Design of Solar Oven

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***Abstract*— Today world is facing the problem of different types of pollution and it is becoming difficult to cope up with the pollution issues. Cooking by traditional or conventional is increasing the problems man is facing and something needs to be done to stop it. In Rural areas people are facing the problem of breathing and chronic diseases. Appropriate steps need to be taken to avoid further problems. A solution is given in this paper that is to use solar energy to cook food in daylight to save the electricity and also decrease the health related problems people face.**

Keywords—Solar energy, rural areas

INTRODUCTION

Usage of energy is increasing day by day. This causes surge in usage of fossil fuel increasing carbon emission and increasing the danger of global warming. Due to advancement in aviation , automobile , cooking methods we have seen the percentage of carbon dioxide has increased drastically . Around the globe, hundreds of millions of people have limited access to cooking fuels [source: SCI]. In most cases, electricity and gas are out of the question; only charcoal and firewood are within reach, and even charcoal can be too expensive. So we're left with wood. Health problems starts rising due to pollution caused by cooking with ‘chulas’ .Major disease like bronchitis, cancer ,lung cancer are found to occur. One estimate puts the number of people who die from this type of air pollution at 1.5 million per year [source: Madrigal]. A solar cooker eliminates the need for an open flame, meaning air. Solar cooking doesn’t use smoke that can contain carcinogens or microwaves that expose your food to potentially dangerous radio waves. When people use open fires to cook indoors, they end up inhaling micro-particles that can cause all sorts of health problems, including both lung and heart disease. Use of solar cookers decreases carbon percentage and provides independence from the main grid sources. Solar cooking doesn’t use smoke that can contain carcinogens or microwaves that expose your food to potentially dangerous radio waves. When you cook over a campfire, the smoke can irritate your eyes and respiratory system, and open fires present dangers to children. Plus, when you cook in a solar appliance, the nutrients stay in the food and don’t leach out. That’s because you don’t use water in solar cooking. And, the temperatures in a solar oven are moderate – around 325 F – so nutrients aren’t destroyed during cooking at a high temperature like on a grill or over an open flame. No fuel burn so no Smoke and no Co2 produce at cooking Co2 emission saving = 0.82kg/KWh (Average for KWh Electricity Generation) considering above calculation total Co2 emission saving is 672*0.82 = 551kg/ year

PCMs	Heat of fusion (kJ/kg)	Specific heat solid/liquid (kJ/kg°C)	Melting point (°C)	Density solid/liquid (kg/m³)
Acetanilide	222	2.0/2.0	118.9	1210/1020
Capric acid	150–158	1.9/1.6–1.7	30.1	–
Lauric acid	212	1.8/2.3	41.0–43.0	1007/862
Acetamide	263	1.9/1.9	82.0	1159/998
Pentadecane acid	159	–	52.5	–
Palmitic acid	198	1.9/2.8	59.9	–
Myristic acid	192	1.7/2.4	53.8	–
Stearic acid	160	1.6/2.2	55.1	965/848
Erythritol	340	1.4/2.8	118.0	1480/1300
Magnesium nitrate hexa-hydrate	163	1.8/2.5	89.0	1636/1550

Phase change materials (PCM)

Literature reported different PCMs appropriate for energy storage in the range of temperature of 50–100 °C. Table 1 displays the thermo-physical features of most common PCMs used in literature. Tested several PCMs namely acetamide, stearic acid, magnesium nitrate hexahydrate, acetanilide, and erythritol by conducting numerical simulation of heat transfer in these PCMs. They reported that it is best for latent heat storage solar cooker to use acetamide. Based on their study and due to its low cost and because of its high availability in the market, acetamide of commercial grade (CH3CONH2) was chosen as the PCM in this study. Acetamide of commercial grade was utilized as a material that stores latent heat with a melting point of 82 °C which is appropriate for the application in this study. The use of a box type solar cooker is limited because cooking of food is not possible due to frequent clouds in the day or in the evening. If storage of solar energy can be provided in a solar cooker, then there is a possibility of cooking food during clouds or in the evening, and the storage will increase the utility and reliability of the solar cookers. If the cooking vessel is surrounded by a PCM unit, then the rate of heat transfer

between the PCM and the food will be higher, and cooking can be faster. Experiments with solar cookers indicate that foods are cooked at temperatures between 95 and 978C. No appropriate and promising PCM, having a melting temperature between 95 and 105 degrees Celsius is available in the literature. Therefore, in the present case, commercial grade acetamide (melting point 828C) is used as a latent heat storage material, which has the nearest melting temperature out of the quoted materials in the literature.

Fabrication of solar cooker

Solar cooker is completely made up of acrylic and copper plate. PCM acrylic is moulded into required design with using spring heater. A offset is created of 1 inch and are joined together on a single plane and is sealed with silicon gel and chloroform such that a space is created between two mates in c Specific heat

order for vacuum. Vacuum allows reduction in leakage of solar irradiation. A non- return valve is present on top of the c_k

Specific heat of phase k in PCM
setup such that it provides easy removal of gases between two mates.

A. Abbreviations and Acronyms:

KTG	Kinetic theory of gases
RMS	Root mean square
TES	Thermal energy storage
SHTES	Sensible heat thermal energy
storage LHTES	Latent heat thermal energy
storage	
PCM	Phase change material

B. Methodology

Plexiglass is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass. It is also used for coating polymers based on MMA provides outstanding stability against environmental conditions with reduced emission of VOC. Plexiglass is the preferred material for constructing solar panels. PMMA is an economical alternative to polycarbonate (PC) when tensile strength, flexural strength, transparency, polishability, and UV tolerance are more important than impact strength, chemical resistance, and heat resistance. Additionally, PMMA does not contain the potentially harmful bisphenol- A subunits found in polycarbonate. It is often preferred because of its moderate properties, easy handling and processing, and low cost. Non-modified PMMA behaves in a brittle manner when under load, especially under an impact force, and is more prone to scratching than conventional inorganic glass, but modified PMMA is sometimes able to achieve high scratch and impact resistance.

Vacuum valve: Vacuum is created to prevent the exchange of energy taking place between the system and surrounding, for this reason we are using the vacuum valve which is a 2- way valve for suction of atmosphere in the recess of glass frame and chamber. These are purchasable online

Insulated door and door handle: For the heat to be restricted to the food chamber and not get absorbed by walls or door. It heat must not get absorbed by the door as the one would tend to burn his/her hand while pulling door open. The door will cover with an insulated material so that the temperature is maintain below its permissible value and human safety can be achieved.

Door seat : the gaskets used to properly seal the micro openings if there are any so that the vacuum is maintained effectively

C. Nomenclature

C_{ap}	Average specific heat between T_i and T_f
C_{lp}	Average specific heat between T_m and T_f
C_p	Specific heat
C_{sp}	Average specific heat between T_i and T_m
m	Mass of heat storage medium
Q	Quantity of heat stored
t	Time
T_f	Final temperature
T_i	Initial temperature
T_m	Melting temperature
l	Latent heat of fusion
ρ	Density
Re	Reynolds number
v	Velocity
T_∞	Surrounding temperature
h	coefficient of heat transfer
μ	Viscosity
σ	Stephan's constant
V	Volume of the PCM layer
t_1	Thickness of the PCM layer

D. Equations

1) By Stefan-Boltzmann Law:

$$J = \sigma T^4$$

To lose 1373 kW over 1 m^2 requires a temperature of-

$$T = \sqrt[4]{\frac{1373}{5.67\times10^{-8}}} T = \sqrt[4]{\frac{1373}{5.67\times10^{-8}}}$$

$$T = 121.477° C \text{ or } 394.47 K$$

This assumes only the surface facing the sun loses heat by radiation: in other words this is only valid for a black surface mounted on a good insulator.

It can therefore be observed that the surface temperature calculated by using the above equations turn out to be $\approx 122°C$.

The air flow taking place over the surface of the acrylic frame is assumed to be $v = v =$ **20 m/s.** Also,

assuming the temperature at which the flow takes place is **30°C°C.** The density and viscosity of air at the mentioned temperature are given by-

$$\rho = 1.1614 \frac{kg}{m^3}$$

Also,

$$\mu = 1.84 \times 10^{-4} \frac{N-s}{m^2}$$

The Reynolds number for the specified conditions is-

$$Re = \frac{\rho v L}{\mu} = \frac{1.1614 \times 20 \times 0.35}{1.84 \times 10^{-4}} = 44183.695$$

The Re value shows that flow over the glass along its length that is- the maximum dimension is too small a value. The flow is thus laminar in nature.

A provision to utilize this rejected heat by using reflective coating in the inner surface of the glass frame. There are several reflective materials available in the market at subsidized rates.

The pressure in the setup will be due to steam formed while cooking, it is in accordance with the KTG

$$P = \frac{Nmv^2}{3V}$$

Where P is pressure exerted by the steam, N is Avogadro number, V is volume of the chamber, v is the velocity and m being mass of the food placed.
Also the velocity of the particles is calculated using the following equations.

$$v = \sqrt{\frac{8k_B T}{\pi m}}$$

A vent needs to be provided in the setup for the steam to escape otherwise excessive pressure built by it, might result in explosion of the frame. The vent with diameter d is found from-

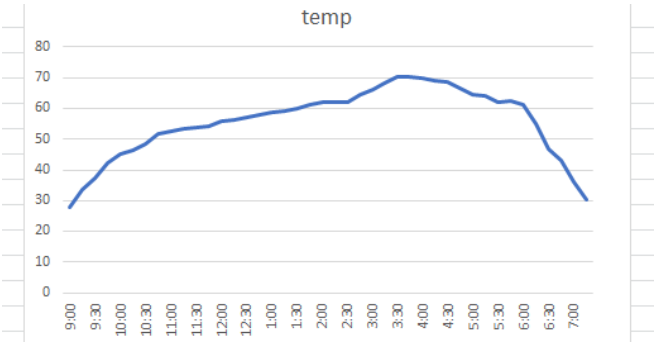
$$Q_s = {\Delta P d^3}/{24\mu}$$

RESULTS AND DISCUSSION:

The results to be obtained from the project are minimum cooking time, cooking temperature as per the theoretical calculations, proper cooking of food. The data from the research papers suggests that the temperature needed to cook food during daylight is sufficient enough for the purpose, cooking after dark requires the PCM to adequately store heat in itself and deliver it to the food during night cooking. PCM is needed to be stored in the some container or arrangement to enhance the efficiency of it delivering the heat suitably to the food. Through the research papers referred it was found that a separate container is taken for the accommodation of the PCM, but in case of such a scenario the container unit was placed away from the cooking place.

Another design comprised of capsule shaped unit that stored the PCM and a blower is provided beneath the set-up to transfer the heat from the capsules to the food chamber. However a need of electrical components is imminent in such a design. As the proposed design claims at not using electricity and consists of an evaluated chamber a need of a new provision is felt. As mentioned in the design calculations a tray like arrangement is made available for the purpose of storing of PCM. The theoretical calculations show that the temperature crosses 120 °C which is the most needed temperature while cooking food at home.

Below figures show the peak temperature achieved in solar- oven . We see rise in temperature from the sun rise (9:00 am) we achieve around 26.7 degrees same as atmospheric temperature ,as time passes we see gradual increase in temperature at 10:00 am ,it achieves around 45 degrees which is substantial difference when checked with environment (28.1 degrees).peak temperature is achieved at 3:30 pm where temp is found out to be 70 degrees .after which temp in solar oven drops gradual after 6:00 and reaches temp of 30 degrees at 7:00



Llimitation:

When compared to electric oven the rate of cooking is higher than solar oven. It cannot provide instantaneous Cooking compared to solar oven. Leakage of heat is higher compared to conventional microwave\oven & temperature achieved is 120 degrees which is less than electric oven. Proper insulation is not achieved .

Conclusion

The setup is showing that the targeted value of temperature inside the oven is achieved that is enough to cook food when the copper plate and the PCM is kept inside the oven to cook food.
The temperatures reached are enough to keep food at the required temperature for a long time even in absence of sunlight.
The temperature can remain to be enough for dawn cooking as well.

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