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A Review on Performance Analysis of Thermal Energy Storage System

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ABSTRACT

The thermal energy can be collected whenever it is available and be used whenever needed with an effective application of Heat Energy Storage. Heat energy storage can be used with any heating system like electric heating or solar system. Because of the intermittent source of solar energy heat energy storage system is mostly recommended and influencing the sector.

This paper reviews experiments will be performed on thermal energy storage prototype using Concrete as the solid media sensible heat material because it is locally available at low cost and easy to handle. Water/Steam is used as heat transfer fluid (HTF). The concrete storage prototype is composed of concrete with embedded pipes. The embedded pipes will be transporting and distributing the heat transfer medium while sustaining the pressure. The concrete stores the thermal energy as sensible heat.

Also, the performance analysis of the thermal energy storage (TES) system will be done on basis of charging time, discharging time, Energy input, energy recovered and on same guideline another analysis of thermal energy storage is proposed using castable ceramic as heat storing material.

1. INTRODUCTION

The TES can be defined as the temporary storage of thermal energy at high or low temperatures. The TES is not a new concept, a has been used for centuries. Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation.

Energy storage improves the performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. Some of the renewable energy sources can only provide energy intermittently. Although the sun provides an abundant, clean and safe source of energy, the supply of this energy is periodic following yearly and diurnal cycles; it is intermittent, often unpredictable and diffused. Its density is low compared with the energy flux densities found in conventional fossil energy devices like coal or oil-fired furnaces. The demand for energy, on the other hand, is also unsteady following yearly and diurnal cycles for both industrial and personal needs. Therefore the need for the storage of solar energy cannot be avoided. Otherwise, solar energy has to be used as soon as it is received. In comparison, the present yield in energy gained by fossil fuels and water power amounts to about 70x1012 kWh. [1] but the technical use of solar energy presently poses problems primarily because of inefficient collection and storage.

2.1 Methods of Thermal Energy Storage

There are three basic methods for storing thermal energy:

1. Heating a liquid or a solid, without changing phase: This method is called sensible heat storage (SHS). The amount of energy stored depends on the temperature change of the material and can be expressed in the form,

$$E = m \int_{T1}^{T2} Cp\, dT \quad \text{----------------------(1)}$$

Where, m is the mass and Cp the specific heat at constant pressure. T_1 and T_2 represent the lower and upper-temperature levels between which the storage operates. The difference (T2 – T1) is referred to as the temperature swing.

2. Heating a material, this undergoes a phase change (usually melting): This is called latent heat storage. The amount of energy stored (E) in this case depends upon the mass (m) and latent heat of fusion (λ) of the material. Thus,

$$E = m \times \lambda \text{----------------(2)}$$

The storage operates isothermally at the melting point of the material. If isothermal operation at the phase change temperature is difficult, the system operates over a range of temperatures T1 to T2 that includes the melting point. The sensible heat contributions have to be considered and the amount of energy stored is given by,

$$E = m[\{\int_{T1}^{T*} Cp\, dT\} + \lambda + \{\int_{T*}^{T2} Cp\, dT]\text{-(3)}$$

Where, C_{ps} and C_{pl} represent the specific heats of the solid and liquid phases and T* is the melting point.

3. Using heat to produce a certain physicochemical reaction and then storing the products. Absorbing and adsorbing are two examples for the bond reaction. The heat is released when the reverse reaction is made to occur. In this case also, the storage operates essentially isothermally during the reactions. However, the temperature at which heat flows from the heat supply is usually different, because of the required storage material and vice versa.

Of the above methods, sensible and latent heat storage systems are in use, while bond energy storage systems are being proposed for use in the future for medium and high temperature applications. The specific application for which a thermal storage system is to be used determines the method to be adopted. Some of the considerations, which determine the selection of the method of storage and its design, are as follows:

- The temperature range, over which the storage has to operate.
- The capacity of the storage has a significant effect on the operation of the rest of the system. A smaller storage unit operates at a higher mean temperature. This results in a reduced heat transfer equipment output as compared to a system having a larger storage unit. The general observation which can be made regarding optimum capacity is that "short-term" storage units, which can meet fluctuations over a period of two or three days, have been generally found to be the most economical for building applications.
- Heat losses from the storage have to be kept to a minimum. Heat losses are particularly important for long-term storage.
- The rate of charging and discharging.
- Cost of the storage unit: This includes the initial cost of the storage medium, the containers and insulation, and the operating cost.

Other considerations include the suitability of materials used for the container, the means adopted for transferring the heat to and from the storage, and the power requirements for these purposes.

The economics of mode of heat storage demands sensible heat storage material which is inexpensive. Solid materials such as cast steel, stone, rock, sand, concrete and ceramic have usually been selected as sensible heat storage media depending on the required temperature range and specific application. [2] The TES system using concrete as the sensible heat storage media is usually implemented by embedding the pipes heat exchanger in concrete to transfer thermal energy to or from the heat transfer fluid like air, synthetic oil. The advantages of using a concrete system include the low cost of the thermal storage media, the high heat transfer rates into and out of concrete, the ease of handling of the material, the availability of the material, and uncomplicated processing. Concrete systems provide all of these advantages and are therefore an attractive option for use.

2. LITERATURE SURVEY/REVIEW

Literature related with the, study of SHS, properties of heat storage materials, various methods and conditions *i.e*. temperature range adopted for the experimentation.

Results obtained regarding the performance of sensible heat storage are collected from different standard books as well as standard journals sites like science direct, research journals of engineering science, *etc*. The literature review can be briefly discussed as follows,

Khare *et al*. [3] has studied candidate materials for high temperature SHS systems. The main difficulty in using solid media for SHS is the large size requirement of the storage bed. However, this can be minimized by using high heat capacity storage materials and allowing high temperature swing.

Tamme *et al*.[4] has studied and compared thermo physical properties of Solid materials cast steel, stone, rock, sand, concrete and ceramic and suggested that castable ceramic and concrete as sensible heat storage mediums for high temperature heat storage applications. Castable ceramic and concrete can hold heat energy in temperature range from 373K to 800 K.

Laing *et al*. [5] has investigated ceramic and high temperature concrete for maximum storage temperatures up to 663° K with storage capacity of 350 kW. He concluded that concrete was the more preferable storage material although ceramic has 20% higher storage capacity and 35% greater conductivity.

Nandi *et al.* [6] has reported concrete and castable ceramic as low cost (25-30 $ kWh) and durable SHS systems. It has been observed that heating the concrete at elevated temperatures causes certain reactions and transformations to occur due to the presence of voids which influence their thermo-physical properties. The compressive strength decreases by about 20% on heating the concrete to 673 K [1].However, such problems can be minimized by the addition of filler materials such as steel needles and reinforcement to improve the mechanical and thermal strength of the material.

John *et al*. [7] has found that after exposure to 10 thermal cycles with temperature increases from ambient temperature to 723K, the concrete bed maintained more than 50% of it's mechanical properties. It can be seen from the previous work that many researchers emphasized the use of high temperature concrete as a SHS material.

3. PROBLEM DEFINATION

There is a lack of research on solid SHS systems based on using water/steam as the heat transfer fluid. The present work seeks to remedy this perceived lack by investigating the thermal storage performance of solid state SHS systems, using local concrete material.

4. AIMS & OBJECTIVES

1) Design and Fabrication of SHS system using concrete as heat storing material.
2) Study the performance of SHS system using concrete as heat storing material.

5. PROPOSED PROJECT SCHEME / METHODOLOGY

Following are the important activities which show how the project will be carried out

5.1 Experimental Setup

The experimental setup composed of pipes embedded in a concrete storage block. The embedded pipes are used for transporting and distributing the heat transfer medium while sustaining the pressure. The concrete stores the thermal energy as sensible heat. A special interface material will be installed to reduce the friction between the concrete and the pipes due to the mismatch of thermal expansion.

The heat exchanger is composed of 16 pipes of high-temperature steel with the inner diameter of

12 mm and wall thickness of 7 mm. They are distributed in a square arrangement of 4 by 4 pipes with a separation of 82 mm. The storage prototype has the dimensions of 0.5 × 0.5 × 4 m.

In order to record data for energy balances, the piping system was equipped with numerous of sensors. The mass flow as well as the water/steam temperature and pressure were measured. The prototype was equipped with thermocouples distributed within the storage material, on the embedded pipes and the header pipe. After the installation of additional reinforcement and measuring equipment, a formwork was installed and the storage space was filled with the thermal storage concrete. The storage prototype was then covered by insulation on all sides and top and bottom.

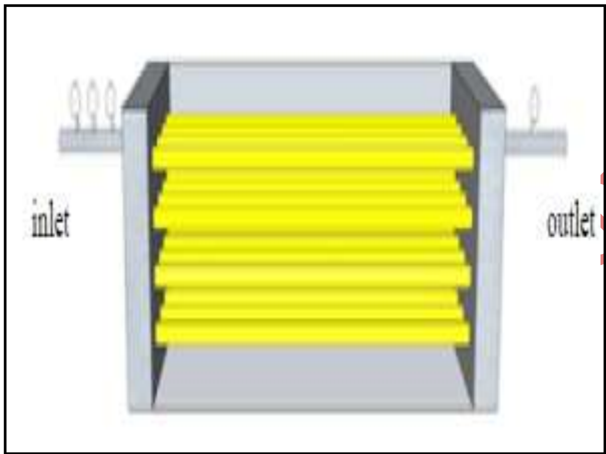

Figure No.1 Schematic of thermal storage

5.2 Experimental Procedure [9]

The experimental investigation will be carried out. As the startup procedure, prior to the experimental processes, most of the water contained in the concrete was expelled by heating the concrete storage prototype from ambient temperature to 180^0C. During the process the water evaporates and there is a buildup of vapor pressure within the concrete. This needed to be carefully monitored to avoid damage to the concrete. The subsequent operating conditions of the concrete storage prototype were:

- Heat transfer fluid (water/steam)
- Maximum internal pressure (10 bar)
- Maximum temperature: up to 180°C
- Test temperature range between 110-180°C
- Mass flow rate: 0.009, 0.012 and 0.014 kg/s
- No. of pipes (3-6)
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6. Conclusion

In this research work, the performance analysis of a thermal energy storage sensible type will be done. For the charging/discharging experiment, it will find that the increase or decrease in storage temperature depend on the HTF temperature, flow rates, and initial temperature.

Following results will be obtain for analysis,

A. Energy Input

B. Charging Time

D. Energy Recovery

E. Energy Efficiency.

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