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Performance Evaluation and Analysis of Integrated Solar Water Heater

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***Abstract*—** In existing water heater, the flat plate collector is used to heat the water. The hot water is being stored in a separate storage tank. The integrated solar water heater stores the water as well as heat it effectively. A flat plate collector is used to absorb the solar radiation and the hot water is stored within the collector. There is no need for the separate storage tank. The conventional integrated solar water heater uses aluminium foil as the collector area to store water during night time due to which convection heat loss occurs. This factor reduces the overall efficiency of the water heater, to minimize this loss an insulation material is used to avoid the thermal losses from the system.In this project, the aluminium foil is replaced by mirror because the reflective rate of the mirror is more (92%) when compared to that of aluminium foil(88%). The integrated solar water heater has been fabricated and the experiment is carried out in real climatic conditions for 24 hours in Coimbatore.Temperature and solar intensity are measured by using thermometer and solarimeter respectively. Temperature, solar intensity, glass temperature and ambient temperature have been measured to study the performance of the integrated solar water heater and the CFD analysis is also done to evaluate the performance.

***Index Terms*—** Flat Plate Collector, Integrated Solar Water Heater, Aluminium Foil, Mirror Glass.

I. INTRODUCTION

Energy and fresh water are the two major commodities that furnish the fundamentals of every human activity for a reasonable and sustainable quality of life. Energy is the fuel for growth, an essential requirement for economic and social development. Solar energy is the most ancient source and the root for almost all fossil and renewable types. Special devices have been used for benefiting from the solar and other renewable energy types since time immemorial. During the early civilizations water and wind power have been employed as the major energy sources for navigation, trade, and information dissemination.

In recent centuries the types and magnitudes of the energy requirements have increased in an unprecedented manner and mankind seeks for additional energy sources.Today, energy is a continuous driving power for future social and technological developments. Energy sources are vital and essential ingredients for all human transactions and without them human activity of all kinds and aspects cannot be progressive. Populationgrowth at the present average rate of 2% also exerts extra pressure on limited energy sources.Solar energy has the greatest potential of all the sources of renewable energy and if a small amount of this form of energy could be used, it will be one of the most important supplies of energy especially when other sources in the country have depleted. The solar power where sun hits atmosphere is 1017 watts, whereas the solar power on earth's surface is 1016 watts. The total worldwide power demand of all needs of civilization is 1013 watts.Therefore, the sun gives us 1000 times more power than we need. If 5% of this energy is utilized, it will be 50 times what the world will require. Thus, in principle solar energy could supply all the present and future energy needs of the world on a continuing basis. Solar energy can be used in different applications. Hot water is an essential requirement in industry as well as in the domestic sector. Water is generally heated by electric heaters. The energy required to run heaters is produced from thermal power stations by burning fossil fuel,namely natural gas.This fuel is a source of pollutants and greenhouse gases. Water heating accounts for approximately one-fourth of the total energy used in a typical single-family home. During the winter, an electric water heater is the single biggest energy user of all domestic appliances.

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II. RELATED WORKS

Y. Tripanagnostopoulos et al (1992) [1] has designed Stationary concentrating solardevices, of the integrated collector and storage (ICS) type, that consist of a cylindrical tankplaced horizontally in a properly shaped, curved mirror envelope. The design of the ICS solarunits with respect to the minimization of thermal losses from the absorber to the ambient.Experimental results were derived from the constructed models, a conventional concentratingstationary ICS prototype, and flat plate collectors of the thermo siphon type. From this resultsit has clearly shows the performance of ICS system is better.

M. Souliotis et al (2011) [2] has designed a heat retaining ICS vessel design consisting of two concentric cylinders mounted horizontally inside a stationary truncated asymmetric compound parabolic concentrating (CPC) reflector trough. The thermal behaviour of the ICS system was compared to that of a Flat Plate Thermosiphonic Unit(FPTU). The experimentalresults showed that the ICS system is as effective during daily operation as it is during the night. Furthermore, the thermal loss coefficient during night gives similar values between the ICS system and FPTU.

A. Harmim et al (2011) [3] has presented the construction and the performance evaluation of a new box-type solar cooker equipped with an asymmetric Compound Parabolic Concentrator (CPC). The optogeometrical design of the cooker was optimized for Adrar which is located in Algerian Sahara. Experimental tests demonstrated that the cooker, which remains in a stationary position during all test period, is suitable for cooking even in winterand without having recourse to tracking towards the sun.

Monia Chaabane et al (2012) [4] studied the thermal behaviour of an integrated collector storage solar water heater (ICSSWH) numerically using the package Fluent 6.3. With respect to the experimental data, the ICSSWH with radial fins of rectangular profile was designed and analysed using software package. The results suggest that the increase of the fins depth leads to higher water temperature and lower thermal losses.

Monia Chaabane et al (2013) [5] has carried out numerical study of ICS system with sensible heat storage unit. Based on the good agreement between the experimental result, a second 3D CFD model was developed with integration of PCM directly in the collector and study its effects. Results show that during the day-time, the latent heat storage unit (LHSU) performs better than the sensible one when myristic acid is used as PCM.

M. Souliotis et al (2013) [6] experimentally studied three ICS system which consist of cylindrical tank horizontally mounted in stationary CPC reflectors. The experimental models can be mounted on horizontal as well as on inclined roofs by adopting the lowest possible depth. Result shows that the studied ICS experimental models, one of them is chosen as the most promised regarding its thermal performance in combination with its size.

Hamdi Kessentini et al (2013) [7] have developed a numerical model to study the thermal performance of ICS system. A prototype of an ICS device was constructed and experimentally tested outdoors in order to observe the variation of water temperature in the storage tanks. The experimental results are presented and the validity of the numerical modelis examined by comparison of the theoretical results with experiments which demonstrates a good agreement. The developed numerical tool within this work can be considered as important for the study of double tanked ICS solar water heater regarding its transient thermal behaviour.

K. Devanarayanan et al (2014) [8] has carried out a detailed literature survey of various ICS system with respect to its thermal performance, design and economic of the system. The various designs of ICPCSSWHs and their performance analysis are reviewed. Recent developments in CPC based ICSSWH show a hopeful design to consume solar energy as a reliable heating source for water heating applications.

III. METHODOLOGY

A. EXPERIMENTAL SETUP DETIALS

The absorber tank is made up of mild steel and it is coated with black paint. The transparent cover consists of a single glazing of 4 mm thickness, 0.9 m length and 0.5 m width. The mirror is used as a glazing which contains three mirror on the three surface of the tapered section as shown in the figure. Then the aluminium sheet is taken as a size of 2 mm thickness, 1 m length and 0.19 m width. It is rolled to form a pipe by using the brazing method. For insulation purpose, the thermocol is covered with the outside surface of the integrated solar water heater. This minimizes the night loss and to avoid the thermal loss from the system. The integrated solar water heater has been fabricated as per the design specification are given in the table below.

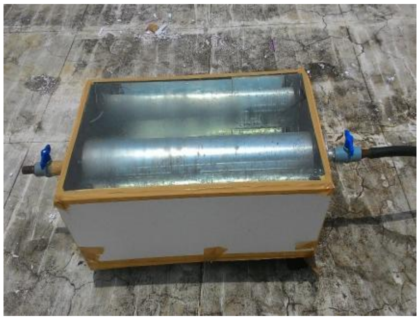


Figure 1: Fabrication of integrated solar water heater

Table 1. Specification Details

Components	Materials
ICS COLLECTOR	Mild Steel
Glazing	Glass
No of Glazing	3
Storage Tank	Aluminium
Capacity	25 L
Insulation	Thermocol

B. ESULT AND DISCUSSIONS

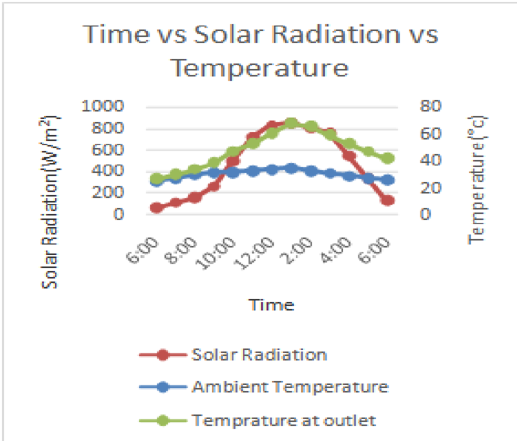


Figure 2. Time Vs Solar Radiation Vs Temperature

The graph indicates that the solar intensity is maximum at 860 W/m^{2}and the temperature at outlet is 68 °C from 6:00A.M. to 6:00 P.M. From 12:00 to 2:00 P.M., the solar radiation and the temperature at outlet are maximum while observed from the readings.

Table 2 : Experimental reading

Time	Ambient Temperature	Solar Radiation	Temperature at outlet
	°C	W/m^2	°C
6:00	25	60	27
7:00	27	110	30
8:00	30	160	34
9:00	32	260	39
10:00	32	500	47
11:00	33	725	53
12:00	34	830	60
1:00	35	860	68
2:00	33	810	66
3:00	31	760	59
4:00	29	550	53
5:00	27	340	47
6:00	26	130	42

ANALYSIS

Mesh Details:

For surface meshing parameter,

Mesh type : All Tri

Mesh method : Patch dependent

For volume meshing parameter,

Mesh type : Tetra / mixed

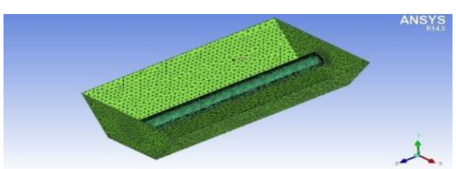
Mesh method : Robust (octree)

Boundary conditions :

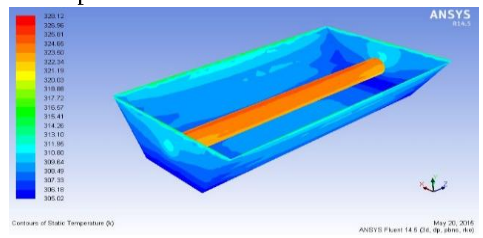
Part Name	Boundary conditions
Mirror glass	Wall
Transparent glass	Wall
Pipe surface	Wall
Int-Air	Interior
Int-Water	Interior

In this analysis, the total number of element and the total number of nodes are present in the tapered section are 295274 and 48702 respectively. Theexternal radiation temperature, internal emissivity, external emissivity and heat transfer coefficient have been considered. For transparent glass,the thermal condition is taken as a radiation and for pipe surface,the thermal condition is taken as a coupled.

Meshed Structure



The meshed structure is further carried out by the following steps. Select the models, materials and cell zone conditions. Then the solution, solution controls and solution convergence criteria are considered. Finally the calculated activities and graphical results have been taken to compare the results with the performance test.



IV. CONCLUSION

The ICS system with Asymmetric CPC Reflector was designed and the system was constructed and tested at coimbatore, Tamil Nadu. The result obtained shows that the water temperature in the system is a function of a solar radiation and the ambient air.A typical day analysis of the system shows that the collector efficiency is high especially around mid-day when the ICS receives the highest energy. Experimental results also reveal that the performance of the solar water heater is mainly affected during night losses. The experiment results shows that the system has an average daily collector efficiency of the system to be 48.42% and the maximum water temperature obtained was 68°C, while the maximum ambient temperature was 36°C. The performance of ICS system can be further improved by using phase change materials in absorber tank and proper insulation of the system. Further work has been carried out to reduce the night losses in ICS water heater and the performance can be improved by using phase change materials in absorber tanks.

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