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A GRAVITY BASED TWO-AXIS SOLAR TRACKING FOR PARABOLOID DISH TYPE SOLAR COOKING SYSTEM

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ABSTRACT

In this paper a mechanism for a two-axissun tracking system based on gravity for a paraboloid dish type solar cooking system is reported in this type of sun tracking system two type of motion is given to paraboloid dish; one is rotation about x-axis and second one is lifting about y-axis. These motions are created with the help of water. The main advantage of this tracking system is that it does not need any electronics devices, motor or gas arrangement. That's why this system is cheaper in cost and construction is easy and rigid. In this paper a brief calculation for flow rate of water used for tracking purpose and temperature and pressure measurement with respect to time is reported.

KEYWORDS: Two-Axis Solar Tracking System, Chain Sprocket, Discharge Tube, Source and Sink Vessels

INTRODUCTION

The need of this era is to maximize the use of renewable energy due to limitation of amount of non-renewable energy due to the limitation of amount of non-renewable energy sources like petroleum, coal, natural gases etc. and due to increase in rate of population growth. Food is one of the basic need of human being. Renewable energy services have large application in sources have large application in cooking process. For ex. Biogas plant, solar cooker etc. solar cooker is most preferable cooking system because of its easy construction, handling. Solar cooker are preferable in India because of high availability of solar energy. An average, in India sun light is available approx. 300 day in year, which make solar cooker more preferable cooking system in comparison to the systems based on non-renewable energy sources. There are several types of solar

- Box type cooker
- Panel cooker
- Parabolic dish type cooker
- Funnel cooker
- Scheffler (paraboloid dish) cooker etc

Paraboloid dish type solar cookers are available in market with or without tracking system. In generally electronic devices are used for tracking system in paraboloid dish type solar cooking system. The main drawback of electronic based tracking system is that it is very costly and the tracking system may be damage due to excess heat. To overcome this problem which is related to electronic based tracking system, a totally new concept is utilized which is based on gravity.

The design and construction of this type of tracking system is quite simple and very cheap in cost as compared to electronics based tracking system.

Recent Trends

As the researchers around the World are doing so much research on various types of tracking systems some of them are based upon the electronic type and some are non-electronic type.

SuhailZakiFarooqui[1] in 2013 have proposed a revolutionary gravity based tracking system in which the top of the box is moving with help of bearing and spring according to the trajectory of sun. This movement is done with help water discharge. There are many drawbacks of this type of tracking system.

- In this system tracking is only for single axis but in this research it is found that only single axis of tracking is not enough for precise tracking. So the setup of two-axis solar tracking system can be used.
- When the weight of cooking pot is increase on system then bearing may be failed to give the required movement for tracking. This problem is overcome intwo-axis solar tracking system.
- This system arrangement is more complicated but setup of two-axis tracking system is simple.
- This system if any component is fail then it will not work properly but intwo-axis system at failure of any component it will not more effected on working of the system. It shows the rigidity of system.
- In this system the performance will reduces with the time due to failure of components like permanent deformation of spring, failure of bearing; so it required maintenance and replacement of components with time to time. The two-axis solar tracking system is required almost negligible maintenance and replacement, so the system is economical.

Bill lane[2] design a specific design methodologies pertaining to photocells, stepper motors and drivers, microcontroller selection, voltage regulation, physical construction, and a software/system operation explanation. It is controlling a sun tracking array with an embedded microprocessor system. It demonstrates a working software solution for Maximizing solar cell output by positioning a solar array at the point of maximum light intensity.

Md. Tanvir Arafat Khan, S.M. Shahrear Tanzil et-al [3] have presented a means of tracking the sun's Position with the help of microcontroller. Specially, it demonstrates a working software solution for maximizing solar cell output by positioning a solar panel at the point of maximum light intensity. His design requires only two photo resistors to sense the light, which lessens the cost of the system. Power consumption of the system is negligible as '*wait*' states are calculated perfectly with the sun's position.

Tiberiu Tudorache, Liviu Kreindler[4] have designed a single axis solar tracker system that automatically searches the optimum PV panel position with respect to the sun by means of a DC motor controlled by an intelligent drive unit that receives input signals from a light intensity sensor. it this design an optimum cost/performance ratio, which is achieved via the simplicity of the adopted mechanical solution and the flexibility of the intelligent command strategy .

These sun tracking with help of electrical or electronics devices which follow the trajectory of sun and it is connected with motor which help to rotate the dish. Due to more circuit, complicated setup and sensitive instruments, this system become tough to handle, maintaining and possibility of damage of electronics devices increases. The temperature is increases upto 100-120℃ due to this damage chances of electronics instruments is increases because mostly electronics instrument are the made of plastics. Setup of this type of tracking system is complicated and it can't be handled by ordinary person. In two-axis tracking system, working is based on the mechanical process. In which water is used as the working fluid. No electronics devices are used for tracking and this setup is simple and rugged. The elevated temperature does not affect any component of system. It can be controlled by any ordinary person, maintenance is very simple and economical.

Parts and Equipment

Anodized aluminum reflector plates for a solar dish, stand to support solar dish, stand to keep pressure cooker, burden tube pressure gauge to measure internal pressure and corresponding temperature of pressure cooker, thermostats to measure the temperature, stop watch, one transparent vessel of 8 liter capacity used as source, another transparent vessel of 4 liter capacity used as sink, two heavy weight vessel of same weight and equal capacity up to 2 liter each used as sink, 3 separated passage tube with injector and control valve, stand for the purpose to hold the vessel of 8 liter capacity, 3 sprockets chain, nut bolts of different sizes. Hook to hinge transparent vessel of capacity 4 liter.

Experimental Setup

In order to understand the arrangement of whole system is briefly explained in the following steps:

- Solar dish arrangement.
- X- axis tracking
- Y- axis tracking

Solar Dish Arrangement

In this arrangement the basic assembling process of solar dish is explained. 36 anodized aluminum sheets as reflector plates are assembled to form a parabolic dish. The dish is supported by a stand. Four swiveling wheels are attached under the stand, which facilitates smooth movement of whole set up. A mild steel hollow cylindrical bar is connected to either ends of the dish and a supporting stand is mounted at the center of the Barton hold the cooking vessel.

Figure 1a: Solar Dish Arrangement

X- Axis Tracking

In this arrangement a secondary stand of height about 1.93 m from the ground level isattached to the primary stand which supports the solar dish. The purpose of this stand is to support the “transparent vessel” named ‘source’ having capacity of 8 ltr. Another “transparent vessel” named “sink” of capacity 4 ltris hinged on the periphery of the dish for its rotation about x-axis. These two vessels are connected by a passage tube through which water flows from source to sink.

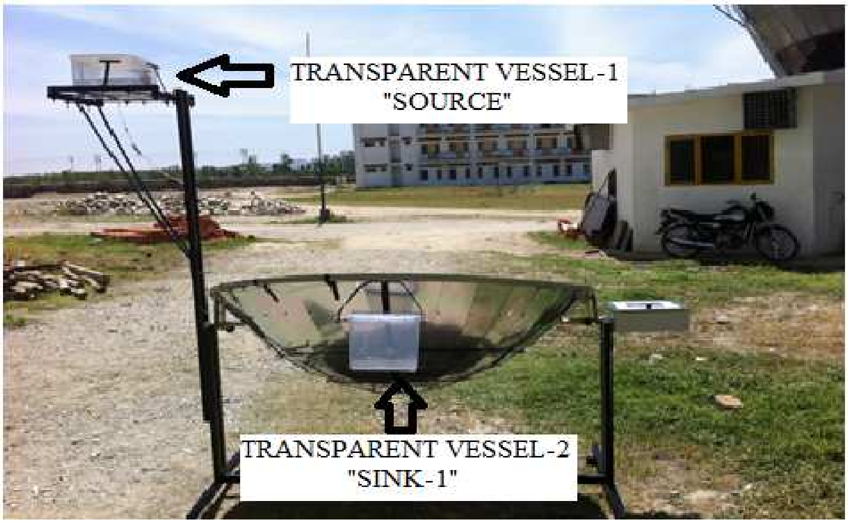


Figure 1b: X- Axis Tracking

Y-Axis Tracking

In this arrangement, three sprockets are used. One sprocket is fixed in the cylindrical bar which holds the solar dish. Another two sprockets are fixed on a metal strip, connected at 90° to the secondary stand. These two sprockets are attached at the farthest ends of the metal strip by maintaining a gap of about .27 m between them. Chain-drive is used to connect these three sprockets. The length of the chain-drive is about 3.65 mat the both ends of the chain, heavy weighted identical vessels sink (2 & 3) about 2ltr each is attached. These two vessels are connected to the “transparent source vessel” by two separate passage tube through which water flows from source vessel to sink (2 & 3) vessels. This arrangement is done for tracking purpose about Y-axis by lifting solar dish from one side of the solar dish. The Y-axis tracking system is shown in the figure 1c and 1d

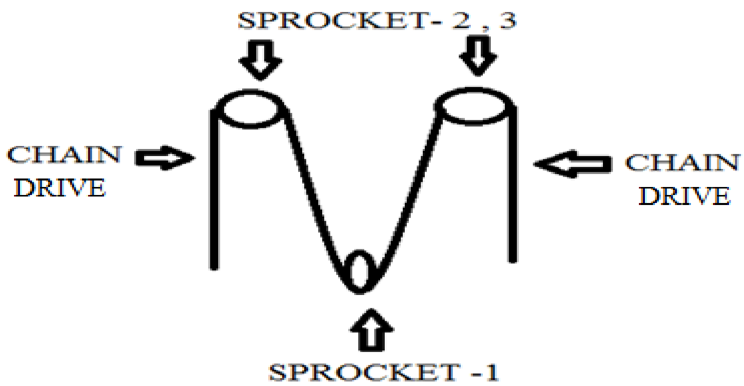


Figure 1c: Schematic Diagram of Y-Axis Tracking

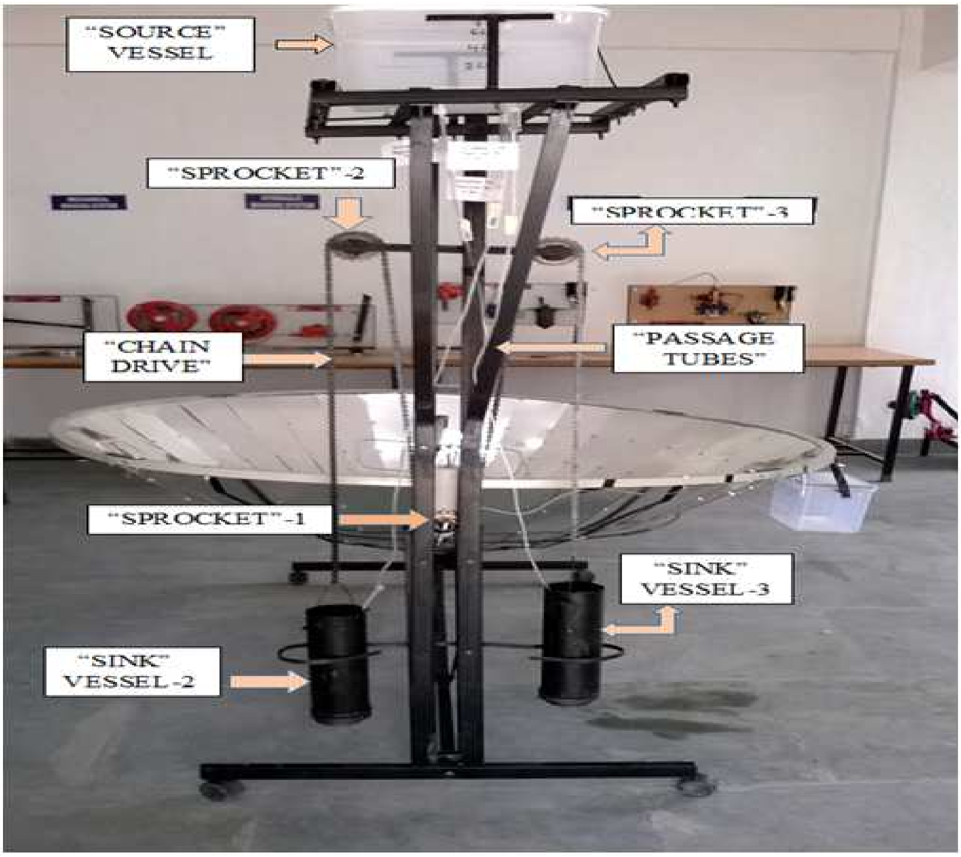


Figure 1d: Y-Axis Tracking

WORKING

- First of all the whole setup of solar dish is taken out to sun light.
- Set the solar dish at an appropriate angle, so that it can reflected maximum of sun ray to center position at which, the food is prepared.
- Initially, the source vessel which is mounted on top of 2^{nd} stand is full of water.
- All three passage tube which connected source vessel to three sink vessel are open to start the flow of water from sources vessel to all three sink vessels.
- Flow rate of water is controlled by "control valve" which is attached with passage tube.
- Amount of water in sink vessels is increased with time, which is responsible for the tracking process.
- Solar dish is rotate about x-axis when the amount of water in sink vessel which is hinged on solar dish is increased with respect to time.
- Solar dish is lifted about y-axis from one side when the amount of water in the heavily weighted sink is increased with respect to time.
- In the whole process of tracking, the efficiency depends upon the flow rate of water from source vessel to sink vessel. Figure 2 shows the complete setup of tracking system.

Figure 2: Final Setup of the Tracking System

Significance of Two Axis Tracking System

It is examined that the tracking in single axis by rotation of solar dish about x-axis is not enough to track the trajectory of sun with respect to time effectively. In order to maximize the beam radiation on the absorber it is required to track the trajectory of the sun more precisely, which can only be achieved by two-axis tracking system and after comparing single axis and two-axis tracking system it is found that the intensity of reflected solar radiation is increased about 10% by employing two-axis tracking system.

Calculations and Measurements

- Diameter of solar dish = 1.44 m
- Angular displacement of solar dish for 6 hours = 90°
- Height of sink1 which is hinged on solar dish from ground level in morning = 1.21 m
- Height of sink 1 which is hinged on solar dish from ground level in evening = .12 m
- Height at which source vessel placed from ground level = 1.93 m
- Length of chain drive = 3.65 m
- Height at which two sprockets are attached from ground level = 1.62 m
- Distance between two parallel sprocket = .27 m
- Distance between sprocket 1 and parallel sprockets = .76 m
- Force required to lift solar dish from 1 side when cooker isn't kept on dish = 5.5 N
- Weight of the solar dish from 1 side when cooker is kept on dish = 7.5 kg

- Weight of each heavy weighted sink vessel = 3.5 N
- Torque required to rotate the dish about X-axis=6.79Nm
- Torque required to rotate the dish about one end =14.2Nm

CALCULATIONS

As we know that the position of sun constantly changes by 15° per hour. Solar dish is generally working for 6 hours in a day (10 am to 4 pm). For this duration solar dish is required to rotate by 90°. During the rotation of dish one side of the dish will move upward and another side downward and the side which will move in downward direction there we have sink-1 and its vertical downward displacement will be about 0.18 m/hour.

Flow Rate of Water Required for Rotation through X-Axis

As the solar dish needs 15° angular displacement in one hour

There for the angular velocity of the dish will be= angular displacement/time taken

$= \frac{15*\pi}{3600*180}$

$=7.2 * 10^{-5} rad/s$

Now velocity of the dish will be= (angular velocity of dish)*(radius of the dish)

$=7.2 * 10^{-5} * \frac{1.44}{2}$

$=5.2 * 10^{-5} m/s$

So the above velocity is the required velocity of the sink-1 in vertical downward direction to track the sun in X-axis only.

Now corresponding to the above velocity the displacement to be covered by the sink-1 in one hour will be

$= 5.2 * 10^{-5} * 3600$

= 0.18m

i.e.$\tau * \theta = m * g * h$

Where m=mass of water required to be flown in one hour

h=vertical displacement to be covered in one hour i.e 0.18m

g=acceleration due to gravity

$$m = \frac{\tau * \theta}{g * h}$$

$$m = \frac{6.79 * 15 * \frac{\pi}{180}}{9.81 * 0.18}$$

$$m = 1kg \ or \ 1litre$$

And the discharge will be =volume of water/3600

$=\frac{1*10^{-3}}{3600}$

$=2.7*10^{-7}m^3/s$

The above discharge can easily be controlled by the control valve and hence X-axis tracking can will be done successfully.

Flow Rate of Water Required for Lifting Solar Dish through Y-Axis

This may be noted that flow rate of water must be same for both heavy weighted sinks to ensure equal vertical displacement.

Now from the experimental observation it is found that,

0.15 m vertical displacement is required in 6 hour for effective tracking. Or 0.025m in one hour.

So the angular displacement of the dish about one end will be= (total vertical displacement of the dish from one end)/ (diameter of the solar dish)

$$\theta = \tan^{-1}\frac{0.1524}{1.44}$$

=6.04° or 0.105rad

Now from the equation 1

$$\tau * \theta = m * g * h$$

$$m = \frac{\tau * \theta}{g * h}$$

$$m = \frac{14.2 * 0.105}{9.81 * 0.15}$$

$$m = 1.06kg\ or\ about\ 1\ litre$$

Now the discharge is=volume of water flown in one hour/3600

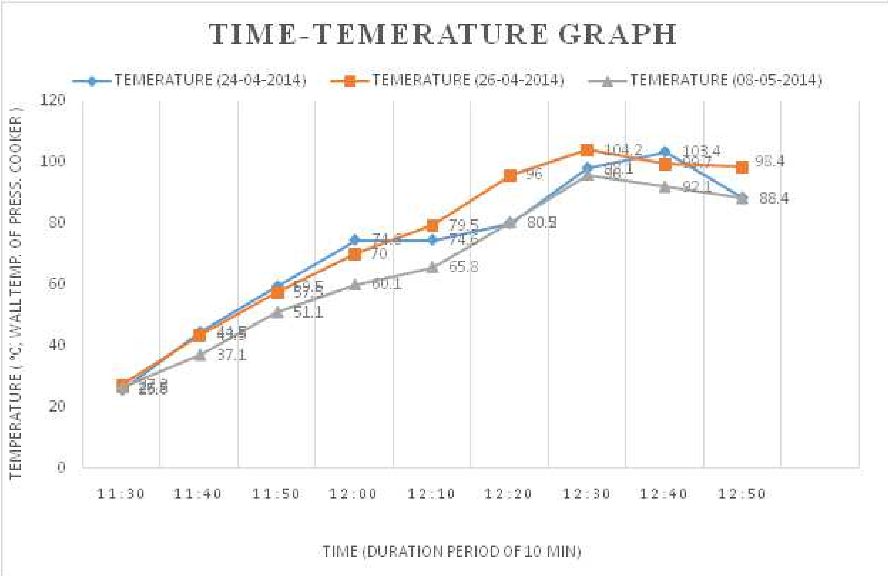
$=\frac{1*10^{-3}}{3600}$

$= 2.78*10^{-7}m^3/s$

But this discharge will be equally divided into sink-2 and sink-3 therefore discharge of water in single sink among 2 & 3 $=1.38*10^{-3}m^3/s$

The above calculated discharge can easily be controlled by controlled by control valve and hence the Y-axis will be done successfully.

Graph for Measurement of Wall Temperature of Pressure Cooker during Testing



Note: Internal pressure of the pressure cooker during above given time period increases from 0 to 15 lbf/inch^2 and according to this pressure range the internal temperature of the pressure cooker rises upto 121℃.

CONCLUSIONS

This paper presents method for eliminating the need of manual solar tracking of the common type of solar cooking system. This tracking system is gravity based tracking mechanism that doesn't require any external power source. The required tracking energy is drawn from potential energy stored in sinks attached to a water source. The whole system has been optimized for 6 hours of cooking per day, during which no manual tracking should be require

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