SIMULATION OF POT IN POT REFRIGERATOR

Umesh C[1], Dr. S Majumdar[2], Dr. N Balakrishnan[3]
[1]M.Tech, Dept. of TPE, NMIT Bengaluru,
[2] Professor, Dept of TPE NMIT Bengaluru [3] Professor, IISC Bengaluru.
Email:chougalaumesh@gmail.com[1]

Abstract
Passive cooling techniques are closely linked to the thermal comfort of the occupants, and it is possible to achieve this comfort by reducing the heat gains, thermal moderation and removing the internal heat. Cooling through evaporation is an ancient method of lowering temperature. The simple clay pot refrigeration is simply suited for preserving the vegetarian food in hot and dry climates. Due to the evaporation the refrigeration takes place through the porous pot material.

CFD analysis is an alternative method to the construction of an experimental model for PASSIVE COOLING SYSTEMS. In this study, a mesh was created from GAMBIT, and imported into HIFUN (High resolution Flow solver for UNstructured mesh) for analysis. Simulations were run with various steady and unsteady models, which were then compared with each other. Unsteady state models were also run with laminar flow.

Index Terms: Passive cooling, Evaporation, Gambit, HiFUN, Refrigeration, Thermal.

I. INTRODUCTION

Cooling through evaporation is an ancient and effective method of lowering the temperature. Both animal and plants use this method to lower their temperature. Trees, through the method of Eva transpiration remain cooler than their environment.[1]

The principle underlying evaporative cooling is the conversion of sensible heat to latent heat. The warm and dry outdoor air is forced through porous wall or wetted pads that are replenished with water from cooler's reservoir. Due to low humidity of the incoming air some of the water gets evaporated. Some of the sensible heat of the air is transferred to water and become latent by evaporating some of water. The latent heat follows the water vapor and diffuses into the air. Evaporation causes a drop in the dry-bulb temperature and a rise in the relative humidity of the air.[2] the aim of this paper is to prediction of the thermal comfort in environment . Which is created by a proposed passive evaporative cooling system. The system makes use of the evaporative effect from water falling from the top to produce a reduction in the temperature of the air entering to the building.[3]

Amrat lal Basediya & D. V. K. Samuel & Vimala Beera Due to the short shelf life of vegetables and fruits, around 30 to 35% of India's total fruits and vegetables production is lost during harvesting to packaging and distribution in a year which reduces the growers share.In this paper they are conducted experiment on the several fruits and vegetables , and compared the life of each item Shelf-life produce without using the Zeer and Shelf-life of produce using the Zeer with different temperature and relative humidity found good result for the Shelf-life of produce using the Zeer.[4]

FACTORS AFFECTING EVAPORATION

There are four major factors affecting that are important for the rate of evaporation .this is important keep in mind that they usually related to each other to influence the evaporation and the rate of cooling.

1. Relative Humidity:

This is the amount of water vapor content in the air as a percentage of the maximum quantity that the air is capable of holding at that temperature .when the relative humidity is low in that air holding of water vapor is very less under this condition air is capable to take additional amount of moisture and if other conditions also meet, the rate of evaporation and cooling rate are more. If relative humidity is more than evaporation, cooling rate will be low.

2. Air Temperature:

Evaporation occurs when water absorbs enough amount of energy to change from a liquid to gas. Air with a relatively high temperature will able to stimulate the evaporative process and also be capable of holding relatively great quantity of water vapour. So areas with high temperatures will have higher rate of evaporation and more cooling will occur. With lower air temperature, very less water vapor can be held, and less evaporation and cooling will take place

3. Air movement:

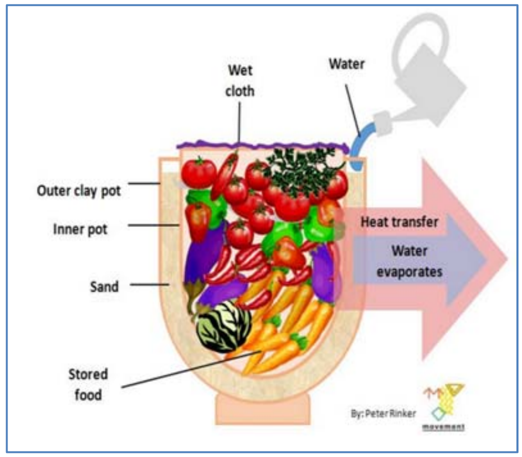
The movement of air is an important factor for evaporation it may natural. As the water from the surface evaporates, then the amount of moisture in the air gets increases so that relative humidity of air increases

If the humid air is remains near the surface so the evaporation rate get slows down. On other hand if humid air been removed away and replaces with different air with this evaporation rate will increases.

4. Surface Area:

The greater the surface area available for evaporation the more amount of water can evaporate, the greater the rate of evaporation.[6]

II. DESCRIPTION OF POT IN POT REFRIGERATION



III-1 construction of pot of clay pot refrigeration

A POT IN POT REFRIGERATION (PIP) is constructed by placing a clay pot within a larger clay pot with wet sand in between the pots and is closed with plate with porous holes.

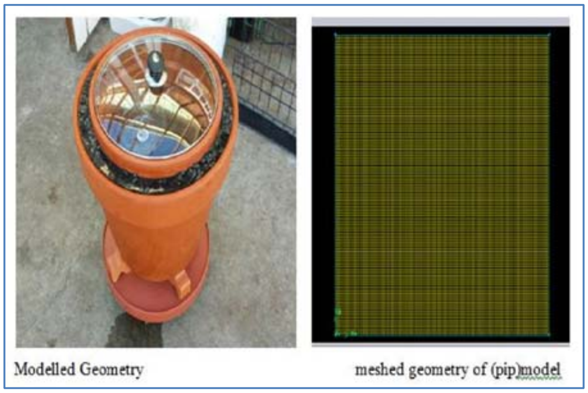
The device cools as the water evaporates, allowing refrigeration in hot, dry climate. It must be placed in a dry, ventilated space for the water to evaporate effectively towards the outside. Evaporative coolers tend to perform poorly or not at all in climates with high ambient humidity, since the water is not able to evaporate well under these conditions. If there is an impermeable separation layer between the food and the porous pots, undrinkable water such as seawater can be used to drive the cooling process, without contaminating the food. This is useful in arid locations near the ocean where drinkable water is a limited commodity, and can be accomplished by using a pot that has waterproof glaze or cement applied to the inner wall where the food is stored.

2.1 Physical Geometry

Pot in pot top wall is closed:

The actual model is made it simple for the simulation, outside line corresponds to Inner pot. That is considered as the Isothermal wall (wet bulb temperature) and top wall is considered as adiabatic wall. Modelled geometry incorporates with height and length of 300mm and 300mm representing a small model as shown in fig. except from top side all three sides considered as Isothermal and top side is considered as adiabatic wall

Actual and modelled geometry



Model Geometry Top Plate with Holes:

Model profile remains same as above but the top cover is having holes. The top plate is made of clay with multiple through holes. The plate has cavities in between holes and is filled with wet sand hence the periphery of the holes is at wet bulb temperature. The dimension of the cover plate

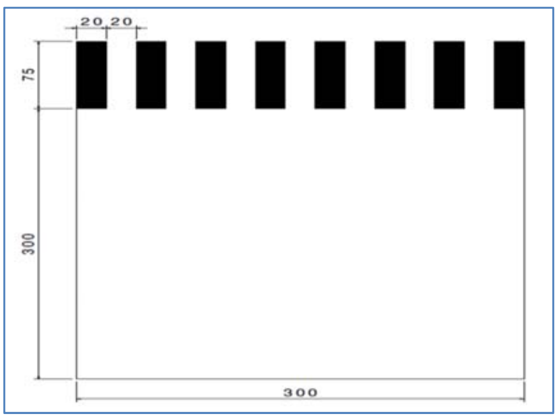


Table 1: Parameters of Pot in Pot

Dia of the top plate	300mm
Thickness of the plate	75mm
Dia of the each hole	20mm
No. of holes	7
Cavity in between each hole	20mm

III. CFD METHODOLOGY

Two software packages GAMBIT (Geometry And Mesh Building Intelligent Tool) version.6.3.26 is usued for creating2-D models and HiFUN (High resolution Flow Solver for Un-structured grid) The models are created by using coordinate system and by applying the mesh on the 2-D model in Gambit. Specifying the boundary zones and types of continuum in Gambit and exporting the meshed model to HiFUN from the Gambit, the geometry was made ready for the numerical solution. Initially in HiFUN reads the Gambit file in which governing equations are used based on the control volume based discretization. Buoyancy effect is considered because in this system buoyancy effect plays a vital role. The pressures, density and temperature are deployed at the normal nodal points and velocity is found at the staggered nodes. Residual for all variables is 10^-4 and it is maximum level of convergence.

HiFUN version 4.1.1 is used to perform the CFD analysis for this project.

Modeling Strategy

A 2D model of the passive cooling system was created, with the aim of calculating temperature distribution. This data can give an estimation of the relative performance of the modeled system.

IV. RESULTS AND DISCUSSION

Results of the optimization analysis show that it is possible to decrease the environmental burdens and energy demand through pot in pot system and passive pan. Many results are obtained with different time. Considering the convective mode of heat transfer, the buoyancy effect is duly taken into account. From the results it has indeed become clear that buoyancy effect is the primary driving force for air flow in the enclosure. Low density fluids have low gravitational force pulling them down, and could rise to higher levels relative to high density fluids. Based on the ideal gas law the density of air at atmospheric pressure and temperature can be readily computed. Moreover, the density of air can be decreased by increasing the temperature at the same pressure. Pressure losses in the system can be reduced by a decrease in the average velocity.

1. The Computational Fluid Dynamics analysis results for the pot in pot cooling system are obtained by two different conditions.

Model 1: closing the pot in pot system top by adiabatic wall.

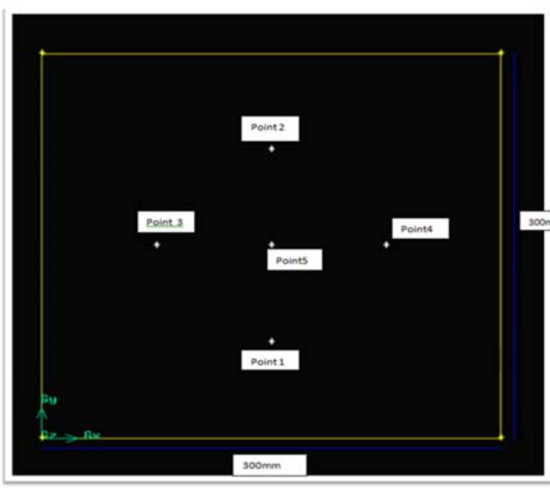
Model 2: Closing the pot in pot system top by wall with holes.

Pot In Pot System:

In a modeled geometry (300*300mm) 5 points are considered inside, with different locations from origin as shown on the table- ,and also points in model1 and model2 are in same positions show in the fig , and fig respectively. In this for different time, temperature variation are calculated from graph and contour plots and comparing with each other so which one is cool at faster rate at particular location .

Table 2: Reference point in the Pot

Points	X	Y
1	150 mm	75mm
2	150 mm	225mm
3	75 mm	150 mm
4	225 mm	150 mm
5	150 mm	150 mm



Comparison between pot in pot with adiabatic plate and plate with holes.

Y-axis : temperature in Kelvin X-axis: time in seconds.

From this graph we can see that temperature comes to equilibrium state at faster rate in pot in pot system closed top cover with holes made of clay as compared to top covered with adiabatic plate. Atmospheric temperature is considered as 308K and relative humidity is 25% from these values we will find wet bulb temperature 293K from psychometric chart.

Pot in pot(PiP) temperature distribution of adiabatic plate and plate with holes against varying time at point 5 (centre).

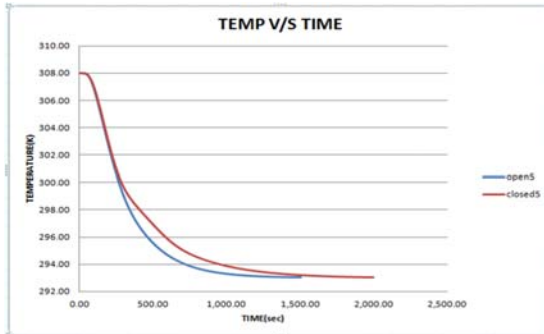
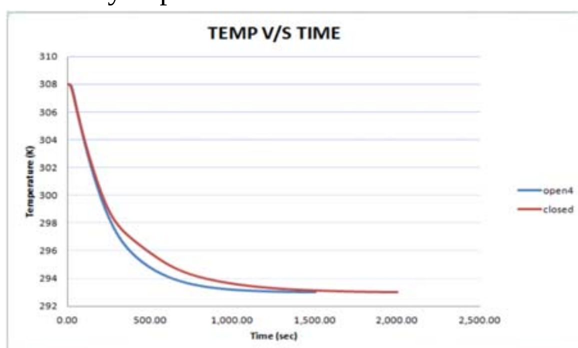


Figure: temperature distribution with respect to time at point 5.

Blue curve indicates the pot top wall with holes

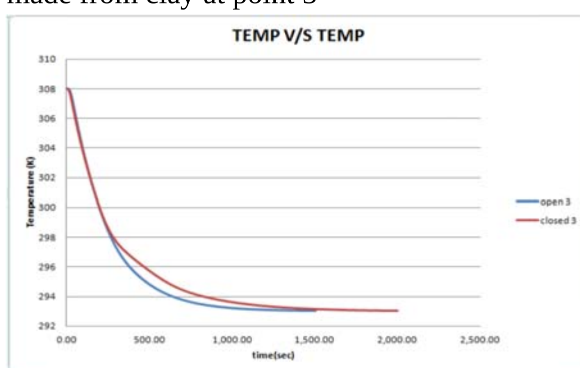
Red curve indicates the pot top closed with adiabatic wall.

Pot on pot temperature distribution of top closed with adiabatic wall and top wall with holes, made from clay at point 4 .



Temperature distribution at point 4 with respect to time

Pot on pot temperature distribution of top closed with adiabatic cover and top cover with holes made from clay at point 3



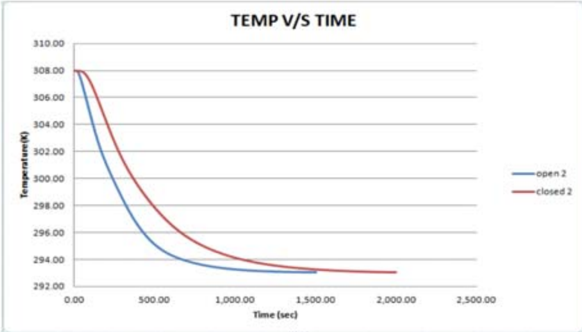
Temperature distribution at point 3 with respect to time

Figure IV-1: Graph of temperature distribution at point 3 with respect to time.

Blue curve indicates the pot top wall with holes.

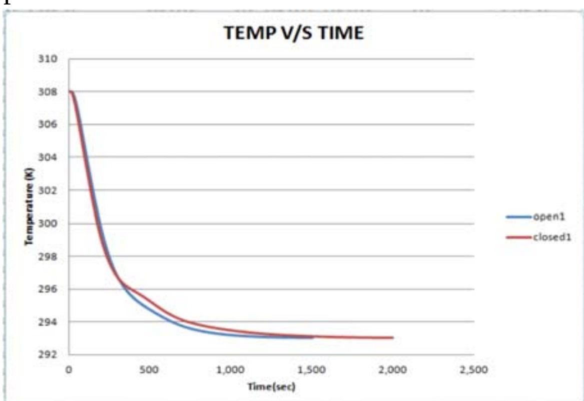
Red curve indicates the pot top closed with adiabatic wall.

Pot on pot temperature distribution of top closed with adiabatic cover and top cover with holes made from clay,at point 2 .



Graph of temperature distribution at point 2 with respect to time

Pot on pot temperature distribution of top closed with adiabatic wall and top wall with holes ,at point 1 .



Graph of temperature distribution at point 1 with respect to time

Blue curve indicates the pot top wall with holes

Red curve indicates the pot top closed with adiabatic wall.

V. CONCLUSION

In this paper analysis were conducted on the popular Pot in Pot design refrigeration technique and it was compared with a new design having upper cover made up of clay and it is having cavity in that sand and water will be filled and it is considered as wet bulb temperature and also it is having multiple holes so from that whatever air is coming will be cooled using the evaporation method. The results obtained were compared and it was found that the new design refrigerator provided better and faster cooling rate than the normal pot in pot refrigeration and also from this Eva transpiration will takes place so that the fresh air circulation will takes place due to.

Thus, this paper provides an insight towards ways of improving refrigeration using only clay as the raw material. Refrigeration of these types will prove immensely beneficial to the rural masses and to people living in the under developed countries. Also as there is no requirement of electricity to run the system, extensive usage of these sorts of refrigeration systems helps in providing greener environment too.

VI. REFERENCES:

NMAIYE Evaporative cooling of water in earthen pot in quiescent air. NSE TRNSACTIONS VOL.31 NO.3

[1] Victor O. Aimiuwu “Evaporative Cooling Of Water In Hot Arid Regions” Energy conversion and Management volume 33, No, 1. pp. 69-74, 1992

[2] A.W.Date “Heat and Mass transfer analysis of a clay-pot refrigerator” International Journal of Heat and Mass Transfer 55(2012) 3977-3983

[3] Zahra Ghiabaklou Thermal comfort prediction for a new passive cooling system Department of Architecture, School of Fine Arts, University of Tehran, Tehran, Iran accepted 19 February 2003 , science direct Building and Environment 38 (2003) 883 – 891

[4] Amrat lal Basediya & D. V. K. Samuel & Vimala Beera Evaporative cooling system for storage of fruits and vegetables. J Food Sci Technol (May–June 2013) 50(3):429–442 DOI 10.1007/s13197-011-0311-6

[5] Odesola, I.F. and O. Onyebuchi. 2009. “A Review of Porous Evaporative Cooling for the Preservation of Fruits and Vegetables”. Pacific Journal of Science and Technology. 10(2):935-941.

[6] Zahra Giabaklou And John A. Ballinger A Passive Evaporative Cooling System by Natural Ventilation Received 4 July 1995; accepted 4 March 1996. Budding and Enoironmenrt, Vol. 31, No. 6, pp. 503-507, 1996.

[7] Bahadori, M.N. An improved design of wind towers for natural ventilation and passive cooling.Sol. Energy 1985, 35, 119–129.

[8] Alahmer a, M.A. Omar b, A. Mayyasb, Shan Dongri “Effect of relative humidity and temperature control on in-cabin thermal comfort state: Thermodynamic and psychometric analyses”. Applied Thermal Engineering 31 (2011) 2636-2644.