Review on Thermal Energy Storage Techniques

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***Abstract* - Thermal energy storage has been a main topic in research for the last 20 years, but although the information is quantitatively enormous, it is also spread widely in the literature, and difficult to find. In this work, a review has been carried out of the history of thermal energy storage and different techniques which adopted for thermal energy storage three aspects have been the focus of this review: Storage methods, Classifications and applications.**

I. INTRODUCTION

As the energy cruces are going to the higher extent it is very essential to harvest the energy which is already available, it may be in low grade form or it may be in the form of waste heat which is going to sink for cooling and recycling the process.

It is very essential to harvest the available energy and make use of it for further secondary heating processes.

Heat is a form of energy which is mostly goes to the sink after the different processes involved; almost 70 to 80% of heat energy is available for harness

In most processes, excess thermal energy is released to the atmosphere or a large body of water to complete a cyclic process or prevent overheating of components or facilities. Although excess thermal energy is impossible to completely eliminate, it has the potential to be harvested and used for applications that would otherwise require additional energy input from other sources. This method of energy transfer is not presently widely employed for several reasons.

This means that recovering unused thermal energy does not decrease the energy usage of the system the designer is concerned with, their own facility, and low fossil fuel prices do not motivate others to seek alternate sources of thermal energy. An increase in overall system efficiency from excess thermal energy recovery would only be seen on a much larger scale in most instances, when the system analyzed is a community or region and the energy inputs from all sources are considered.

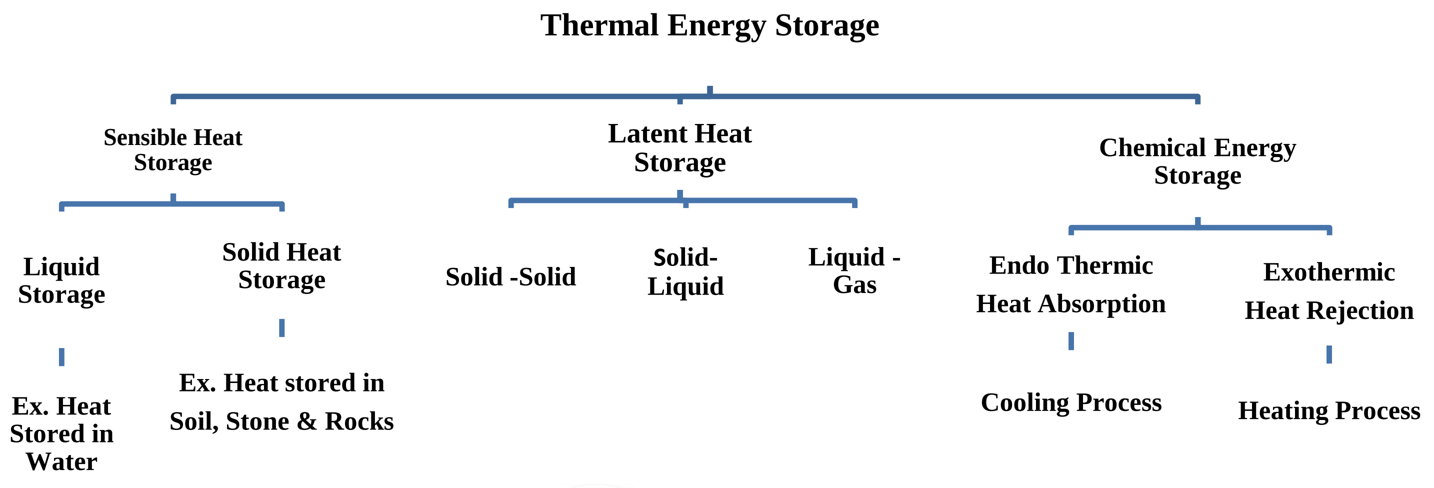
Compared to the heat energy recovering and re utilization of other form of energy available from different thermo mechanical processes are very easy but harvesting and reusing the heat energy is very difficult.

So it is very important to study about different methods of thermal energy storage.

II. THERMAL STORAGE TECHNIQUES

Applications

- Solar Heat collection and storage - In earlier time the only use of solar energy was heating the water, by collecting the solar radiations by using solar panel which consist number of tubes and inside these tubes water is circulated. This type of storing heat energy is one of the short time storage processes which can be utilized within limited period of time.
- Maintaining the Building temperature by using phase change material - By using phase change material inside the room temperature maintained constant for a longer period, initially a thin coating is to be done over the wall by making the cavity. Depending on the requirement room temperature may be increased or decreased by coating insulating material inside or outside the wall.
- Vapor Absorption Refrigeration system - During the 18th century the only method of producing lower temperature is the vapour absorption refrigeration method, where ammonia is heated by collecting solar radiation and which is sent through the evaporator chamber where heat is absorbed by ammonia vapour and the evaporator chamber temperature is decreased. And this temperature was much below atmospheric temperature and food is preserved.
- Thermal Energy Recovery - Recovering the thermal energy from burnt exhaust gases from various combustion sources and utilized that for some secondary heating purpose.



In this present review work various methods of storing thermal energy storage in different materials and different systems.
Methods of storing Thermal storage

- Sensible Heat Storage
- Latent Heat Storage
- Chemical Storage
- Bonding Energy method

Individual methods of thermal energy storage methods will be discussed in further scenario.

Sensible Heat storage

In this method heat energy is stored in any material which changes its surface temperature.
In sensible storage its molecular motion gets disturbed and its randomness increases due to this increase in molecular motion its internal temperature increases and hence its surface temperature increases.

Latent Heat Storage

In this type of energy storage method heat energy is stored inside the material without changing its surface temperature. This is mainly due to the latent heat storing capacity of that particular material.

Chemical Storage method

In this Chemical energy storage method heat stored by using two types of chemical reactions which are named as a) Endothermic chemical reaction and b) Exothermic chemical reaction .
These reactions are carried out at different working conditions for different applications.
For example for in cooling or heat absorbing applications endothermic reactions should be carried out by using some chemical mixture where heat energy available is utilized for carrying out the endothermic reaction and hence its lowers the surrounding temperature And in similar case Exothermic reaction are also used in heating applications , this ids carried out by reacting some chemical mixture which reacts and liberates heat energy which is further utilized for heating application of the surrounding.
There are three main methods of storing thermal energy in any material: reversible chemical energy, sensible thermal energy and latent thermal energy. Chemical energy is absorbed or released when a chemical reaction occurs in a material, thus changing the organization of the molecules. If this process is reversible, it can be used to capture and recover energy. An example of this is splitting water into its component gases, diatomic oxygen and diatomic hydrogen and then recombining them into water. This can also be done to ammonia through the reversible Haber process by combining and separating the nitrogen and hydrogen atoms.

Water storage technology

Possible “sensible heat” storage media are liquid (especially water) and solid materials (especially soil and stone).
The *hot water tank* is one of the best known thermal energy storage technologies. The hot water tank serves the purpose of saving energy when applied to, e.g., a solar tap water system or an energy supply system with cogeneration. The major aim of an electrically heated hot water tank in a tap water system is to shave the peak in electricity demand and consequently improve the efficiency of electricity supply.

Short-term storage
The storage volume (hot water tank) of a solar hot water system will generally be between 1,5 and 2,0 times of the daily hot water demand. With short-term storage, too, a sufficient insulation has to be provided to minimize the heat losses within the system.
The efficiency of a solar thermal system is to a large extend defined by the heat demand (amount of hot water). With increasing heat demand the heat output per collector area rises and thus the heat costs are reduced.

Mid-term storage for solar supported district heating
In order to cover the heat demand for hot water in district heating outside the heating season mainly by solar systems a thermal storage with a capacity for 3 to 5 days has to be installed; housing estate Gneiss-Moos/Salzburg. Even if, according to project data of a solar supported district heating plant - Figure 12 a and 12b -, the solar share for *space heating and hot water preparation* at the annual average is of about 14 %, the *solar share for hot water preparation* outside the heating season is more than 80%.

Long-term storage for solar space heating
Because of the discrepancy between solar radiation and space heat demand *monovalent* solar space heating in cold and temperate climates is only possible if a long-term thermal storage with a heat capacity of at least six months in existing housing and of about four month in low-energy housing is provided.
The application of hot water storage (water tanks made of concrete or steel) for seasonal storage require, even for a one-family house in low-energy building standard, a storage volume of about 80 m³ in combination with a collector area of about 80 m².

Central solar heating plants with seasonal storage
Due to technical and economic reasons, seasonal storage of solar heating is economic mainly on larger scale, i.e. for a group of houses utilizing common large-scale heat storage through district heating.
Seasonal storage solar heating technologies have been studied intensively in several northern countries and have also been a part of international collaborative work within the framework of the IEA Solar Heating and Cooling Program. The national and international efforts over the last ten years have resulted in major improvements in technology and economics. Also, the concerns in the environment and the very recent disturbances in the world oil markets have brought the large-scale solar technology closer to realization.

Principle of Thermal Energy Storage
When a thermal storage need occurs, there are three main physical principles to provide a thermal energy function:

- *Sensible heat*

  The storage is based on the temperature change in the material and the unit storage capacity [J/g] is equal to heat capacitance × temperature change.
  In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a material, practically a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium, the temperature change and the amount of storage material

$$Q = \int_{Ti}^{Tf} m\,Cp\;dT \quad 1 \qquad\qquad Q = m\,Cp\,(Tf - Ti) \quad 2$$

Where: Q is the amount of thermal energy stored or released in form of sensible heat (kJ), T is the initial temperature (°C), T_f is the final temperature (°C), m is the mass of material used to store thermal energy (kg), and C_p is the specific heat of the material used to store thermal energy (kJ/kg°C).

Latent heat storage
Latent heat storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa.

- *Phase-change*

  If the material changes its phase at a certain temperature while heating the substance then heat is stored in the phase change. Reversing, heat is dissipated when at the phase change temperature it is cooled back. The storage capacity of the phase change materials is equal to the phase change enthalpy at the phase change temperature + sensible heat stored over the whole temperature range of the storage.
  The storage capacity of the LHS system with a PCM medium is given by:

$$Q = \int_{Ti}^{Tm} m\,Cp\;dT + m\,a_m\,\Delta h_m + \int_{Tm}^{Tf} m\,Cp\;dT \quad 3$$

Where: Q is the amount of thermal energy stored or released in form of sensible heat (kJ), T_i is the initial temperature (°C), Tm (°C) is the melting temperature (°C), T_f (°C) is the final temperature, m (kg) is the mass of heat storage medium (kg), cp (kJ/kg°C) is the specific heat (kJ/kg°C), am is the fraction melted (-) and, Δh_m is the heat of fusion per unit mass (kJ/kg).

Latent heat of solid – liquid phase change

There are several options of energy storage with solid – liquid phase change with distinct advantages and disadvantages. As compared to sensible heat storage, the phase change by melting and solidification can store large amounts of heat or cold, if a suitable material is selected. Melting is characterized by a small volume change, usually less than 10%. If a container can fit the phase with the larger volume, usually the liquid, the pressure is not changed significantly and consequently melting and solidification of the storage material proceed at a constant temperature. Upon melting, while heat is transferred to the storage material, the material still keeps its temperature constant at the melting temperature, also called phase change temperature.

Latent heat of liquid – vapour phase change

The liquid-vapour phase change by evaporation and condensation also usually has a large phase change enthalpy; however, the process of evaporation strongly depends on the boundary conditions:

In closed systems with constant volume, evaporation leads to a large increase of the vapour pressure. A consequence of the rising vapour pressure is that the temperature necessary for a further phase change also rises. Liquid-vapour phase change in a constant volume is therefore usually not useful for heat storage.

In closed systems at constant pressure, evaporation leads to a large volume change. This is difficult to realize and thus also not applied for heat storage.

An open system at constant, that means ambient **pressure**, is a third option. This option avoids a change of the phase change temperature. Upon loading the storage with heat, the storage material is evaporated. Because the system is open, the storage material is lost to the environment. To retrieve the stored heat from the storage, the storage material has to be retrieved from the environment. This means it has to be a natural part of the environment. The only technically used material today is *water*.

- *Chemical reactions*

  The sorption or thermo chemical reactions provide thermal storage capacity. The basic principle is: AB + heat ⇔ A+B; using heat a compound AB is broken into components A and B which can be stored separately; bringing A and B together AB is formed and heat is released. The storage capacity is the heat of reaction or free energy of the reaction.

Thermal Energy Storage Materials

Materials are the key issues for thermal storage. The classical example for phase change materials is the Glauber salt (sodium sulphate). Metal hydrides are well-known hydrogen stores in which hydrogen is absorbed into the metallic structure with the help of heat, or turning it around, adding hydrogen would release heat and removing hydrogen absorb heat. In this way metal hydrides also work as thermo chemical heat storage ($AB=MeH_x$).

Physical, technical, and economic requirements

A suitable phase change temperature and a large melting enthalpy are two obvious requirements on a phase change material. They have to be fulfilled in order to store and release heat at all. However, there are more requirements for most, but not all applications. These requirements can be grouped into physical, technical, and economic requirements.

Physical requirements, regarding the storage and release of heat:

Suitable phase change temperature T_{pc} → to assure storage and release of heat in an application with given temperatures for heat source and heat sink.

Large phase change enthalpy Δh_{pc} to achieve high storage density compared to sensible heat storage.

Reproducible phase change, also called cycling stability → to use the storage material as many times for storage and release of heat as required by an application.

Technical requirements, regarding the construction of storage:

Low vapour pressure → to reduce requirements of mechanical stability and tightness on a vessel containing the PCM

Small volume change → to reduce requirements of mechanical stability on a vessel containing the PCM

Chemical stability of the PCM → to assure long lifetime of the PCM if it is exposed to higher temperatures, radiation, gases.

Compatibility of the PCM with other materials → to assure long lifetime of the vessel that contains the PCM, and of the surrounding materials in the case of leakage of the PCM

This includes destructive effects as for example the corrosivity of the PCM with respect to other materials, but also other effects that significantly reduce or stop important functions of another material.

Safety constraints → the construction of storage can be restricted by laws that require the use of non toxic, non-flammable materials. Other environmental and safety consideration can apply additionally.

III. SUMMERY

A review of Thermal Energy Storage has been carried out. The information obtained

Is presented divided into three parts: techniques. Classification and applications. Methods used by researchers as potentially TES are described, together with their thermo-physical properties.

Commercially PCMs have also been used. Different methods of thermal Storage are described can be found. Problems of Short term storage, long term Storage of the Thermal energy and their Applications are discussed. Heat transfer is considered mainly from a theoretical point of view.

IV. REFERENCES

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