Experimental Study of Performance Analysis of Conical Solar Still using Nano Fluid

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Abstract- *As per Daily Requirement of potable water is increasing steadily with growing population. Many methods has been developed & used for desalination of water. Desalination of Water using solar energy by Solar Still is one of the way for potable water production from brackish and seawater. This work focuses on the productivity enhancement of solar still by decreasing the shadow effect for maximum utilization of solar radiation by using conical solar still. The analysis is done by using parameters like depth of water in basin, day time, basin water temperature, heat transfer coefficient, solar radiation, etc. The Dunkel's model is used for calculating heat transfer coefficients. The stress analysis & thermal analysis is been done to study the safety of set up against load acing on it by using ANSYS R15 and R18. To improve performance of conical solar still the Nano fluid of copper oxide is added to basin water in % of 0.1.The performance of solar still will be compared with & without Nano fluids. The Yield per hour is measured & daily efficiency is been calculated.*

Keywords- Depth of Water, Heat transfer coefficient, Solar Radiation ,Nano Fluid, Ansys R15,R18,CFD too, Thermal Efficiency

I. INTRODUCTION

PROBLEM STATEMENT

A conventional basin type solar still is simply an air tight basin that contains a shallow layer of saline water, a sloped top cover of a transparent material usually glass and side metal frame walls. The cost of building and operating a conventional still is relatively low compared to those involving sophisticated designs. However, the conventional or standard basin type solar still proven to have a low thermal efficiency with low daily distillate productivity. The efficiency and yield of the conventional solar still depend on different factors: the design and functionality of the still, location, weather conditions, etc. Their low thermal efficiency is due to the considerable shadow caused by the walls of the basin that tend to decrease the absorption of solar radiation that could have been used for water distillation process.

Rate of evaporation of basin water is one of the factor on which productivity of still depends. As the rate of evaporation of water is depends on conductivity of base fluid. The base fluid used will be water which will have less conductivity & hence low evaporation rate.

II. LITERATURE REVIEW

H E Gad et.al, compared the performance of conical solar still with conventional solar still. The conical solar still includes a galvanized iron circular base basin diameter is 100 cm, cone Depth is equal to 33 cm, basin area is 0.8 m^2. The sides and basin are covered with 0.7 mm thick galvanized iron. All the sides and base of the still are insulated with foam of 5 cm thick. Experiment was carried out at constant water height equals to 3 cm all over the test. The water height is kept constant by compensation from the black steel feed water tank which preheats the feed water 100 cm, cone height is equal to 33 cm, basin area is equal to 0.8 m^2.[1]

Badawi W. Tleimat et.al, did the productions of several solar stills of different designs, some with double strength window-glass covers and others with plastic-film covers. Two small identical solar stills were designed and tested over a period of two years. One was covered with a double-strength window glass (0-125 in. thick) and the other was covered with a Tedlar plastic film (0.002 in. thick) which was mechanically treated to produce a wettable surface. Of the four other solar stills tested, three were covered with the Tedlar film and the fourth was covered with the double-strength window glass. These units were of different designs.The factors of major importance in designing for the use of plastic film are its flexibility and its high thermal expansion coefficient. So, instead of plastic cover, glass covers gives higher productivity since it can transmits more amount of radiations incident on it.[2]

Ismail et.al, designed & manufactured a transportable hemispherical solar still. The still mainly consists of the circular basin (tray) and absorber plate carrying the saline water, the hemispherical cover, the conical-shaped distillate collector, the distillate output plastic container, and the mobile support structure. The basin of the still (tray) and absorber plate, and the collector were all fabricated using aluminum. The basin contains the absorber aluminum plate which has a surface area of 0.5 m^2 and a thickness of 4 mm. The absorber was coated with black paint to maximize absorption of the incident solar radiation on the basin. The hemispherical cover, located on the top of the solar still unit, was made of a transparent plastic with absorptivity and transmissivity equal to 0.9 and 0.8, respectively. In experimentation, tests started around 8:00 am when the still was allowed to warm up for approximately 1.5 h before measurements of distillate yield and temperatures were taken at every 30 min time interval for approximately 8.5 h. During these tests, the hourly measurements of wind speed and solar radiation were recorded. The still efficiency and performance conversion ratio (CR) were calculated.[3]

V. K. Dwivedi et al, carried out thermal modeling of a double slope active solar still has been on the basis of energy balance of east and west glass covers, water mass and basin liner under natural circulation mode.. The thermal model of distillation system has been validated for hourly data for inner and outer glass cover temperatures, water temperature and the yield. The hourly thermal and exergy efficiency of active solar still have also been evaluated for 0.03 m water depth. In experimental setup, the areas of double slope solar still and flat plate collector are 2 m^2. The flat plate collector is integrated with double slope solar still in such a way that the hot water from collector plate enters into the basin under natural circulation. The inlet and outlet connections to the collector plate are taken from the bottom of the basin.[4]

Imad Al Hayek et.al, compared the effect of using different design of solar still on water distillation. Two different basin-type solar stills were designed from locally available materials and locally manufactured components. Both solar stills have 1 m^2 basin areas for comparison purposes, are made of 1.5 mm galvanized stainless-steel sheets, and covered with 4 mm transparent glass. The bases of the stills were blackened on their interior surfaces to enable maximum absorption of solar radiation.[5]

III. PROJECT DETAILS

A) Future Scope

In this work conical shape solar still is been manufactured as it will minimized shadow effect & increased the solar radiation absorption time & hence productivity. Also Nano fluid of copper oxide will be added to basin water so thermal conductivity value will increase, evaporation rate will increased which affect productivity & efficiency of system.
Though passive solar stills are simple in design, fabrication and have low water production cost yet it has not been fully commercialized due to its low efficiency and productivity. A number of performance parameters such as water depth, cover tilt angle, condensing cover cooling, dyes, wicks, reflectors, sun tracking system, thermal and energy storing materials, etc. greatly affect the output of the passive solar still.

B) Objectives

To study various parameter affecting productivity of solar still.
To manufactured conical solar still setup for experimental study.
To study productivity of solar still performance considering various parameters.
To study effect of nano fluid on performance of solar still
To calculate daily efficiency of solar still.

C) Methodology

In this work experimentation will be done on Solar still to study the performance of the system. The set up will be manufactured & observations will be done for basin water temperature, glass cover temperature, ambient temperature, space temperature, productivity. By using temperature's heat transfer coefficient, daily efficiency will be calculated. Stress analysis will be done. Results will be validated by using CFD tool. The total work will be carried out in following steps,

Project abstract selection
Project mapping
Project scope
Literature survey
Design & Fabrication
Experimentation
Calculations
Results
Validation of results.
Analysis

Experimental Setup

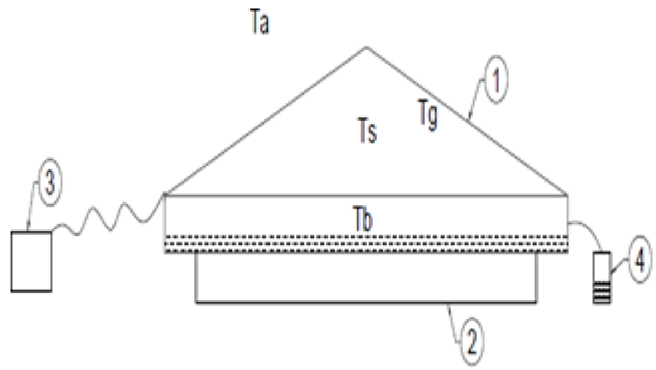

Fig. 1 Line Diagram of experimental setup

1. Glass Frame
2. Base Frame
3. Temperature Indicator
4. Measuring Flask


Fig. 2 Actual Photograph of Experimental Setup

1. Base Frame:- The base frame of solar still shown in fig. 5.3 is fabricated by Mild Steel sheet 3.12mm thick. The Base frame is of circular plate is of diameter 1100mm. Water basin is formed on base frame by welding 900mm diameter welded ring of 50mm height, at the top to store water. The support of base frame is of 50 mm height as shown in fig. The base plate is been black painted to absorb maximum amount of solar radiation so evaporation can be increased. The themocol is used for insulation purpose to avoid heat loss to surrounding

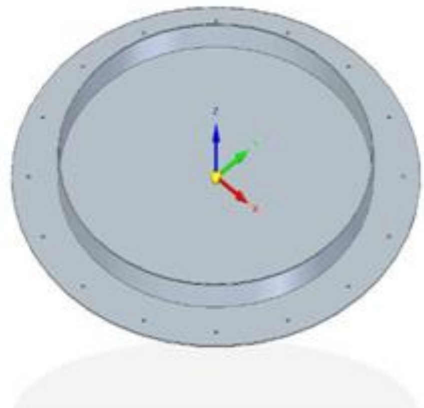
Fig. 3.Base Frame of Experimental Set up

2.Glass Frame:- Glass frame shown in fig. 4 allows to transmit all the solar radiation incident on it to water. The shape of glass frame is conical which will minimize the shadow effect which is observed in other conventional still. The base diameter of cone is 1010mm & diameter of top is 128 mm. The angle of tilt of glass frame is 20^0 with height of cone 210mm.

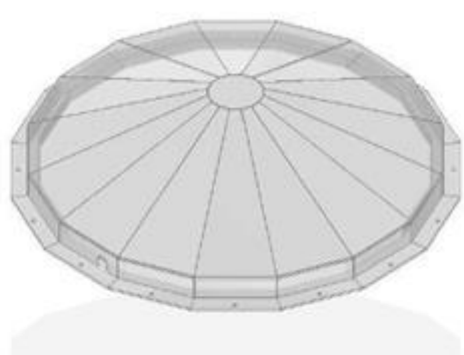
Fig. 4. Glass frame of experimental setup

3. Temperature Sensors:-Temperature of ambient air, basin water temperature, temperature of space inside solar still, & glass temperature are measured by using thermocouples PT100. To measured temperature of basin water & steam silicon coated thermocouples are used. Thermocouples are connected to universal temperature indicator.

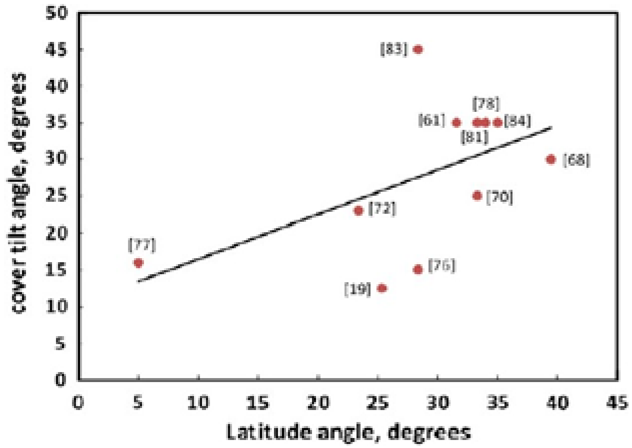

Fig 5. Relation between latitude angle & cover tilt angle [18]

Generally it is found that optimum angle of tilt for solar still is closer to latitude angle. As latitude angle Φ of Pune City, is 18.55^0 from fig. approximately optimum angle of tilt is found to be 20^0. The same is been prove by analytical method.

The optimum angle of tilt (β) is given by,

$$\tan\beta = \frac{\sum(Hb * \tan(\phi - \delta))}{(\sum Hb)}$$

The beam radiation H_b is difference of global radiation H_g & diffuse radiations $H_{d.}$

Also, declination angle δ is calculated by using equation,

$$\delta = 23.45 \sin[\frac{360}{365}(284 + n)$$

Where, 'n' is day of the year.
The value of angle of tilt is,

$$\tan\beta = \frac{\sum(Hb * \tan(\phi - \delta))}{(\sum Hb)}$$

$$\tan\beta = \frac{(5.403428)}{(14.72)}$$

$$\beta = 20.1_{3^o}$$

IV. STRESS ANALYSIS

The base plate dimensions are decided based on requirement of base area of $0.5m^2$ so the basin diameter is selected 0.8m. As the weight of water 40 N is acting on basin area by considering weight of water the stress analysis is done in ANSYS software. The material for base plate selected is Mild steel. The PV glass is selected as glass material. The properties of both are given Fig.

Density	2.52e-006 kg mm^-3
Coefficient of Thermal Expansion	9.e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Compressive Yield Strength	250 MPa
Tensile Yield Strength	380MPa
Tensile Ultimate Strength	420MPa
Young's Modulus	9100 MPa
Bulk Modulus	7583.3 MPa
Poisson's Ratio	0.3
Shear Modulus	3500 MPa

Fig 3. Properties of glass.

Density	7.87e-006 kg mm^-3
Coefficient of Thermal Expansion	1.219e-005 C^-1
Specific Heat	4.34e+005 MJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm
Compressive Yield Strength	250 MPa
Tensile Yield Strength	370 MPa
Tensile Ultimate Strength	440 MPa
Young's Modulus	205 MPa
Bulk Modulus	167.2 MPa
Poisson's Ratio	0.29
Shear Modulus	79.457 MPa

Fig 4. Properties of Mild Steel

The 3D model of experimental setup is prepared in Solid Edge software as per the dimensions. All parts of glass & base are connected together to be a single unit. The 3D model is of solar still is shown in fig. 5

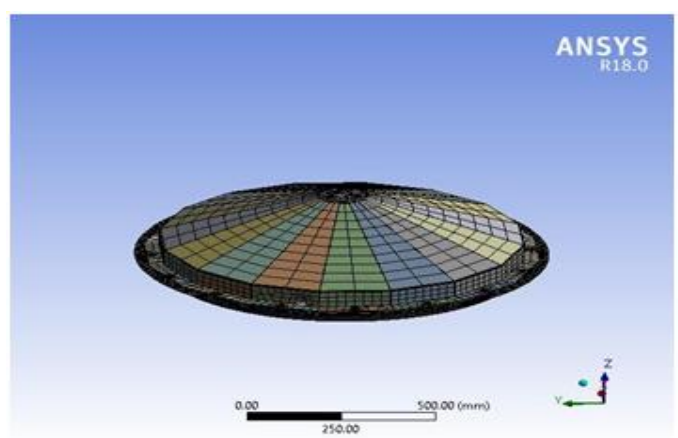

Fig.5. 3D model of solar still

This 3D model is called in ANSYS for doing stress analysis. In stress analysis the meshing will be done by dividing the model in no. of parts. For doing meshing Hex dominant method is selected. The all quad type mesh is selected because it will give maximum accuracy. No. of nodes selected are 141059 7 no. of elements are 18619. The fig. 6 shows 3D model after meshing.

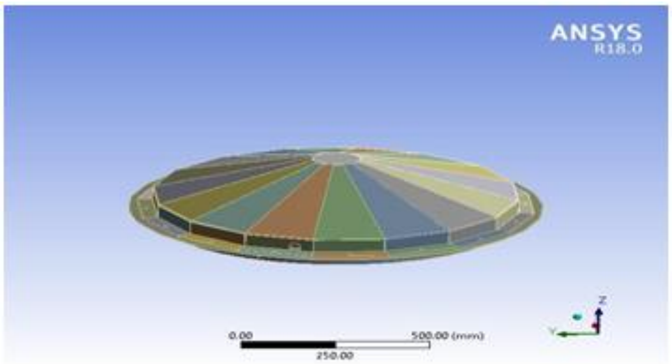

Fig. 6. Meshing of 3D Mode

After meshing in fluid solid interface domain the fluid will be added to model. The fluid is water which will have load of 40N which will be acting on base of solar still. Fig. 7 shows model in fluid solid interface domain.

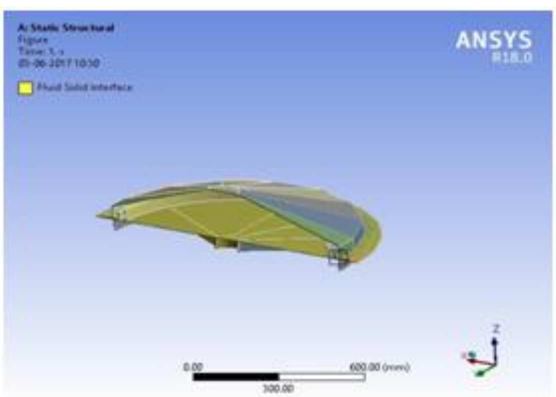

Fig.7. Fluid Solid Interface

By considering the load of water acting of base the analysis has been done. The results are as follows,

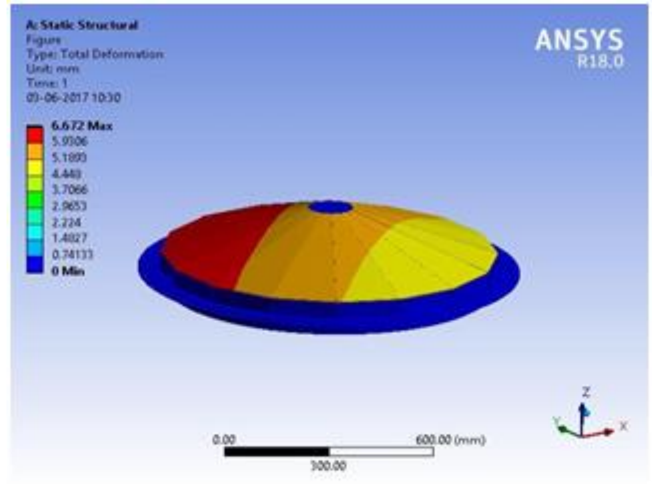

Fig. 8. Equivalent (Von Mises) Stress

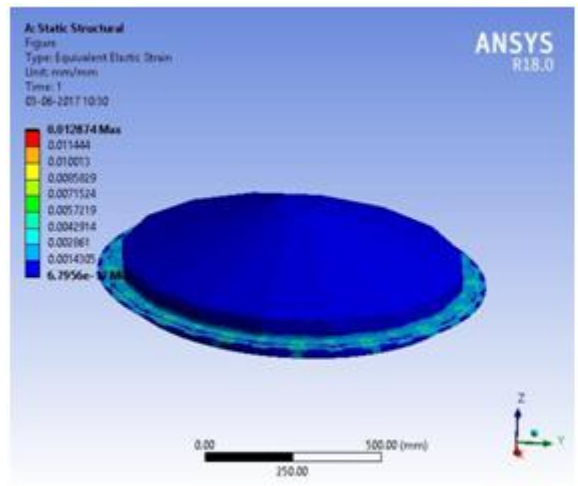

Fig 8. Equivalent Elastic Strain

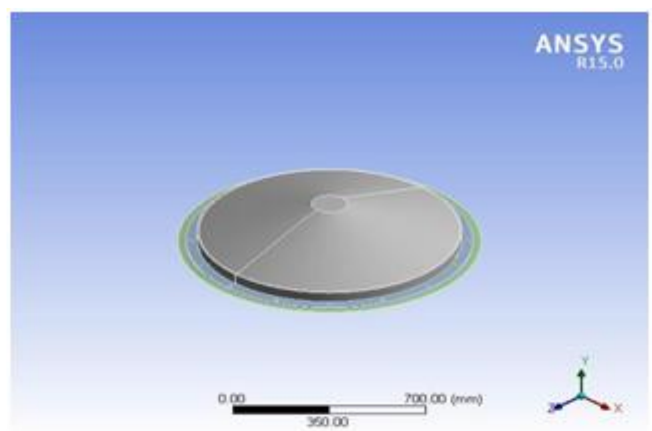

Fig. 9. Total Deformation

Fig. 9. shows maximum value of Von Misses stresses are 80.66 MPa is less than 250Mpa which is yield strength of plate. Also Fig. 9 shows equivalent elastic strain & total deformation produced in still respectively. The maximum elastic strain obtained is 0.012874 mm & maximum total

deformation is 6.672mm which are negligible values. Hence the solar still will be safe for the load acting on it.

Thermal Analysis

In experimentation, during day time solar still continuously subjected to solar radiations & ambient temperature. The radiations from the sun will be absorbed by the basin water because of it water will be get heated, its temperature increases up to evaporation point, it will starts evaporating. Due to low temperature of glass surface vapor condensed on it. As water will be heated up to evaporation point temperature inside the still is also high. Also when Nano fluid will be added in basin water temperature inside still will increase further more compared to water. From above, it is understood that temperature will play very important factor in performance of solar still. Hence it is necessary to do thermal analysis of solar still. While doing thermal analysis material & there properties considered are shown in table To study thermal analysis of solar still 3D model has been prepared in Solid-Edge software as per the required dimensions. The solar still consist of two part one is of top cover & another is base of solar still. For top cover material is solar glass & base is made of mild steel. The properties of glass & mild steel are given in table. Also fig 10 will represent 3D model of experimental setup.

Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	3.150 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled

Fig 10. 3-D model of experimental setup

3-D model is called in ANSYS R15.0 software for doing thermal analysis. The geometry of the model is repaired by space cleanup. Also rechecking is done with design module. In space claim extra edges, tangents, duplicate surfaces, spines, gaps, & intersection were prepared. For doing analysis of solar still in ANSYS meshing is done. The meshing is done by using Hex dominant method. All quad type mesh is selected because it wll give accurate results. Total no. of nodes selected are 66975. The no. of nodes selected are 66975 because even if number of nodes increased results remains same. 24466 is the the total number of element & global setting is used for element inside nodes. Table gives details about meshing & fig shows 3-D model after meshing.

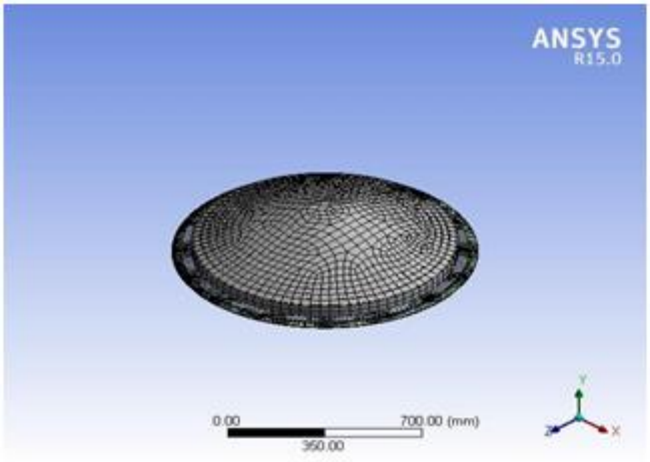

Fig 11. 3-D model of solar still after meshing.

The model is constrained at one point and boundary conditions of ambient temperature are selected. The observation are made from morning 9am to evening 9pm in step of 1 hour for solar radiations of particular day. the temperature reading obtain for 9 days.

V. CONCLUSION

1. The stress analysis & thermal analysis shows that for given load & temperature the selected material is safe.
2. It is observed that basin water temperature, heat transfer coefficient, productivity will be increases with increase in ambient temperature for constant water depth & % of Nano fluid.
3. Also as % of Nano fluid increases the productivity of solar still increases for 0% , 0.05%, 0.1% for water depth of 1cm water obtain is 2.19l it, 2.45 lit., 2.89 lit respectively.
4. Purity of Water Increases due to increasing shadow effect.

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