MATHEMATICAL MODELLING AND SIMULATION OF THE PERFORMANCE COMPARISON OF TWO SOLAR WATER HEATERS

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Introduction

This research is on selecting efficient solar energy harnessing for water heating. Modeling, simulation and analysis were done using flat plate and parabolic solar collectors using MATLAB Simulink. Solar ray harnessing efficiency was calculated by varying the solar position and identified optimum position of the collector of water heater system. By this research, it was tried to achieve maximum energy harnessing from the sun cost effectively. A mathematical model is used to evaluate the annual variation of the temperature. This was achieved through analyzing the annual irradiance variation. Simulation model was tested by varying design parameters of water heater system. Results were used to design an efficient and cost effective solar water heater.

Methodology

A mathematical model was developed to model the parabolic collector and flat plate collector. The main purpose of the mathematical model was to tune the parameters of the parabolic collector and to compare the two collector structures to decide on the best method. The model consists of several subsystems such as date number generation, solar vector calculation, error angle calculation, error correction, collector orientation efficiency calculation, total solar radiation calculation, collector heat absorption and storage tank.

Initially collected solar radiation data were analyzed. Next step was to identify the most suitable orientation of the collector in order to maximize the efficiency. To achieve this MATLAB model was created. The plan was to place the collector horizontally and align the collector axis (axis through the focal points of the parabola) to north south direction and calculated the angle that the collector should be rotated in order to align the axis of the parabola with the sun. This was calculated for different times within a day. Then the collector axis was rotated slightly on the horizontal plane and the above calculation was repeated. And this was repeated for the whole 180 degrees. Output of the simulation was a 3D graph. Using the above graph the angle which gives a minimum variation within a day was selected as the best angle for that particular day. Then to keep the axis of the collector in optimum position, axis along the parabolic collector was inclined in different angles and the error angle was calculated for different times within a day. This data was plotted with MATLAB and the optimum tilt angle was calculated. From the above calculations the maximum variation of the parabolic collector, which works without the orientation change was calculated as approximately 10 degrees. A criterion was formulated in order to calculate the diameter and the focal length of the parabola.

Also MATLAB code was developed to calculate the efficiency of the parabolic collector for a given angle. In this program the focal length and the opening of the parabola is changed to meet the above criteria.

Results and Discussion

Solar radiation variation in hourly within the whole year in (Kandy region) Sri Lanka is shown below.

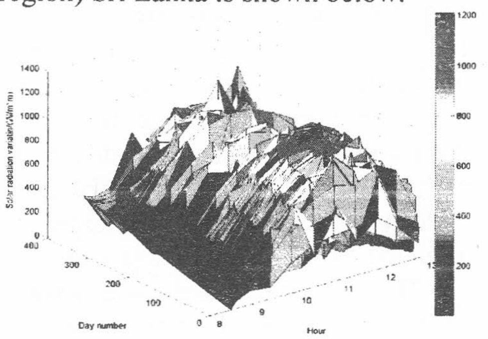

Fig 1: Annual irradiance variance in Sri Lanka (Kandy Region) 2009

A MATLAB code was developed to calculated the solar Zenith and Azimuth angles when input the date, time and the coordinates of the location. Rotation of the parabolic collector around the tracking axis to align the sun throughout the year is shown below.

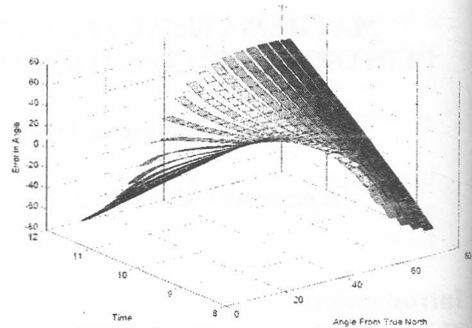

Fig 2: Error in angle for a given orientation and time

Then we tried to incline the axis from the horizontal and calculate the error to see if we can get any reduction in mean deviation of the error angle. But there was no improvement as seen from the results. Therefore parabolic collector can focus rays at least with 10 degree inclined to its normal.

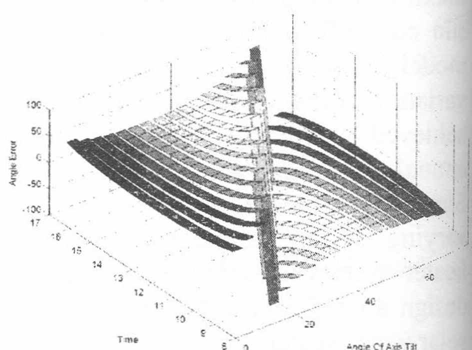

Fig 3: Angle error variation with axis tilt and time

When designing the parabolic collector it is important to calculate focal length (f) and the opening of the parabola (d). From using the percentage rays that go through the collector, best parameters for the parabolic collector were calculated.

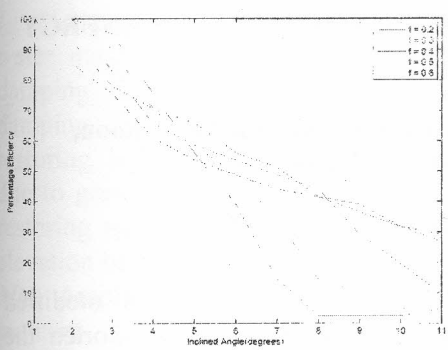

Fig 4: Variation of efficiency with Focus length and angle

Finally temperature for unit length of the water inside the tube for a given solar radiation and flow rate was calculated.

Table 1: Temperature comparison when error correction is done

	Minimum Temp/(°C)	Maximum Temp/(°C)
Parabolic collector	65	200
Flat plate collector	35	65

Table 2: Temperature comparison when tracking is done 100%

	Minimum Temp/(°C)	Maximum Temp/ (°C)
Parabolic collector	65	300
Flat plate collector	35	75

Conclusion

The effect of alignment is higher on the parabolic collector, therefore it is very important to align the parabolic collector with the sun. The parabolic collector was designed in order that the efficiency developed into greater than 50% for error angles of 0-10 degrees. With the simulation we can observe that correcting the collector orientation weekly keep the error within 10 degrees. If automatic tracking was used the temperature obtained can be much higher than this, although it is expensive. If the orientation of the plate can be corrected at brief intervals the parabolic collector is the cost effective energy harnessing method. But if manual correction is not possible flat plate collector will be the best option.

References

Clean energy project analysis:retscreen® engineering & cases textbook, RETScreen® International Clean Energy Decision Support Centre.

Kyoga Foundation, Solar Water Heaters in Industrial Processes, Project Number: 130, Kampala, Uganda.

http://www.powerfromthesun.net/book.htm

Manuel Blanco-Muriel *et al,* (2001)