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DEVELOPMENT OF LATENT THERMAL ENERGY STORAGE SYSTEM FOR COOLING APPLICATIONS

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ABSTRACT

Day by day energy needs are increasing and there is a mismatch between energy supply and energy demand. Buildings are major consumers of energy of approximately 27% in the world wide. And also increasing concerns about climate change and environmental emissions have led to conserving energy through the development of several energy-efficient systems. Latent thermal energy storage system is one important method among different thermal energy storage methods due to excellent features like high energy storage density, storing thermal energy at constant temperature. In spite of these it has very poor thermal conductivity of phase change materials which would reduce energy storage capacity and reduces time for melting and solidification thereby heat transfer from heat transfer fluid to PCMs (Phase Change Materials) decreases. The main aim of present investigation is to enhance the thermal properties of PCMs with dispersion of nanoparticles which suit for development of thermal energy storage for building applications. The overall work is split up into three phases. In first phase fatty acid type which is a member of organic PCM is selected suitable for cooling application, then it is characterize for thermal properties. In second phase nanoparticles are synthesized using sol gel method and In the third phase Nano-based PCMs (NPCMs) are prepared with dispersion of nano particles in PCMs (1%, 2%) with different mass fractions using ultra sonic vibrator. Then NPCMs are characterized for thermal properties like thermal conductivity, heat energy storage density, specific heat etc using differential scanning calorimeter (DSC), transmission electron microscope (TEM), Scanning electron microscope (SEM). Results are validated comparing pure PCMs with NPCMs. And also predicting the better one among different proportions of nano based PCMs.

Key words: *TEM, DSC, SEM and PCM.*

I. INTRODUCTION

Thermal strength garage (TES) is a generation that stocks thermal electricity with the aid of heating or cooling a storage medium so that the saved strength can be used at a later time for heating and cooling packages and strength generation. TES systems are used specifically in homes and commercial tactics. In those applications, approximately half of the strength fed on is within the form of thermal energy, the call for for which can also range in the course of any given day and from someday to next. therefore, TES systems can help stability strength call for and deliver on a day by day, weekly and even seasonal foundation. They can also reduce peak call for, electricity intake, CO2 emissions and costs, even as growing usual performance of electricity systems. furthermore, the conversion and garage of variable renewable energy in the form of thermal power can also help boom the percentage of renewable in the power mix. TES is becoming specifically important for power storage in aggregate with concentrating solar power (CSP) plants where sun warmness may be stored for energy manufacturing while daylight is not available.

There are 3 steps of TES systems as follows:
1) sensible warmth garage this is based on storing thermal energy via heating or cooling a liquid or stable storage medium (e.g. water, sand, molten salts, rocks), with water being the most inexpensive alternative;

2) Latent heat storage using phase trade materials or PCMs (e.g. from a solid country right into a liquid nation); and three) thermo-chemical storage (TCS) using chemical reactions to store and release thermal power.

Thermal energy garage (TES) includes some of distinctive technologies. Thermal electricity can be saved at temperatures from -40°C to greater than four hundred°C as realistic heat, and chemical energy (i.e. thermo-chemical strength storage) the use of chemical reactions. whenever temp in no way constant say 40C in a while it has to preserve lower temperatures say -23C to human comfort temp say 22C.for this motives latent method is selected.

Thermal electricity garage has huge no. of programs like solar,Engines,aircon and constructing. on this paper deals extensive software this is buildings. examine to rest strategies of TES latent is high-quality appropriate for constructing software

This paper is divided into three steps:
1. Selection of Materials which are best suit of cooling applications
2. Synthesis and characterization of nano materials.
3. Validating results.

Selection of Materials which are best suit of cooling applications
Phase change materials (PCMs) also called as latent heat unit. The name implies that PCMs are changes its phase when heating or cooling takes place. Ice is the best example for PCMs when ice is in solid stage it release cooling effect and convert in to liquid. When it absorb cooling it convert its phase liquid into solid.

Fig 2.1: Phase change materials

Types of PCMs:

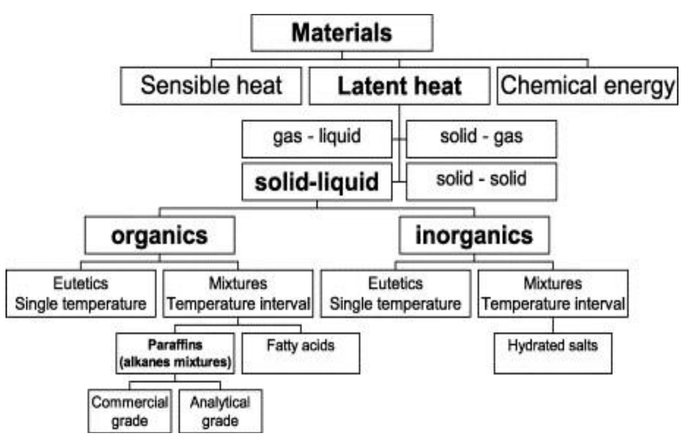

Fig 2.2: Flow Chart

After study of various types of PCMs it is found that inorganic materials are selected because this materials not consisting of or deriving from living matter. Inorganic type materials also have many types these are listed below.

Table 2.1: Inorganic Type Materials

Compound	Melting temp	Heat of fusion	Thermal conductivity	Density
Propyl palmiate	10	186	NA	NA
Isopropyl palmiate	11	95-100	NA	NA
Capric-lauric acids	13.5	142.2	NA	NA
Isopropyl stearate	14-18	140-142	NA	NA
Caprylic acid	16,16.3,16.7	148.5	0.148	901

As cited above list is prepared by literature survey and among all materials caprylic acid is selected even above materials having less melting temperature because caprylic acid shows good effect with nano encapsulation and micro encapsulation. Nanoencapsulation is the coating of various substances within another material at sizes on the nano scale. Microencapsulation is a process by which solids liquids or gases may be enclosed in microscopic particles by formation of thin coatings of wall materials around the substance.

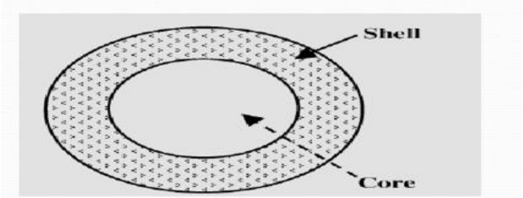

Fig. 2.3: Microencapsulation

In order to enhance thermal properties of caprylic acid it is need to add base material. Copper is selected because of its superior properties like thermal energy storage capacity and occupies small area when it is in nano stage.

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II. SYNTHESIS AND CHARACTERIZATION OF NANO MATERIALS

Synthesis: Sol gel Method:
The sol step by step evolves in the direction of the formation of a gel-like diphasic device containing both a liquid section and strong phase whose morphologies range from discrete particles to non-stop polymer networks. within the case of the colloid, the quantity fraction of particles (or particle density) can be so low that a significant quantity of fluid can also want to be removed first of all for the gel-like homes to be recognized. this could be carried out in any quantity of approaches. The simplest approach is to allow time for sedimentation to occur, after which pour off the closing liquid. Centrifugation can also be used to boost up the technique of section separation.

After synthesis a new materials is formed called nano based PCM called NPCM.
characterization:
For characterization SEM, TEM and DSC techniques are used here.

Transmission electron microscopyTEM: it's also occasionally conventional transmission electron microscopy or CTEM. it is a microscopy approach in which a beam of electrons is transmitted through a specimen to form an photograph. The specimen is most usually an ultrathin segment much less than a hundred nm thick or a suspension on a grid. An image is formed from the interplay of the electrons with the sample because the beam is transmitted thru the specimen. The image is then focused onto an imaging device, consisting of a fluorescent display screen, a layer of photographic movie, or a sensor consisting of a price-coupled device.

Fig 2.4: Transmission electron microscope

scanning electron microscope SEM: it's far a form of electron microscope that produces pictures of a sample via scanning the surface with a targeted beam of electrons. The electrons react with atoms within the specified pattern, producing various alerts that comprise records approximately the sample's floor topography and composition. The beam which contain electron is scanned in a raster scan sample, and the beam's role is mixed with the detected signal to produce an photograph. SEM can obtain decision higher than 1 nanometer. Specimens can be discovered in excessive vacuum in traditional SEM, or in low vacuum or wet conditions in variable strain or environmental SEM and at a huge range of cryogenic or accelerated temperatures with specialized gadgets.

Fig 2.5: Scanning Electron Microscope

Differential scanning calorimeter DSC: it is a thermo analytical approach in which the difference in the amount of heat required to growth the temperature of a pattern and reference is measured as a feature of temperature. each the pattern and reference are maintained at nearly the same temperature upto end of the test. generally, the temperature program for a DSC evaluation is designed such that the sample holder temperature will increase linearly as a

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characteristic of time. The reference sample has to a properly-defined warmth ability over the range of temperatures to be scanned.

Fig 2.6: Differential scanning calorimeter

c. Experimental set up and calculations:

Mass of refrigerant (R134a) (m) = 230grm.

1. Compressor details:-

Compressor Power = 0.167 H.P

1 H.P = 746 W

Therefore Power = 0.167×746=124.582 W

Fig 2.7: Compressor

2. Specifications of compressor:-

Table 2.2

Type	Suction
Volts	230
Power	4W
Speed	1400 PRM
Current	0.11A
Cycles	40/50 Hz

3. Condenser details:-

Fine type 7 inch single row condenser is used

Heat rejection in the condenser = m cp ΔT

= m cp (T2 – T1)

= 0.250×129.98(80-50)

= 0.85 KJ

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4. Expander details & Evaporator:
Diameter of capillary tube = 0.050 inch.
Length of capillary tube = 5ft.
Length of the evaporator coil = 30ft.
Evaporating coil diameter = 1/4 inch

5. Specifications of cold storage:
Volume = 0.02577 m3
Capacity = 25.99 liters.

III. VALIDATING RESULTS

The outcome of this result is validated as follows,

3.1 Results of characterization:
Pure PCM without dispersion of copper:
TEM & DSC results

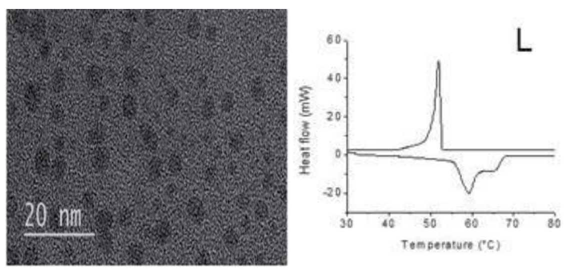

Fig 3.1:Pure PCM without dispersion of copper

PCMs with dispersion of Copper materials:
1% of copper and 99% of PCM

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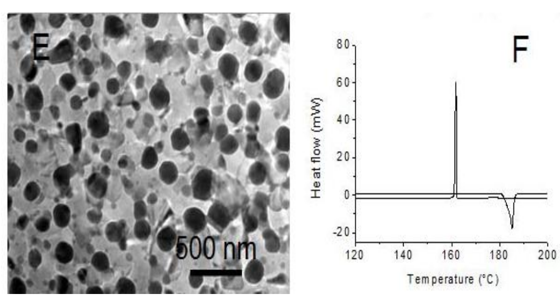

Fig 3.2:PCMs with dispersion of 1% Copper

2% of copper and 98% of PCM:

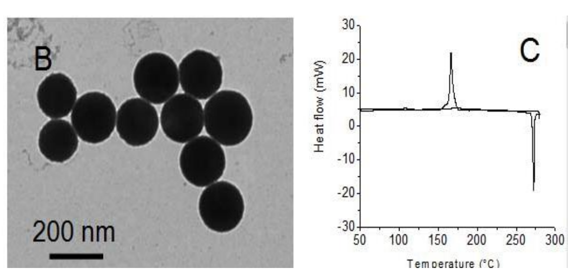

Fig 3.3: PCMs with dispersion of 2% Copper

3.2 Results of experiment:

The model experiment has reached as per the desired requirements. The following is results obtained during the testing.

PCM are observed for 24 Hours.
Temperature of the cold chamber -220C
Temperature reducing rate at 5C per hour up to -28C and from there the temperature will remains constant for about 5 hours and again temperature will raises steeply.

Table 3.1: Experimental results without PCM

s.no	Temperature ◦C	Time in hr
1	-27.37	0
2	-22.59	½
3	-18.21	1
4	-15	1 ½
5	-9.9	2
6	-7.9	2 ½
7	-8	3
8	-5.9	3 ½
9	0	4
10	4	4 ½
11	5.5	5

Experiment is conducted without PCMs and graph is plotted, as shown in bellow where x axis represents temperature◦C and time in hr

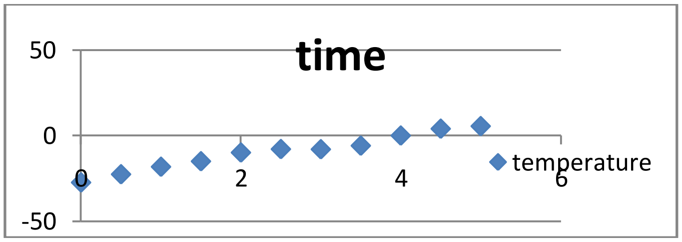

Fig 3.4: Variation of Temperature vs Time

Table 3.5: Experimental results with PCM

S.NO	Temp◦C	Time in hr	S.NO	Temp◦C	Time in hr
1	-27.37	0	17	-7.25	8
2	-25.63	1/2	18	-6.99	8 ½
3	-22.99	1	19	-6	9
4	-19	1 ½	20	-6	9 ½
5	-18	2	21	-6	10
6	-17.65	2 ½	22	-6	10 ½
7	-16	3	23	-5.69	11
8	-15	3 ½	24	-4.01	11 ½
9	-14.77	4	25	-3.12	12
10	-13	4 ½	26	-2.87	12 ½
11	-12.84	5	27	-2	13
12	-11.66	5 ½	28	0	13 ½

13	-11	6	29	1.39	14
14	-10.44	6 ½	30	2	14 ½
15	-9.82	7	31	2.12	15
16	-9	7 ½	32	2.67	15 ½

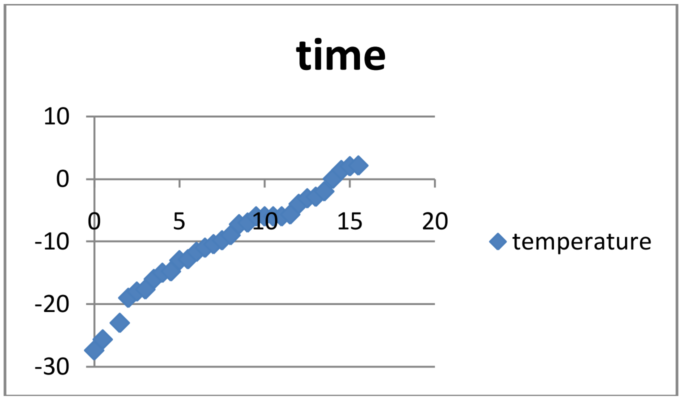

Fig 3.5: Variation of Temperature vs Time with PCM

IV. CONCLUSION

- Pure PCM without dispersion of copper is studied and characterized by using TEM and DSC and obtained following properties:PCM Type **-** Caprylic acid
  Melting point – 16 °C
  Heat of fusion (kJ/kg) – 148.5
  Thermal conductivity (W/m K) – 0.149
  Density (kg/m3) – 901 in liquid phase
- Different mass fractions of copper dispersion in PCM are characterized as follows:
  1% copper dispersion
  Melting point – 15.2 °C
  Heat of fusion (kJ/kg) – 156
  Thermal conductivity (W/m K) – 0.2
  Density (kg/m3) – 921 in liquid phase
  2% Copper dispersion
  Melting point – 14°C
  Heat of fusion (kJ/kg) – 161.1
  Thermal conductivity (W/m K) – 0.241
  Density (kg/m3) – 953 in liquid phase
- After characterization it can be found that 2 % copper dispersion is shown best result over pour PCM
- Test concluded that use of PCM within the partitions of a cold can keep and restrict the upward push in air temperature in the bloodless garage all through loss of strength. as the PCM melts, it absorbs the thermal load that enters the bloodless garage area, as a consequence limiting the upward push inside the cold save temperature. The experimental outcomes shows that PCM could be applied to restrict temperature rises at some point of loss of electrical strength, which can also arise because of an accidental strength loss or finished purposely to gain electrical load transferring. The modeling turned into extended to are expecting the temperature modifications in a large bloodless keep and the results additionally suggest that PCM can restrict the upward thrust in air temperature. This modeling paintings can be prolonged to research the consequences of increasing the floor vicinity, and positioning of PCM panels in special manner. it's also discovered that after power supply is off this method is cheapest whilst as compared to other change strength sources.

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