Experimental Investigation on Phase Change Material

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Abstract – The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. This paper also summarizes the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications.

Index Terms – PCM, Thermal Energy, Isothermal.

1. INTRODUCTION

PCMs absorb and emit heat while maintaining a nearly constant temperature. Within the human comfort range of 68° to 86°F (20° to 30°C), latent thermal storage materials are very effective. They store 5 to 14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. Thermal energy can be stored in well-insulated fluids or solids. It can be generally stored as latent heat-by virtue of latent heat of change of phase of medium. In this the temperature of the medium remains more or less constant since it undergoes a phase transformation. Phase change storages with higher energy densities are more attractive for small storage.

1.1. Energy storage methods

The different forms of energy that can be stored include mechanical, electrical and thermal energy

1.1.1. Mechanical energy storage

Mechanical energy storage systems include gravitational energy storage or pumped hydropower storage (PHPS), compressed air energy storage (CAES) and flywheels. The PHPS and CAES technologies can be used for large-scale utility energy storage while flywheels are more suitable for intermediate storage. Storage is carried out when inexpensive off-peak power is available, e.g., at night or weekends. The storage is discharged when power is needed because of insufficient supply from the base-load plant.

1.1.2. Electrical storage

Energy storage through batteries is an option for storing the electrical energy. A battery is charged, by connecting it to a source of direct electric current and when it is discharged, the stored chemical energy is converted into electrical energy. Potential applications of batteries are utilization of off-peak power, load leveling, and storage of electrical energy generated by wind turbine or photovoltaic plants. The most common type of storage batteries is the lead acid and Ni–Cd.

1.1.3. Thermal energy storage

Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo chemical or combination of these. An overview of major technique of storage of solar thermal energy is shown in Fig. 1.

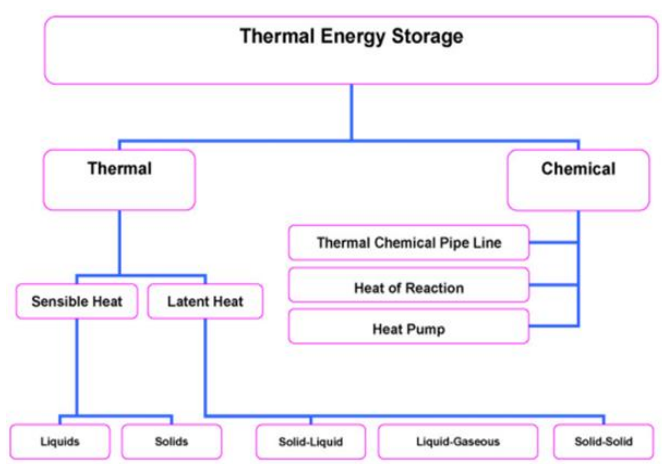

Fig. 1. Different types of thermal storage of solar energy.

2. RELATED WORK

M Zhang [10] presented the development of a thermally enhanced frame wall that reduces peak air conditioning demand in residential buildings. He also found the average space-cooling load was reduced by approximately 8.6% when 10% PCM was applied and 10.8% when 20% PCM was used in 2005. M Ibanez [2] explained the thermal improvements in a building due to the inclusion of PCMs depend on the climate, design and orientation of the construction, but also to the amount and type of PCM in 2005. Y Zhang [5] investigated the basic principle, candidate PCMs and their thermo physical properties, incorporation methods, thermal analyses of the use of PCMs in walls, floor, ceiling and window etc. and heat transfer enhancement are discussed in 2007.

V V Tyagi [6] presented the thermal performance of various types of systems like PCM trombe wall, PCM wallboards, PCM shutters, PCM building blocks, air-based heating systems, floor heating, ceiling boards, etc., in 2007. U Stritih [12] presented an experimental and numerical analysis of cooling buildings using night-time cold accumulation in phase change material (PCM), otherwise known as the „free-cooling principle‟ in 2007.

H Liu[7] investigated the concept of the high thermal storage capacity of phase change material (PCM) can reduce energy consumption in buildings through energy storage and release when combined with renewable energy sources, night cooling, etc in 2009. PCM absorbs night coolness and give it in day time, but by providing coolant its back up time gets increased.

3. LATENT HEAT STORAGE MATERIALS

PCM: Phase change materials (PCM) are ‘‘Latent’’ heat storage materials. The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid. This is called a change in state, or ‘‘Phase.’’ Initially, these solid–liquid PCMs perform like conventional storage materials, their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat at a nearly constant temperature. They store 5–14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. A large number of PCMs are known to melt with a heat of fusion in any required range. However, for their employment as latent heat storage materials these materials must exhibit certain desirable thermodynamic, kinetic and chemical properties. Moreover, economic considerations and easy availability of these materials has to be kept in mind.

4. THERMAL ENERGY STORAGE SYSTEMS

4.1. Thermal energy storage

Thermal energy storage (TES) is achieved with greatly differing technologies that collectively accommodate a wide range of needs. It allows excess thermal energy to be collected for later use, hours, days or many months later, at individual building, multiuser building, district, town or even regional scale depending on the specific technology. As examples: energy demand can be balanced between day time and night time; summer heat from solar collectors can be stored interseasonally for use in winter; and cold obtained from winter air can be provided for summer air conditioning. Storage mediums include: water or ice-slush tanks ranging from small to massive, masses of native earth or bedrock accessed with heat exchangers in clusters of small-diameter boreholes (sometimes quite deep); deep aquifers contained between impermeable strata; shallow, lined pits filled with gravel and water and top-insulated; and eutectic, phase-change materials.

4.2. EXPERIMENTAL PROCEDURE:

A comparison has been made between different sized latent heat storage vessels and sensible heat storage in a water tank with different degree of stratification. The storage vessel consists of a number of closed cylindrical pipes filled with the phase change medium (paraffin)(Fig. 5). These pipes were surrounded by heat transfer fluid. Bajnoczy et al. studied the two-grade heat storage system (60–308C and 30–208C) based on calcium chloride hexahydrate and calcium chloride tetrahydrate. Authors also studied the storage capacity changes during the cycles and possible use of a solar energy storage system for domestic water-heating system. Whenever solar energy is available, it is collected and transferred to the energy storage tank that is filled by 150 kg encapsulated phase change material (PCM). It consisted of a vessel packed in the horizontal direction with cylindrical tubes.

Sharma et al. designed, developed and performance evaluate of a latent heat storage unit for evening and morning hot water requirements, using a box type solar collector. Paraffin wax (m.p. 548C) was used as a latent heat storage material and found that the performance of the latent heat storage unit in the system was very good to get the hot water in the desirable temperature range.

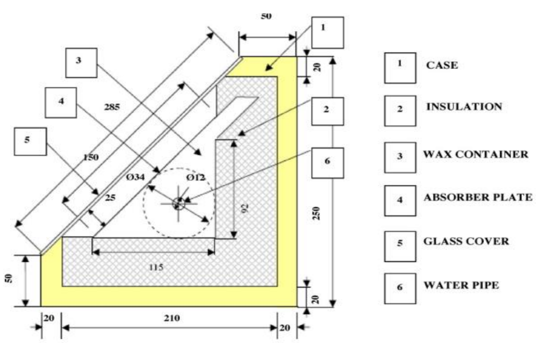

Fig 2 Schematic of the experimental apparatus cross-section

Mettawee and Assassa investigated a the thermal performance of a compact phase change material (PCM) solar collector based on latent heat storage. In this collector, the absorber plate–container unit performs the function of both absorbing the solar energy and storing PCM. The collector's effective area was assumed to be 1 m2 and its total volume was divided into five sectors. The experimental apparatus was designed to simulate one of the collector's sectors, with an apparatus-absorber effective area of 0.2 m2.

Outdoor experiments were carried out to demonstrate the applicability of using a compact solar collector for heating. Experiments were conducted for different water flow rates of 8.3– 21.7 kg/h. The effect of the water flow rate on the useful heat gain was studied. The heat transfer coefficients were calculated for the charging process. The experimental results showed that in the charging process, the average heat transfer coefficient increases sharply with increasing the molten layer thickness, as the natural convection grows strong. In the discharge process, the useful heat gain was found to increase as the water mass flow rate increases.

5. EXPERIMENTAL RESULTS

Table 1: Temperature variation at 3kg/min during charging

Time elapsed (in min)	Thermo couple 1	Thermo couple 2	Thermo couple 3	Thermo couple 4	Thermo couple 5	Thermo couple 6
2	34	34	34	34	34	34
4	35	36	35	37	35	38
6	37	38	37	39	39	39
8	38	39	38	41	39	41
10	40	41	40	41	40	41
12	41	42	41	44	41	44
14	43	44	42	45	42	44
16	43	45	43	46	45	46
18	43	45	43	46	43	46
20	44	46	45	47	44	48
22	45	46	45	48	46	48
24	46	47	46	49	46	49
26	47	48	47	49	47	51
28	47	48	47	50	48	50
30	48	50	48	51	48	55
31	49	50	49	51	49	51
34	51	52	49	52	49	52
36	50	52	50	52	50	53
38	50	52	51	53	55	53
40	51	53	51	53	51	53
42	51	54	51	54	51	55
44	52	55	52	54	51	54
46	53	56	53	55	53	53
48	53	57	53	55	53	55
51	54	58	54	55	54	55
52	55	59	54	55	54	57
54	56	59	54	56	55	56
56	57	60	55	56	55	56
59	59	61	55	57	55	59
60	60	61	56	57	57	57

TABLE 2: TEMPERATURE VARIATIONS AT 3KG/MIN DURING DISCHARGING

Time elapsed (in min)	Thermo couple 1	Thermo couple 2	Thermo couple 3	Thermo couple 4	Thermo couple 5	Thermo couple 6
2	69	63	57	57	55	55
4	62	60	56	56	56	58
6	060	59	56	55	55	55
8	58	57	55	54	53	54
10	57	57	54	53	54	53
12	56	56	54	52	55	52
14	54	55	53	51	53	51
16	54	54	52	51	52	55
18	53	54	52	50	59	50
20	53	53	51	49	51	49
22	52	53	51	48	51	49
24	51	52	50	48	59	48
26	50	51	50	48	50	49
28	49	51	49	47	49	47
30	49	51	49	47	49	48
31	48	50	48	46	48	46
34	48	49	48	45	47	45
36	47	49	47	45	47	44
38	47	49	47	44	48	44
40	47	48	46	44	49	43

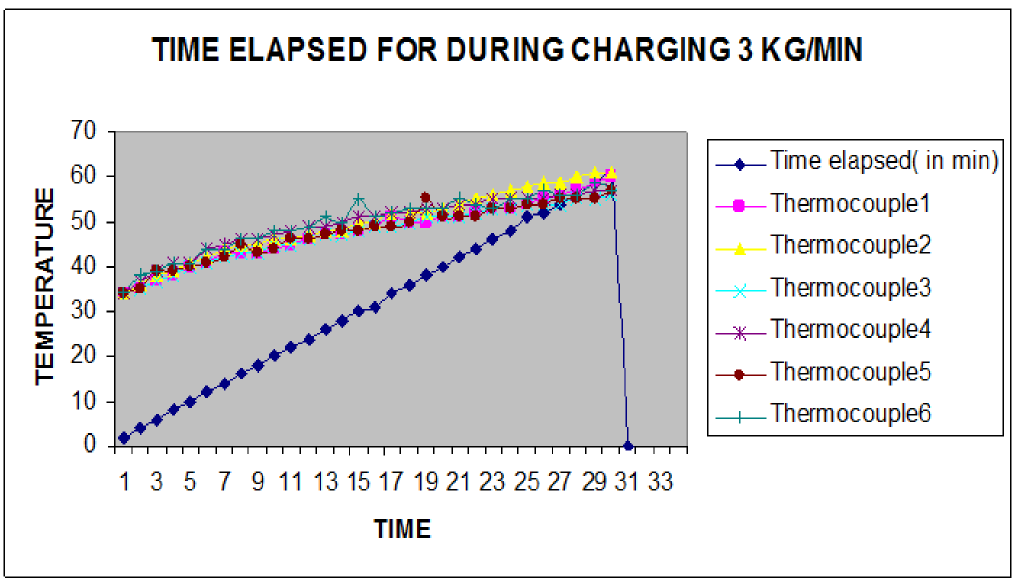

Fig 3: Time Elapsed for during charging 3Kg/MN

6. CONCLUSION

This project is focused on the available thermal energy storage technology with PCMs with different applications. Those technologies is very beneficial for the humans and as well as for the energy conservation. This project presents the current research in this particular field, with the main focus being on the assessment of the thermal properties of various PCMs. That project also presents the paraffin melt fraction studies of the few identified PCMs used in various applications for storage systems with different heat exchanger container materials.

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