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Experimental Study of the Green House Effect On Solar Cooker and Water Heater Integrated with PCM Materials (Paraffin Wax, Stearic Acid And Zinc Nitrate Hexahydrate)

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Abstract: *As the environment is getting unbalanced constantly due to constant emission of green house gases and increasing prices of fuel, more and more people are turning towards renewable source of energy. Solar radiation is considered to be one of the cleanest and readily available sources of energy and because of the same, experimental study should be done on enhancing the effect of solar radiation directly on a solar cooker. In this experiment we are using Aluminum containers because of the good conductive property of aluminum. A glass case is used to produce the Green house effect. Copper tube is used for the heating for water. PCM (Phase Change Materials) that are used are Paraffin Wax, Stearic Acid and Zinc Nitrate Hexahydrate and the food materials that are used are Rice, Mung Beans and Bulgur (Dalia). It is observed that using the Glass Case (Green house effect) results into saving a significant amount of time in cooking, in other words using Green house effect results into much faster cooking rate as compared to while not using green house effect. The time(minutes) taken by different PCM materials without using the glass case is as follows => Paraffin Wax : Rice(106)>Mung Beans(76)>Bulgur(54) ; Stearic Acid : Rice(101)>Mung Beans(92)>Bulgur(59) ; Zinc Nitrate Hexahydrate : Rice(121)>Mung Beans(104)>Bulgur(58), and the time (minutes) taken while using the glass case are as follows => Paraffin Wax : Rice(91)>Mung Beans(68)>Bulgur(50) ; Stearic Acid : Rice(94)>Mung Beans(85)>Bulgur(52) ; Zinc Nitrate Hexahydrate : Rice(105)>Mung Beans(92)>Bulgur(44). This concludes that using Green House effect is more beneficial as compared to using solar cooker solely.*
Keywords*-Solar cooker, Green house effect, Phase change material*

I. INTRODUCTION

The continuous depletion of our energy resources and continuous emission of green house gases is mainly driving the world more towards the use of renewable sources of energy. Solar energy is known to be one of the best and cleanest source of energy now days, thus making solar cooking one of most cheapest and ideal way of cooking. Despite all its benefits, solar cooking has its limitations, such as during cloudy season, or evening times when sun light is not available, the solar energy cannot be utilized in a solar cooker directly. This project focuses on the use of PCM (phase change material) as a thermal energy storage material used in the solar cookers, thus increasing its efficiency as well as removing the limitation of night cooking or cooking in a cloudy season [1]. Adding PCM material to a solar cooker not only increases the efficiency of the solar cooker as it heats up the vessel, it stores the solar energy also thus making it possible for it to be used later. This project focuses on a new kind of design that includes cooking of food using the solar energy and also the heating of water using the heat from the PCM material that is basically solar energy itself. It also includes the use of green house effect with the help of a glass container to give maximum heat to the vessel, thus increasing efficiency. In this process, we compare the capacity of heat storage of different PCM materials by comparing the time taken to cook food and heat up water. The survey of the literature regarding the solar system [2].

Domanski et al (1994) investigated the possibility of cooking at late hours (evening hours) using PCM as a storage media. He made a vessel in which two aluminum containers are connected together with a gap between the inner and outer walls. The outer and inner vessels have a diameter of 0.18 and 0.14 m [3]. The annular gap between the outer and inner vessels is 0.02 m. This gap is covered with a removable aluminum cover into which three circular holes were drilled to allow inserting of thermocouples and permit direct visualization during filling or removing of the PCMs. A circular aluminum cover is used as the lid for the inner vessel. The gap between the outer and the inner vessels is filled with 1.1 kg of stearic acid (melting temperature 69. 8C) or 2 kg of magnesium nitrate hexahydrate (melting temperature 89. 8C) which leaves sufficient space for expansion of the PCMs on melting. Buddhi and Sahoo (1997) studied the use of phase change material (PCM) in a box type solar cooker as a heat storage material, in this design the PCM was filled below the absorbing plate. It was used to cook in the evening or during cloudy days, they used steraic acid (melting point 69^o C, latent heat of fusion 161 KJ/Kg) as a PCM for heat storage. In this type of design, time required for cooking is slow as the rate of heat flow from the PCM to the cooking pot is slow. Sharma et al. (2003) designed a box type solar cooker with a cylindrical PCM storage unit for cooking at night and on cloudy days. In this design, since the storage unit surrounds the cooking vessel, the rate of heat transfer is faster between PCM and the vessel, therefore the cooking takes place at a faster rate also. They used 2.0 kg of Acetamide (melting point 82^o C) as a latent heat storage material, and a second batch of food could also be cooked if it was loaded before 3:30PM during winter. They recommended that the melting point of the PCM should be between 105^oC and 110^oC for night cooking.

II. EXPERIMENTAL SETUP

2.1 CONSTRUCTION DETAILS-

This container is made of two aluminum vessels, attached concentrically to each other with the help of TIG welding done by aluminum filler rods. A cubical shaped glass container is used to get the green house effect, which is put on top of the aluminum container. One of the aluminum containers is smaller than the other one, the smaller one is put inside the bigger one. The main focus of this design is efficiency, unlike other conventional designs; this design helps in trapping a lot more heat because of the Green house effect and the sunrays entering the setup from all directions. The basic dimensions of the container are as follows-

2.2 DESIGN OF VESSEL-

Design of vessel is shown in figure 1.

Diameter of Outer cylinder	-	29cm
Diameter of Inner cylinder	-	21cm
Outer cylinder Height	-	31cm
Inner cylinder Height	-	21cm
Cooker's Volume (volume of inner vessel)	-	$\pi * r^2 * h$
	-	$7273.57 cm^3$

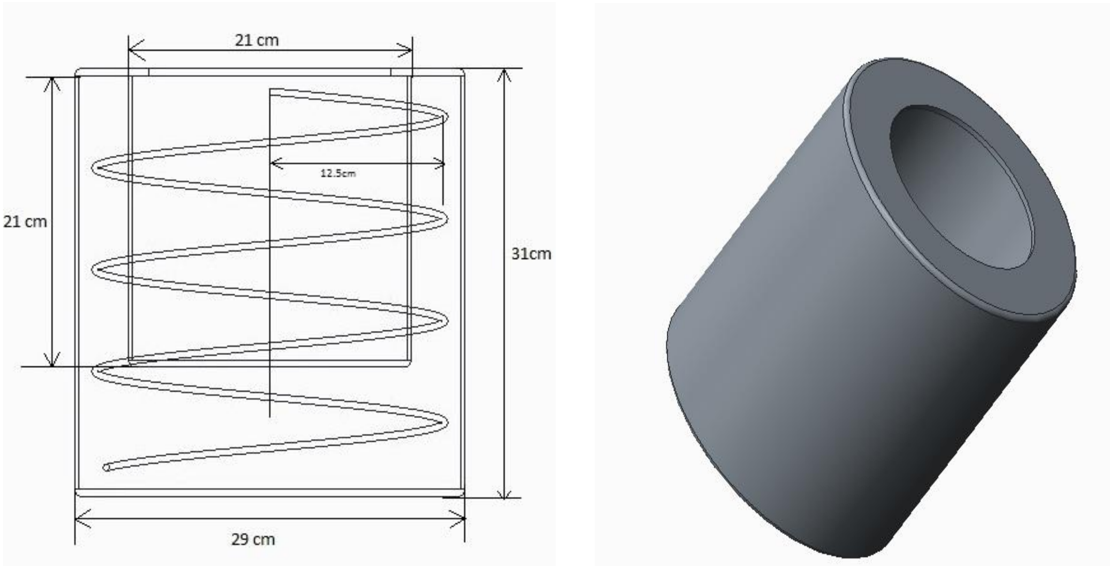

Fig.1. Specifications of Vessel

2.3 DESIGN OF COPPER TUBE-

Diameter of Copper tube (d)	-	5 mm
Diameter of the Coil (D)	-	25 cm
No. of turns (n)	-	3
Pitch of the coil (P)	-	7.5 cm
Extensions at top and base point(E)	-	5 cm
Total length of the copper coil (L)	-	(n * (2 * π * R)) + (2* E)
	-	(3* (2 * 3.14 * 12.5)) + (2 * 5)
	-	245.5 cm = 2.455 m

2.4 DESIGN OF GLASS CASE-

Design of glass case is shown in figure 2.

Dimension of side faces	-	(46 x 38) cm
Dimension of top and bottom face	-	(38 x 38) cm
Volume of cube	-	(L * B * H) cm^3
	-	(46 * 38 * 38) cm^3
	-	66424 cm^3

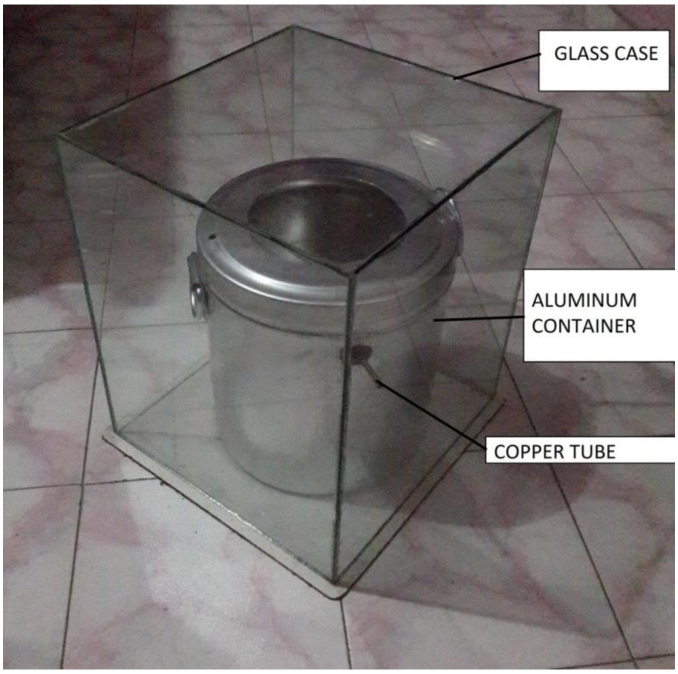

Fig.2. Solar Cooker with green house effect

2.5 WORKING-

As soon as the sun rays start falling on the glass container, it starts trapping heat with the help of Green House Effect. At the same time, sunrays also hit the container (Black body) directly, thus heating it up resulting in the heating of the phase change material placed between the inner and the outer cylinder. The heating of the PCM helps in heating up the copper tube, resulting into the heating of the water that is placed inside the copper tube, also heating up the inner container at the same time. The final effects partially depends on the kind of phase change material (PCM) being used. Some PCM materials are supposed to store heat when heated up and radiate it on cooling back down, they act as a thermal energy reservoir, while others are supposed to amplify the effect of heating, thus heating the container they are in contact with much more then normally sunrays would. This design utilizes the sun rays efficiently, thus absorbing as much heat as possible because of the unique design.

2.6 PCM SELECTION -

1) Name - Paraffin Wax
Melting Point - 58-60 ^oC
Density - 900 kg/m^3
Latent Heat - 220J/g
Specific Heat Capacity C_p - 2.9 J/g-K

2) Name - Stearic Acid
Chemical Formula - $CH_3.(CH_2)_{16}.COOH$
Molecular Weight - 284.48
Melting Point - 54^oC
Density - 847 kg/m^3
Latent Heat - 198.91 J/g
Specific Heat Capacity C_p - 2.359J/g-K

3) Name - Zinc Nitrate Hexa Hydrate
Chemical Formula - $Zn\ (NO_3)_2.6H_2O$
Molecular Weight - 297.49
Melting Point - 36^oC
Density - 2.065 g/cm^3
Latent Heat - 147J/g

III. CALCULATION AND RESULT

Assume water's initial temperature to be 21^oC
Amount of food taken = 5 Kg.
Volume of cooker (inner vessel) - 0.00727 m^3
Density of Water - 1000 kg/m^3
Specific Heat of water (C_p) - 4.817 KJ/Kg-K

Table 1: PARAFFIN WAX

PARAFFIN WAX								
FOOD	WITH GLASS CASE				WITHOUT GLASS CASE			
	Initial Temp.(^oC)	Final Temp. (^oC)	Time Required (min)	Energy Required(J)	Initial Temp. (^oC)	Final Temp. (^oC)	Time Required(min)	Energy Required (J)
RICE	21	73.5	106	1097.25	21	79	91	1212.2
MUNG BEANS	21	70.6	76	1036.64	21	74.4	68	1116.06
BULGUR	21	67	54	961.4	21	71.2	50	1049.18

Table 2: STEARIC ACID

STEARIC ACID								
FOOD	WITH GLASS CASE				WITHOUT GLASS CASE			
	Initial Temp. (^oC)	Final Temp. (^oC)	Time Required(min)	Energy Required	Initial Temp. (^oC)	Final Temp. (^oC)	Time Required(min)	Energy Required
RICE	21	69.4	101	1011.56	21	71.4	94	1053.36
MUNG BEANS	21	66.5	92	950.95	21	68.8	85	999.02
BULGUR	21	56	59	731.5	21	59.2	52	798.38

Table 3: ZINC NITRATE HEXAHYDRATE

ZINC NITRATE HEXAHYDRATE								
)FOOD	WITH GLASS CASE				WITHOUT GLASS CASE			
	Initial Temp. (°C)	Final Temp. (°C)	Time Required(min)	Energy Required	Initial Temp. (°C)	Final Temp. (°C)	Time Required(min)	Energy Required
RICE	21	53	121	668.8	21	60.0	105	815.1
MUNG BEANS	21	49.2	104	589.38	21	54.4	92	698.06
BULGUR	21	46.2	58	526.68	21	50	44	606.1

IV. CONCLUSION

In this study, the performance of a PCM integrated solar cooker is tested with and without green house effect. A simple aluminum container was designed with the help of welding and a copper tube was coiled inside it. It is observed that the use of Green House Effect increases the rate of cooking significantly, thus making it much more advantageous for general use.

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