Cooling of Room with Ceiling Fan Using Phase Change Materials

M. Joseph Stalin, S. Mathana Krishnan, P. Barath, *Member, IAENG*

Abstract— **In this modern world, human life is strictly adhered to comforts. Air conditioning plays a major part of it. Nowadays, we are exhausting our valuable conventional energies for our well being. Thermal loads in living buildings are rising due to living standards and hence comfort cooling in buildings is becoming increasingly important. The demand for comfort cooling is expanding very quickly around the world. Cold thermal storage systems have the potential to become the one of the best solutions to the electric power imbalance between production and demand. It also acts as an alternative and advantageous one over conventional cooling plants. Thermal energy storage is renewable source of energy to develop cooling system, which minimize environmental impact such as ozone depletion and global warming. Several methods of air cooling in room are in practice. Recent developments are in progress to make effective cooling by eliminating conventional energies. One such method is effective cooling of room using phase change materials by ceiling fan. Thermal energy storage systems using phase change materials have been recognized as one of the most advanced energy technologies in enhancing the energy efficiency. Thermal energy can be stored as latent heat which is of latter use, when substance changes from one phase into another by either melting or freezing. Mounting of PCM along with ceiling fan impart air conditioning effect. The PCM has done the trick of harnessing the room's hot air and let cool air to the room. Therefore, heat energy is absorbed and the effect of coolness increases. With prices of AC elevating, this method proves to be the cost effective and energy conserving. Unlike conventional air conditioners, the PCM in ceiling fan provides cool air free of cost and electricity. In the absence of electricity and also during power cut we have a cooling back up.**

Index Terms— **Cold thermal storage systems, conventional cooling plants, ozone depletion, global warming, phase change materials, effective cooling, cost effective.**

I. INTRODUCTION

DUE to the effect of heat in summer, people are longing for comforts and so they prefer Air Conditioning System. Free cooling is an emerging and major research area among scientists and it must be the alternative to Conventional Air Conditioning Unit. Now-a-days, electricity is a major demand in India. But usage of AC consumes lavish amount of electricity comparing to other equipments. A system has been designed which gives cooling effect by ceiling fan along with phase change materials.

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Phase change materials are the most efficient thermal storage medium and it absorbs latent heat during its phase change. D W Hawes [4] described the different types of PCM, its characteristics, its manufacturing technique and various applications of PCM in 1993. J S Kim [11] studied thermal performance of randomly mixed PCM in 2003 and laminated PCM–wallboard systems have been numerically evaluated and results are compared. Belen zabla [1] listed over 150 materials used in research as PCMs, and about 45 commercially available PCMs in 2003. M M Farid [9] reviewed previous work on latent heat storage and provides an insight to recent efforts to develop new classes of phase change materials (PCMs) for use in energy storage in 2004. 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. A wallboard new PCM material is experimentally investigated by F Kuznik [8] to enhance the thermal behavior of light weight building internal partition wall in 2008. F Kuznik [3] described the thermal performances of a PCM copolymer composite wallboard in a full scale test room in 2009. 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. Air Conditioning system pollutes the environment by various gas emissions and hence by fixing our system, carbon emissions gets eradicated. Ceiling fan is one of the equipments which are used from our ancient days. Using this ceiling fan, cooling effect is provided in the room. People are longing for cooling effect without spending lavish amount of energy and money.

Hence, researchers are looking for an alternative in all fields by replacing conventional energies. This paper focuses on free cooling of room using phase change material along with ceiling fan.

II. Description

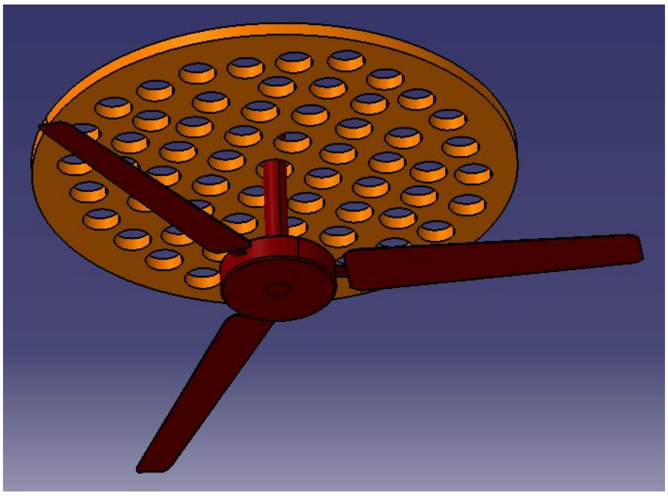

Fig 1 Design of PCM with Ceiling fan

At present, all of our houses comprises of ceiling fans in each and every room. It is pondered that the standard specifications of fan are a blade span of 60 inch, a blade pitch of 14 degree, a housing diameter of 9.8 inch. The system consists of mounting of PCM of thickness 5 cm which is like a circular disc and it gets hold of fan's circumferential diameter which subsumes a gob of perforated holes of 20 mm diameter for efficacious absorption of heat in air. At the beginning, phase change materials are in idle mode when they are purchased from the chemical industry. Soon after it was incinerated to the temperature of 50 degree Celsius using water bath as far as the passive crystals of PCM melts. At this moment, the PCM is made active. Then the aluminium packets are used to seal the PCM and its better conductivity is the ultimate reason for its preference. The control volume of air is affected by very small extent and it is equalised by increasing the fan's speed. On comparing the entire control volume, the reduction in control volume is insignificant. The placement of circular disc of PCM is at 30 cm aloft the fan's housing for air flow. Inside the circular disc of PCM the small aluminium tubes are fitted which has the inlet from water tank of the residence and has the outlet to the environment. The aluminium material is selected for its good conductivity and the heat absorbed from the room by the PCM is taken away by the water from the tank. The insulated pipe is fitted from water tank to the inlet of the PCM and from PCM onwards it is coupled with aluminium tubes. Self regulating valves are fitted in the inlet of the insulated piping for controlling the mass flow rate of water. The mass flow rate of water is fine turned automatically by self regulating valves. The speed of the fan and heat absorbed by the PCM are the two governing factors based on which the adjustment of mass flow rate is done. According to the prevalence of temperature in the PCM, the heat is efficaciously transferred by the water within certain time. The PCM material used is Paraffin wax whose latent heat is 180 KJ/Kg K and the melting point is 29 degree Celsius with its grade HS29. The Phase change materials are selected based on its melting point and the operating temperature range. The ultimate reason for the selection of HS29 is that the mean film temperature of atmosphere is 37 degree Celsius and the human comfort temperature is 25 degree Celsius. The thermal conductivity of the material is 0.21 W/m K.

III. Working

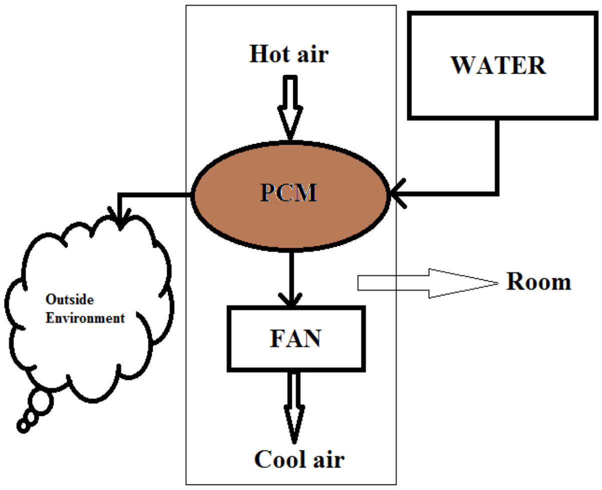

Fig 2 Overview of the cooling system

When the fan is set in motion, the discharge of air takes place from top of the housing to the person remaining at rest beneath the fan. The air flow is enhanced and the air is squeezed downwards due to the arrangement of blades in angles. The postulate of ceiling fan is that the hot air flows upward and air at ambient temperature is squeezed downwards. Because of the installation of PCM aloft of the fan's housing, the hot air which is directed up passes through the perforated holes in the circular disc of the PCM. Owing to the contact of PCM with hot air, the forced convection process takes place. The PCM which is placed aloft of fan's housing absorbs the heat of air because the melting point of PCM is lesser than ambient temperature. The high latent heat of fusion of PCM per unit mass results in small amount absorbing huge amount of heat energy. Due to the high specific heat, it provides additional sensible heat storage and also avoids sub cooling. Water flows through the aluminium piping which absorbs the latent heat of melting of PCM, thereby carries away the heat to outside of the home. The discharge of water to the environment is comparatively low which flows like a pattern of droplets of water and hence there is no difficulty in letting and discharging of water. PCM which is at low temperature absorbs the heat continuously from the hot air and the cooled air is squeezed downwards by the fan blades. The cooling effect is similar to AC whereas it eradicates environmental hazards like ozone depletion and global warming. The self regulating valve present in the inlet of the insulated piping is kept slightly open so that the flow will be laminar and it is automatically adjusted by sensing temperature of PCM and the fan's speed. When the fan's speed and temperature is high then

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the valve opening is also enlarged because of the compensation of removal of generated excess heat. Due to the high conductivity of aluminium, heat transfer is effective and room temperature keep on decreasing. Whenever the ceiling fan is operated the cooling effect is felt continuously.

IV. CALCULATIONS

Assumptions:

- The size of the room is 15 * 15 * 15 ft3
- 55 holes of diameter 0.06m each are made in the circular disc of PCM

TABLE I
TEMPERATURES IN MADURAI (INDIA)

Month	Day (max) oC	Night (min) oC
Jan	30	21
Feb	33	22
Mar	36	23
Apr	37	26
May	38	26
Jun	37	26
Jul	36	26
Aug	36	26
Sep	35	25
Oct	32	24
Nov	30	23
Dec	30	21

- Average day time temperature T1 = 36oC
- Average night time temperature T2 = 24oC
- Let Room comfort temperature Tc = 25oC
- Difference in temperature dT = 11oC
- The wall of the room is made up of Brick (plastered on one side) which has a thickness of 40 cm.
- The floor of the room is made up of concrete (22 cm) with insulation (2.6 cm).
- The Ceiling of the room made of plaster (concrete)
- 4 number of persons living in that room

Load Calculations:

TABLE II
HEAT TRANSFER COEFFICIENT VALUES FOR VARIOUS MATERIALS

Materials	U in W/m2K
Wall Brick (plastered on one side)	1.0
Plaster Ceiling	1.15
Floor Concrete with insulation	1.0

Wall:

Q1 = U * A * dT
= 1.0 * 20.9 * 11
= 0.23kW

Since there will be 4 walls,

Qw = 0.23 * 4

Heat received by the wall = 0.92kW

Floor:

Q2 = U * A * dT
= 1.0 * 20.9 * 11
= 0.23kW

Heat received by the Floor = 0.23kW

Ceiling:

Q3 = U * A * dT
= 1.15 * 20.9 * 11
= 0.27kW

Heat coming from ceiling = 0.27kW

Humans rejecting heat while doing light work q4 = 0.183 kW

For 4 persons, Q4 = 0.732kW

Heat rejected by the Equipment in the room:

Q5 = kW * 3600 * Use factor

Power = 225 kW

Use factor = 0.68

Q5 = 0.153 kW

Total Heat load, Q a = Q1 + Q2 + Q3 + Q4 + Q5
= 2.305 kW
= 0.66 tons

For 15 min duration, Q a = 2074.5kJ

Volume of the room = 95.56 m3

Density of air = 1.225 kg / m3

Mass of air = volume * Density
= 117 kg

Heat absorbed to attain the room temperature 25 degree Celsius = m* cp* dT
= 117 * 1.005 * 11

Qb = 1294kJ

Total Heat energy, Q = Qa + Qb= 3368.5 kJ.

Latent Heat = 150 kJ/kg.

Density =790kg/m3.

Mass of PCM = Total heat load / Latent heat
m = 22.45kg
m = 23kg (approx).

Volume needed to pack the PCM = Mass / Density of PCM
= 0.029114 m3.

Number of hole, N = 55.

Diameter of circular PCM disc, d = 1 m.

By calculation,

Height of the disc, h = 0.0462m.

Surface area of contact between air and PCM = No. of holes * 2πrh
= 55 * 2 * π * .03 * .0462
= 0.4789m2.

Mass flow rate = (h * A * dT) / L
= (100 * 0.4789* (36-25))/150
= 3.51 kg/s

Backup time for PCM without water circulation = m * L / h * A * dT
= 2 hours 15 minutes.

Time to reach Comfort temperature = Heat load / h*A*dT
~ 2 hours

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V. RESULTS AND DISCUSSION

The upcoming graph explains the different temperatures in Madurai (India) for all the months from January to December during both day and night.

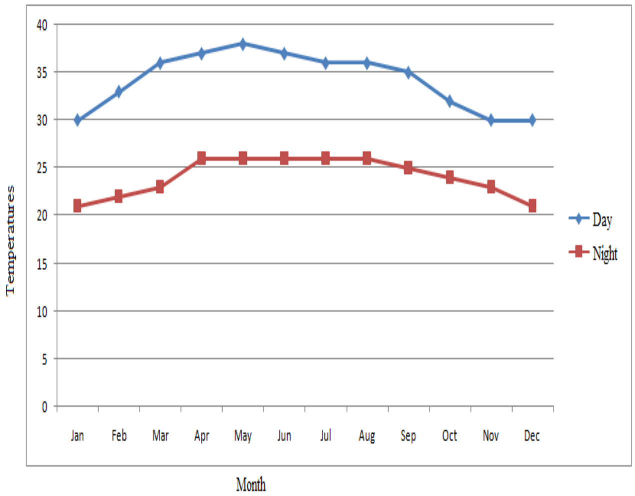

Fig 3 Temperatures in Madurai

The following graph explains the different types of PCM that could be used in the fan and their respective mass flow rate are tabulated.

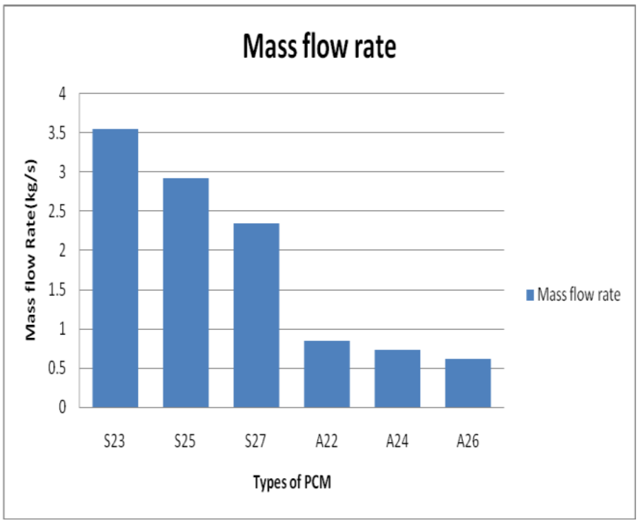

Fig 4 Types of PCM vs. Mass flow rate

The following graphs are plotted with the room temperature with respect to the operating time.

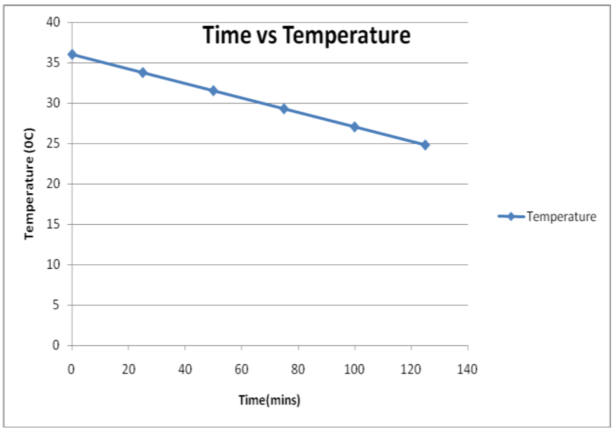

Fig 5 Time vs. Temperature

VI. CONCLUSION

There are lots of new concepts in which our researchers are working on to arrive at a better solution, for effective cooling effect with reduced energy and cost. This concept gives a great solution for better cooling with minimum losses. Maintenance is very easy compared to other systems and the overall cost of the system is very cheap comparing to other cooling devices. The usage of coolant to carry the heat energy in the PCM extends its backup time, thereby efficaciously improving the performance of the system. This system reduces the usage of power to a great extent thereby saving energy. With the increasing demand of Air Conditioning systems, this system would give better and a perfect replacement with better efficiency and reduced cost.

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