Synthesis of Properties & Techniques for Microencapsulation of PCM Used For Refrigeration Process

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Abstract – In past years, the use comprising PCM (Phase change material) in form of structuring materials have been researched. The most developed skills in reference to energy comprising the advancement of energy efficiency and sustainability of structuring is phase change material within TES (thermal storage systems). The proposed research work aims on appropriate process to involve PCM material in association with construction. Within the TES different ways to use the PCM are incorporated including their applications. An innovative approach implemented to use the advanced PCM in addition with the construction section is soundly called Microencapsulation. In the present work four areas have been considered: characterization as well as fabrication of microencapsulated PCM, he solicitation of microencapsulated PCM in construction and sectors for textile industries, to study the properties of slurry comprising microencapsulated PCM and lastly, to implement the slurry in TES.

Keywords: PCM, Microencapsulation, TES Systems, Slurry, Textile etc.

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INTRODUCTION

The rapid development in business and advancement in industries leads to the elevation in need of energy quickly. Although, sources of energy such as conventional fossils are restricted, and utilizing these results in production of toxic fumes, that ultimately leads to variation in climate and causes pollution in atmosphere. In present days, the thermal energy storage systems are essential for reducing the dependency on fossil fuels and associate towards utilization of more environment friendly and efficient energies. The problem of global warming is major issue to be considered in respect to conditions of the environment. Global warming can be explained as the elevation in the temperature of earth surface and the water bodies continuously with time. Due to the effects of greenhouse, the heat energy of the sun is captured on the earth itself and therefore, it rises the environment temperature. Hence, in order to overcome this problem of global warming; refrigeration systems are conventional method which is also reliable (Tyagi, et. al., 2011)

Materials of phase change are the ones which have more synthesis of heat. They can devour or release the latent heat at the time when the material temperature bridges over or goes beneath the temperature of change of point. A lot of investigations have been carried out – additionally is continuing – with the focus to utilize this capability as in form of storage of energy. The ultimate implementation is identified by straight-forwardly on the category of material utilized as form of (melting point) phase change material in addition with the quantity of encapsulated PCM. The storage ability comprising heat in regards to paraffin wax is more compared to other materials of PCM. They are cost effective and easily available. Furthermore, a better variation in temperature of the phase change comprising paraffin wax can be utilized based on the composition of chemical constituents. The PCM material quarantine by the means of microencapsulation provides their introduction to a vast range of applications such as walls, panels of insulation, devices used for physiotherapy, coating material, fabrics and fibers. Amid the procedure, the probable communication among the paraffin wax ought to be kept in a vessel prior of being implemented in buildings. Shells of polymers are considered to be the basic alternative technically in order to microencapsulate phase change materials. On the other hand, the host microencapsulated, the rise in transfer area of heat, in addition with differences in the volume control due to the occurrence of phase change (Borreguero, et. al., 2010).

The fundamental norms of utilizing PCMs is basic, by the way of supply of heat, the phase of the material gets changed in both directions among solid state and liquid state at a consistent temperature at the point where it completely gets in the solid form. In the same manner, when the heat is released, the phase of the material changes from liquid state to solid state. Structurally defined buildings as per standards have plenty of thermal inertia in addition with it provides natural conditioning of air comprised inside the housings. As far as industries are concerned, the tendency is to reduce the thickness of wall in order to minimize weight, consumption of material, expenses in transportation and the time consumption in construction. The storage of latent heat by the means of involving a PCM incorporated in few structure materials is shrewd way in order to pay off regarding small storage capacity in reference to the maximum building structures of modern types yet as next era. The prime drawback of light weight buildings is the lower thermal masses which have the tendency to get a huge change in temperature because of heating loads and cooling loads on external basis. The use of PCM in these types of structures can reduce the difference in the temperature, prominently due to the presence of loads from solar radiation (Tyagi, et. al., 2011).

The process of microencapsulation comprising the PCM includes covering them in a hard and thin shells of polymers since PCM have the ability to change their phase from solid to liquid and back inside the shells. The application of microencapsulated PCMs are in several sectors, such as in storing heat for buildings, in addition with textile sectors and in control of environment on micro climate basis in the field of cultivation and agriculture (Shin, et. al., 2005)

MICROENCAPSULATION

Microencapsulation is a process by the means of which the dispersed particles or solid dewdrops or the considerable liquid are confined or bounded with respect to a consistent layer of polymer substance (shell) in order to give capsule inside the range from micrometer to millimeter, which are termed as microcapsules, as per fig. 1 (Tyagi, et. al., 2011)

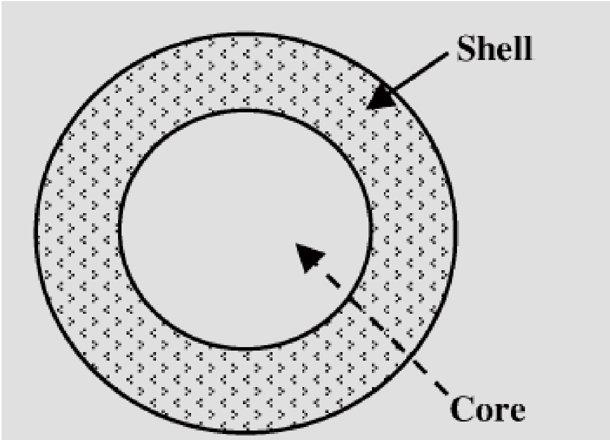


Fig.1 Detail diagram of microcapsule

The shape of the microcapsules might be spherical, in addition with an ongoing wall covering the core; on the other hand the others are non-symmetric and have different shapes, including few small dewdrops of the material of core rooted upon the capsule. The microencapsulation might be done on entire three phases of matter i.e. solid, gaseous and liquid phase. This permits liquid in addition with gaseous phase of material to be tackled with more ease compared to solid state, and could bear few extent of conservation while tackling with dangerous materials (Tyagi, et. al., 2011).

The explanation regarding microcapsules relies on the core substantial as well as the process of deposition in regards to the shells (fig. 2)

1. Core-shell (mononuclear) type of microcapsules have core where it is surrounded by shell.

2. Capsules of Polynuclear comprises of several cores covered inside the shell

3. Matrix form encapsulation where the material of the core is dispersed continuously within the material of the shell.

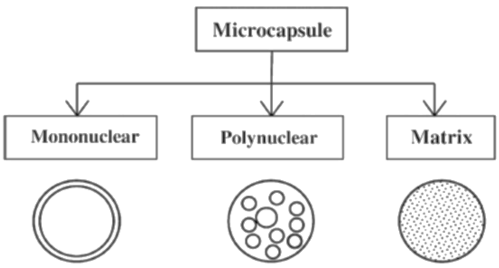


Fig.2 Categories of Microcapsules

Benefits of Microencapsulation Process (Jyothi, et. al., 2012):

Advantages regarding Microencapsulation procedure (Jyothi, et. al., 2012):

1. In restricting enzymes including micro-organism

2. Precaution from heat, bases, acids, oxidation and ultra-violets

3. Advancement of shelf time due to neglecting reactions for degradation

4. Layering up the senses such as, taste and smell

5. Better quality in processing, surface and reduced waste of constituents

6. Regulating liquids as in form of solids

7. There is a growing demand for healthy food-items for small children that give them the essential nutrients while they grow up. The process of Microencapsulation can facilitate the essential nutrients in a delicious manner among children.

8. Visual segment development in addition with concept appraisal

9. Copy paper without carbon was initially the first product to implement microcapsules

10. The variety in the production of fabrics in present time utilizes materials which are microencapsulated in order to advance the properties of their products.

11. Encapsulation of pesticides are done in order to liberate afterwards, permitting the farmers to implement the pesticides in reduced quantity as compared to the high concentrations of harmful chemicals that were found to be used formerly.

12. Materials found in edible items are compressed due to many reasons

13. Straight flow and controlled release of energy particles

14. Microencapsulation agrees to involvement of unable to get along compounds.

PROCESS:

Microencapsulation is accompanied by number of methods, with respect to several functions in thoughts. Microcapsules are a non-essential small vessel which encloses the material of core individually including the hard shell. Hence microcapsules bear direct liquids as solid form of material. They work well in reference with change of phase in addition with variation in the volume comprised in the core and withhold the changing phase material as the core. Microcapsules might handle with respect to dispersion of aqueous particles or fine particles and increase the provision of phase change material like the other building materials are treated by the particle state in their processing. The temperatures of change of phase in between – 10 degree to 80 ◦C are likely to generate with microcapsules (Tyagi, et. al., 2011).

Many processes connected to physical, chemical in addition with Physico-Chemical tactics have been recognized in order to produce microcapsules. The commonly used methods are:

► **Physical Processes:** The procedure contains the application of microcapsule wall by mechanical means or fit along the core of the microcapsule. The different ways are:

- Spray-Drying & spray-congealing
- Fluidized-Bed Technology
- Pan coating
- Co-Extrusion
- Spinning Disk

► **Physico-Chemical Processes:** The process comprises of a physic-chemical method in which coacervation or gelation that result in stable solid material. Several techniques involved in this are:

- Coacervation
- Polymer-polymer incompatibility
- Solvent Evaporation
- Rapid Expansion of Supercritical Fluids resulting in Polymer Encapsulation
- Microspheres of Hydrogel

► **Chemical methods:** This is one of the widespread techniques based on chemical process which is utilized for PCM microencapsulation in the process of polymerization of situ, which undertakes the record in comprising suspension of polymers, in addition with emulsion and interfacial, even when other methods are present (Jamekhorshid, et. al., 2014). Fig.

3 depicts and resembles numerous types of process of polymerization applied to obtain microcapsules of PCM, which are mentioned below:

- polymerization of interfacial,
- polymerization of suspension
- polymerization of emulsion

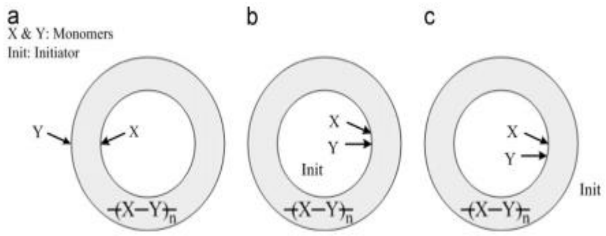


Fig.3 Schematic diagram to explain the difference between the different methods of chemical microencapsulation: (a) interfacial polymerization, (b) suspension polymerization, and (c) emulsion polymerization.

PREPARATION

Arrays of paraffin in reference to microencapsulation in addition with shells of silica were manufactured involving various weight ratios of paraffin/TEOS by the means of sol-gel improvement at different values. The paraffin encapsulation is obtained by condensation and hydrolysis actions of TEOS within emulsion of O/W in the acid catalysts (Liu and Yinghong, 2015).

Up to this extent, in structures regarding storage of thermal energy implementation there consists of 3 samples of MEPCM which were advanced by encapsulating wax of paraffin with respect to poly (methyl methacrylate-co-methacrylic acid). On the other hand the outcome of the percent weight including the initiator to the ratio of monomers of the shell for the properties of MEPCM were too investigated as the resin comprising PMMA-MAA have the ability to get inter linked on various ratio of molecules of MMA/MAA (Weiguang, et. al., 2017)

As per depiction in table 1, phase change material which is penetrated in the material of the core is n-octadecane. The material of n-octadecane has the ability to hold high latent heat, and provide suitable temperature for phase change which is inside the comfort thermal series. MMA (methacrylate) which has purity of 98% in addition with methacrylic acid (MAA) were utilized as the monomers of the shell. BPO (benzoyl peroxide) with 98% purity, was utilized as in form of thermal soluble oil dominant inside the limit of 0.5% to 1.5% associated the weight of monomers of the shell. The emulsifier utilized is the sodium 1-dodecanesulfonate (S-1DS) (Weiguang, et. al., 2017).

Table 1: Raw materials in order to create of MEPCM with PMMA-MAA shell

Items	MMA (g)	MAA (g)	n-octadecane (g)	S-1DS (g)	BPO (g)	Initiator (%)
PMMA-MAA1	2.40	0.60	7.00	0.10	0.030	1.0%
PMMA-MAA2	1.80	1.20	7.00	0.10	0.045	1.5%
PMMA-MAA3	1.50	1.50	7.00	0.10	0.015	0.5%

Fabrication process:

Fig. 4 depicts a basic process in order to use initiators of oil soluble type in order to fabricate the MEPCMs with respect to shells of PMMA and PMMAMAA. The phase of the oil was created by blending the monomer shells MAA and MMA and the melt form of n-ocatadecane at temperature of 40 degree Celsius including the prior identified quantity of thermal initiator (BPO). The phase of oil was then normalized in phase of water at 900 ml of water which was deionized and with little quantity of emulsifier at a rate of 7000 rpm for the duration of 5 minutes to obtain a static and stable emulsion of O/W. Further, the emulsion was poured in 3 round bottom flasks prior of being deoxygenated comprising gaseous stage nitrogen for 60 minutes at the temperature of 40 degree Celsius and the speed of rotation was 250 rpm. The reaction of microencapsulation was managed inside the flasks which were dipped while a bath of water was ongoing stressed within the speed of 250 rpm in addition with at the ongoing range of temperature at 80 degree Celsius for 5 hours. At last the microcapsules were gathered, rinsed and heated for 20 hours at 60 degrees for drying (Weiguang, et. al., 2017)

Sample characterizations:

The sample of MEPOCM which were fabricated was presented through SEM (Scan electron microscope) by the means of VP sigma. During the interim the material of shell can be a material of non-conductive type, initially a layer of 5nm thick gold was covered on the testers since to expand the electrical conductivity on prior basis the research done on microscopic level was administered as explained in the research undertaken by Suzuki (Weiguang, et. al., 2017). Calibrating the DSC (differential scanning calorimetric) components were utilized that was the fusion enthalpies in addition with melting temperature (heating onset temperature) comprising the phase change of microencapsulation tester material as per standards of ISO 11357 beneath the methodologies followed dynamically. At the weight at atmosphere levels including rate of heat at 2 degrees per min starting from 5 degrees to 50 degrees in the tests conducted.

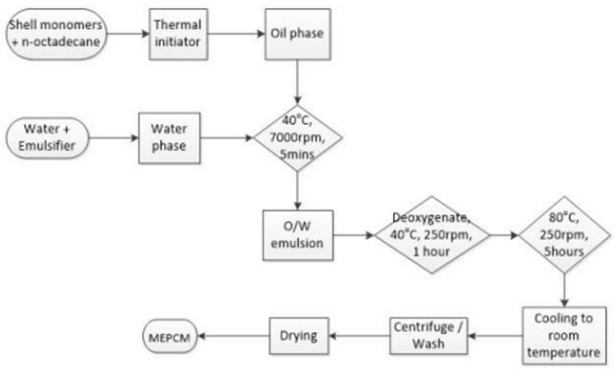


Fig.4 Demonstration of fabrication process of MEPCM

The stability on thermal basis comprising the MECM was observed by analysis from TG (thermo gravimetric) (EXSTAR6000 TG/DTA6300, SII Nanotechnology). The tests of TG based on present research were given under the gaseous nitrogen covering protection a difference of heat of 50 degree Celsius to 500 degree Celsius with rate of heat as 10 degree Celsius per minute.

MANUFACTURING

In several sections around the globe, concrete is utilized widely for domestic and commercial structures. In normal climates, the comparatively huge masses of thermal comprising concrete walls might be beneficial, since they capture the energy at daytime and liberate energy at night time, decreasing the requirement for auxiliary heating or cooling. Moreover, the storage capacity of energy regarding concrete within any fluctuations through the introduction of PCM in the concrete blend. Utilization of biocidal material of microencapsulated type fungus resistant mortar and concrete carrying these microcapsules are performed in the experiment. In order to manufacture the reinforcement, the membranes of capsules which are zeolites and material such as zeocarbon are utilized. The material for core selected was d-limonene. Greater friction or impact of zeocarbon or zeolite at the time of blending and process of casting of mortar or concrete might take place (Tyagi, et. al., 2011). Fig. 5 depicts basic concept of anti-fungal capsules and fig.6 depicts the process of manufacturing.

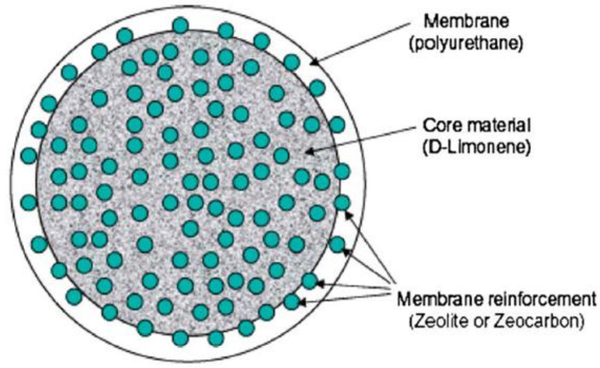


Fig.5 Constituents of anti-fungal microcapsule

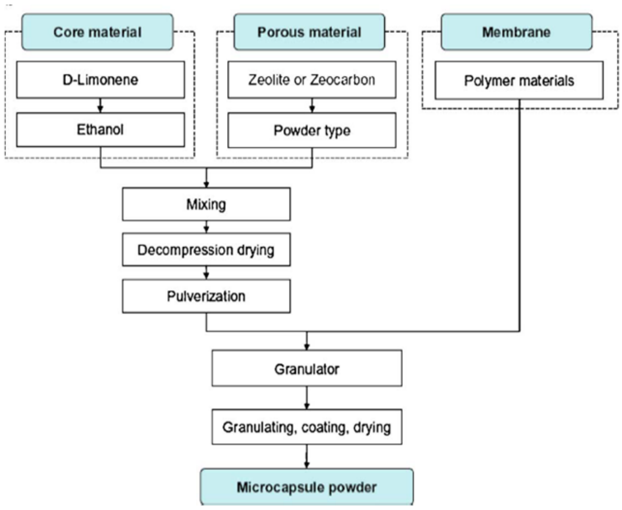


Fig.6 Microcapsule manufacturing process

PHYSICAL CHARACTERISTICS OF MPCM

By the means of complex process regarding coacervation of particles of MPCM were created by microencapsulating pure form almost 99% of n-Tetradecane in gelatin material in the research work. The process generates inter-connected microcapsules in the series of 70 to 260 μm diamenter. The average diameters of microcapsules were 145 μm. Entire particles comprised of 2% by load regarding nucleating source effectively. The readings from microscope and study from DSC depicted, that each capsule was closely 88% PCm material and 12% of material of shell (Yang, et. al., 2003). Fig. 7 shows the image of MPCM microscope level.

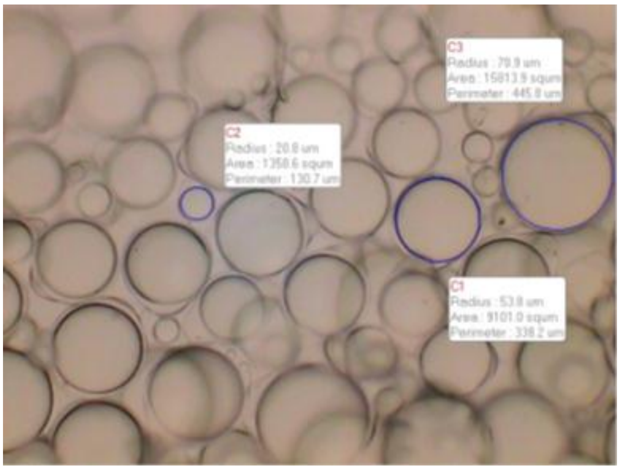


Fig.7 MPCM Micrograph

THERMAL PROPERTIES OF MPCM

In order to identify the thermal properties of MPCM, DSC was used. DSC calibrated the quantity of heat which was absorbed or liberated by instance in contradiction to a standard reference. The energy absorbed or liberated was noted in the manner of temperature and time element. In order to get the latent heat of fusion, use of outcome energy vs temperature cure was plotted, points of melting and crystallization as reference by numerous expertise in the field of differential scanning calorimeter. Fig.6 depicts a basic endotherm curve regarding MPCM slurry at mass fraction of 17.4%. The melting point of MPCM slurry was calibrated by observing the temperature at which tangent to the highest inclination pf DSC endotherm bounds the line of base. The area covered by the base line in addition with endotherm is equal to the latent heat of fusion of the sample (Yang, et. al., 2003).

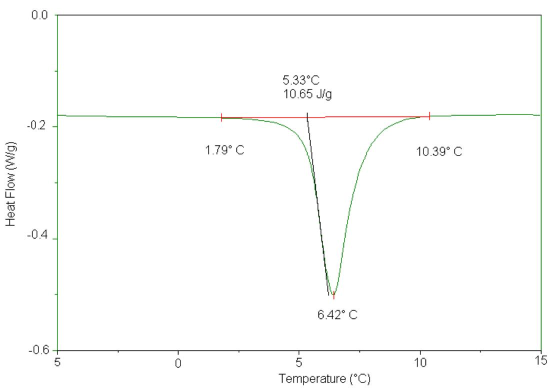


Fig.8 Basic DSC Endotherm

APPLICATIONS OF MEPCM (microencapsulated phase change materials)

Vapor Compression Refrigeration: This system absorbs and decreases the heat from region to be cooled and subsequently liberates the heat in various places within the vapor compression refrigeration and uses a dispersion fluid refrigerant moderately. Fig. 7 presents a basic vapor compression of single stage frame. Each of the individual stage has four subparts: thermal expansion valve, a compressor, condenser component, and lastly an evaporator. Within the state of thermodynamic flow, the refrigerant pass through the compressor and additionally the state of thermodynamic condition is found since the saturated vapor is bounded to elevated pressure carrying a subsequent raised temperature.

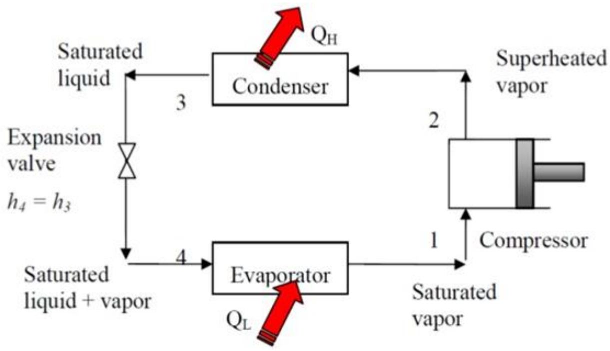


Fig.9 Vapor compression cycle system

Vapor Compression Refrigeration with PCM: In the model with mechanism showing below the following assumptions have been made:

Following presumptions have been made which are given as:

a) There is a consistency among the physical properties regarding the material and temperature.

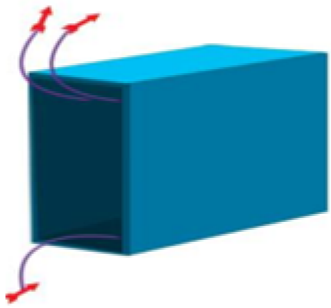
b) The transfer of heat in the solid and liquid stage signifies the quasi steady-state as the melting or solidification forms are easy.

c) The resistant contact thermally and the resistance offered thermally comprising the evaporator is neglected with reference to PCM.

d) As observed in the cycle of vapor compression

By the means of coil or any method of dispersion of the PCM fluid which covers the complete evaporator. Inside the compartment comprises of pathway or place for storage of PCM that is conserved with respect to other compartment. Within the refrigeration, the compressor is in sate where liquid PCM releases the heat and gets converted in to solid by the heat transfer through the refrigerants. The figure below depicts the PCM box.

(a)



(b)

(c)

(d)

Fig.10 Conventional Evaporator, PCM box with PCM passage, Heat releases from PCM and Heat taken from the food respectively

The time where the compressor is subjected to off stage, the temperature increases in the evaporator or the food chamber by placing fresh items or opening the refrigerator door. When the temperature is increased in the thermostat, the temperature; compressor again begins to load on electricity. In these situations the bounded PCM occupies the further convectioned heat through the food items conserved it away from the temperature of thermostat. This definitely rises the off-state of the compressor therefore, consumption of power and rise in life of compressor and condenser. The heat is released from the PCM to advance solid bounded layer the food chamber in off-state are demonstrated in the figure.

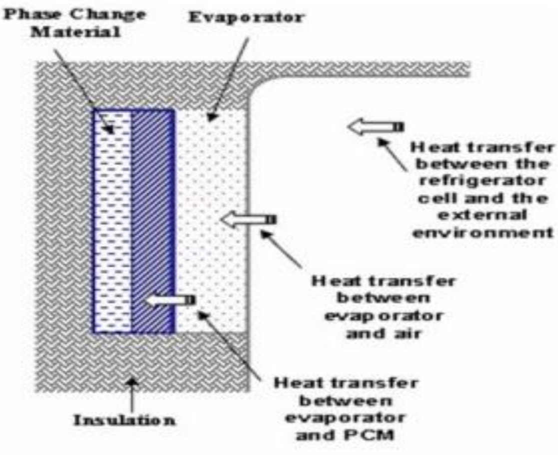


Fig.11 Refrigerator model comprising PCM

Textile applications: The use of PCM which are microencapsulated in the production of textiles has been developed and consistent to flourish in North America, including Japan and West Europe.

Building Applications: Materials of phase change had been in construction to advance the comfort thermally, regarding lightweight saving of energy. Moreover, there are few limitations in use of PCM material in building. Initially, the PCM might connect with the structure of the building and hinder the properties of the materials of construction; second the leaking of PCM might become a problem in context of, current time period of the building; thirdly, the solid form of PCM had lower transfer coefficient of heat. Overall to rectify these problems, (MEPCM) has been applied in building materials on convectional type (Zhao and Zhang, 2011).

CONCLUSION

The process of microencapsulation is used to make prepared MEPCM as in manner of new type of thermal storage of energy in composite material. The ground work methods that researched were classified in 3 classes, which is physical, physic-chemical and chemical. The technology of microencapsulation has better capability and is being used in few different sectors of applications for instance, fabrics, medical field etc. The present paper provides observations processes of PCM microencapsulation, training and manufacturing of properties based on physical and thermal aspects comprising MEPCM.

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