl-SiO2 composite phase change materials. An effective method based on molecular dynamics simulation was proposed and validated to predict the thermal properties of composite phase change materials effectively. The structure and physical properties of the NaCl-SiO2 composite phase change materials was analyzed from the microscopic point of view. The structural deformation during phase transition process of composite phase change materials system was observed and radial distribution function was calculated to analyze the local structure. The results indicate that the thermal conductivity of NaCl is enhanced remarkably with a maximum increase of 44.2% by adding 2.4% volume fraction of SiO2 nanoparticles and the mechanism of the thermal conductivity enhancement was discussed at the atomic level. The shear viscosity increases with the increase of the volume fraction of nanoparticles, with a maximum average increase of 23.6%.

Conclusion

From the above discussions it can be concluded that molten salts are a novel heat transfer system whose potential is just beginning to be realized. They are safe, environment friendly stable, and efficient for higher temperature systems. It has been proved that molten salts have a higher latent heat capacity than conventional materials, and minimal temperature changes are needed to increase their heat capacity. Also it is revealed that thermal properties can be improved by mixing nano particles with molten salt and further experimental studies are required in this area.

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