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Proposing Novel Approach for Solar Still Performance Enhancement by Using Gravity Assisted Heat Pipes: Experimental and CFD Modeling

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ABSTRACT

The great increase of population tends to increase the demand of fresh water for humans, animals, and agriculture. There is a lack of potable water while salt water is abundant but not suitable for human usage. Solar distillation is one of humans' earliest methods for water treatment, and it is still one of the most popular treatment solutions. For this purpose, a modified solar distiller using flat plate solar collector with gravity assisted heat pipes was design and constructed in Faculty of Engineering, Menoufia University, Egypt, Latitude 30.565º N and longitude 31.013º E. An experimental program was conducted in two ways simultaneously. The first; two conventional distillers with a basin having water depths of 2 and 9 cm. The second, one modified solar distiller with 9 cm water depth using flat plate solar collector with gravity assisted heat pipes. The results obtained indicated that the daily productivities for conventional solar distillers with water basin depths of 2 and 9 cm are 1.48667 and 1.67333 lit/m^2, respectively. Also, the daily productivity for the modified distiller with water basin depth of 9 cm is 1.75333 lit/m^2. The enhancements in daily productivity of conventional distiller and modified one with 9 cm compared to conventional distiller with 2 cm water depth are 12.55% and 17.93%, respectively. A CFD modeling of transient mode for two conventional distillers with 2 and 9 cm water basin depth was performed. The differences between experimental and CFD results show that the daily average difference percentage between the simulated and experimental absorber plate temperature related to the experimental results was 11.74%, for glass cover temperature was 7.53% and for the hourly productivity was 9% for basin water depth 2 cm and 30.9 for 9 cm basin water depth.

Keywords: *Solar energy; Flat Plate solar Collector; Thermosyphon; Solar Distiller; Desalination*.

1 Introduction

Energy consumption increases dramatically with the increase in human population [1]. The world population is expected to have doubled by the middle of the 21st century, while the global demand for energy is expected to increase by 1.5 to 3 times by 2050 [2]. Potable water and clean air are the most valuable resources for human survival [3]. The world's supply of potable water is running out because of the high increase rate in water demand in the last two decades. Durkaieswaran and Murugavel [4] reported that freshwater demand per person increased from 75 to 100 lit/day in the twentieth century. Water covers 70% of our planet and the fresh part for drinking and irrigation is incredibly rare. Only 3.5% of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use [5,6].

Conventional basin solar stills were studied by El-Sebaey et al [7-9]. They concluded that the daily productivity was between 2 to 4 lit/m2 day. Tanaka [10,11] and Dev et al. [12] studied the effect of internal and external reflectors, they found that the daily productivity was increased between 2 to 3.5 times without reflectors. Badran et al. [13] and Prasad et al. [14] investigated the performance of solar stills coupled with flat plate and parabolic concentration collectors. Madhlop and others [15-18] studied solar stills coupled with separated condensers. Nafey et al. and others [19-23] evaluated the daily productivity of solar still by increasing the free surface using floating perforated black plate, floating cum tilted wick, wire type, and energy storage medium [24]. Tanaka and other researchers [25-29] investigated the effect of recovering energy from vapor latent heat, sandy heat reservoir, shallow solar pond, and phase change materials on the still daily productivity [30].

A modified distillation system has been designed and made by N. H. Mahmoud et al. [31]. The system comprises a solar distiller with a single slope with solar water heating system. A thermal storage system is being used by the solar water heating system. During the day, solar energy is captured by the solar water heating systems and stored in thermally insulated water tanks. When necessary, the distiller uses this energy as a heat source. The modified distiller has been compared to another standard solar distiller that solely uses solar energy as a heat source. The four seasons have been the focus of experiments that have been run throughout the day. Additionally, the impact of incorporating zinc oxide nanoparticles with a diameter of 23–28 nm into the thermal storage system's working fluid has been examined. With two distinct volume fractions of 0.05% and 0.1%, nanoparticles have been introduced. The findings revealed that an increase in the conventional distiller's production varies from 46.8% to 105.4%, with an annual average of 67%, was obtained. Without nanoparticles, the storage system's daily efficiency was 48%; for 0.05% and 0.1% volume fractions of nanoparticles, respectively, it was 50.7% and 51.2%, respectively.

Mousa et al [32] have conducted a thermal storage system with a flat plate solar collector at a latitude of 30.56° N and a longitude of 31.01° E, Faculty of Engineering, Menoufia University in Shebin El-Kom, Egypt. The system consists of a flat plate solar collector, recirculation pump, and insulated water tank making up the thermal storage system, which collects solar energy and stores it as sensible energy. The measurements were made between August 2015 and August 2016. According to the findings, the storage tank reaches a temperature of roughly 80 °C in the summer and 55 °C in the winter. In summer, the average stored energy reached a maximum of 16.11 MJ/day and a minimum of 10.26 MJ/day in fall. About 13.69 MJ/day of stored energy was estimated on a yearly average basis. Nanofluid with zinc oxide nanoparticles were added to the tap water. For volume fractions of 0.05% and 0.1%, the stored energy rises by 3.36% and 7.78%, respectively. Additionally, the system daily efficiency was enhanced by 4.81% and 6.57% in comparison to the previous state without nanoparticles.

Mousa M. Mohamed and Mostafa A. Abd El-Baky [33] conducted experiments on stepped basin solar water distillers using two different materials: cement and aluminum absorbers. They made two modifications to these distillers in order to increase their efficiency. The first modification involved adding a separate condenser to the cement absorber distiller to improve the condensation process and daily productivity. The second modification involved using a plate thermosyphon charged with acetone located at the bottom of the water basin in the aluminum absorber distiller to increase the input energy and improve water vaporization and condensation. The optimal tilt angle of the glazing surface was found to be between 10 and 20° at a latitude angle of 30° N. The daily productivity of the cement absorber distiller was found to be 2.08 lit/(m^2.day), which increased by 18% with the addition of the separated condenser and 11% increase in the overall efficiency. The average daily productivity of the aluminum absorber distiller was 2.96 lit/(m^2.day), which increased to 3.49 lit/(m^2.day) with the use of the plate thermosyphon and 15% increase in the overall efficiency.

To enhance the efficiency of the solar distiller, Brusewitz [34] recommended using a stepped basin solar still. The use of a secondary condenser on the distiller's shaded side was suggested and found the secondary condenser decreases the distiller's output rate and operational efficiency. Pandey [35] conducted an experiment to cool the glass cover of the solar still with driven air bubbling. The results indicated that ambient air bubbling, ambient air bubbling after drying, both dry ambient air bubbling enhanced distillate output by 33.5%, 47.5%, and 30.5, respectively. The effect of placing two movable flat reflectors on the sides of the distiller was investigated by Hegazy and Mahmoud [36]. In two different examples, experimental and theoretical research has been done. Periodic adjustment was the first, and sun tracking was the second. According to the findings, following the sun results in incidence solar radiation that is 20% higher efficiency and productivity that is 25% higher than daily adjustment.

Fath and Elsherbiny [37] studied the installation of a passive condenser in the shaded area of a single sloping distiller. Theoretical investigation of diffusion, purging, and natural circulation were three techniques of vapor transfer from the distiller space to the condenser that was discussed. They found a 45% increase in distiller efficiency by purging over without using condenser. Badran et al. [38] described a solar still with a flat-plate collector added. The fin-tube collector was connected to a distiller basin such that its exit fed the still basin rather than the common storage tank. The results showed that using tap water as a feed increases system output by 23.1% and using salt water as a feed increases production by 52%.

There are two CFD simulation modes, steady and transient mode. Steady mode was presented in [39-41]. The transient mode is more complicated than the steady mode as there is no experimental data to be fed, only the designed still model (configuration and dimensions) with still orientation, mesh, date, and location of the experiment, are to be known as a feeding data. So, it makes more calculations and needs more time. The output from the program is the values and contours of temperature distribution within simulated solar still and the mass transfer rate. M. Keshtkar et al. [42] made 2-D transient simulation for conventional solar still and the location of the experiment was Iran. A comparison between different water basin depths and different inclination angles was made. They concluded that simulated data coincided with experimental data. El-Sebaey et al. [43] made 3-D transient simulation for single slope double basin solar still (SSDBSS) with experimental study. The location was Shebin Elkom, Egypt, absorber area (1m×1m) with water basin depth 2 cm. 1,226,770 elements of structured mesh was presented. The experimental and simulated distilled water per day were 2.855 and 3.148 lit/m^2 so there was an error of 10.26 %.

The objective of the present work is to investigate the increasing the daily productivity of conventional solar stills by adding energy from bottom of water basin with flat plate solar collector with gravity assisted heat pipes. Three models of solar distillers were designed. The first is conventional one with 2 cm water basin depth, the second is conventional one with 9 cm water basin depth, and the third is a modified distiller with 9 cm water depth using flat plate solar collector with gravity assisted heat pipes. Also, CFD simulation for conventional distillers was aimed to compare the experimental results with simulation in transient mode to evaluate the performance.

2 Methodology:

2.1 Experimental Setup:

A schematic diagram of the fabricated experimental conventional distiller is presented in Figs. 1 and 2. The conventional distiller is made from galvanized iron sheets (1.5 mm thickness) with a basin dimension of 300 mm ×500 mm. The wall height of the high-side wall is 230 mm., and the low-side wall is 90 mm. The whole internal basin surfaces were painted black to raise their absorptivity of solar energy. Furthermore, the distiller is well thermally insulated with glass wool to decrease the heat loss from the distiller to the ambient. Traditional transparent glass 4 mm thick, with inclination angle of 25°, is used to cover the distiller. Silicon sealant is used to fill the gaps between the glass cover and distiller body to prevent any vapor leakage to the ambience. The condensed water has been collected throughout a PVC tube that is fixed at the lower end of the glass cover. Moreover, the distiller contains a feeding tube and a drain one, so that the basin water level can be controlled.

All the previous specifications were made for the 2 cm water basin depth. For 9 cm water basin depth, the difference was for high-side wall and low-side wall lengths which were 290 mm and 150 mm, respectively. The modified distiller has the same specifications and dimensions as the conventional one with 9 cm water basin depth, but the modified one is coupled with flat plate solar collector with gravity assisted heat pipes to add energy to the water from the basin bottom Fig. 3. The photo of the experimental set-up is shown in Fig. 4. The inclination angle of heat pipes that coupled between the flat plate solar collector and the water basin of solar still was adjusted at 12o as optimum angle as Mousa et al. [44].

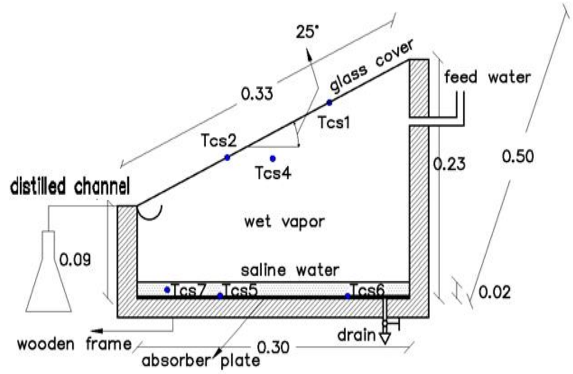


Fig. 1 Conventional solar still with water depth 2 cm

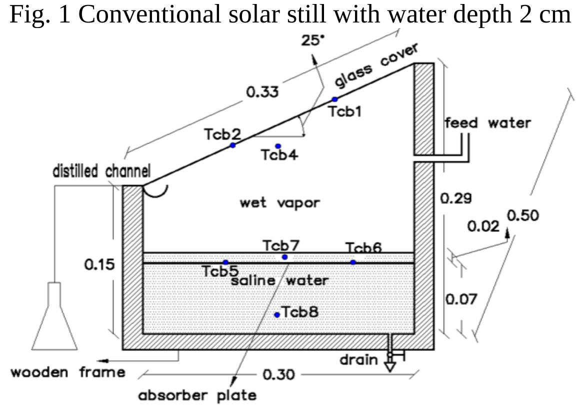


Fig. 2 Conventional solar still with water depth 9 cm

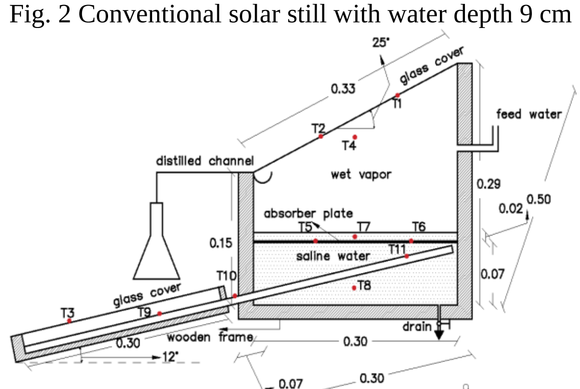


Fig. 3 Modified solar still with water depth 9 cm

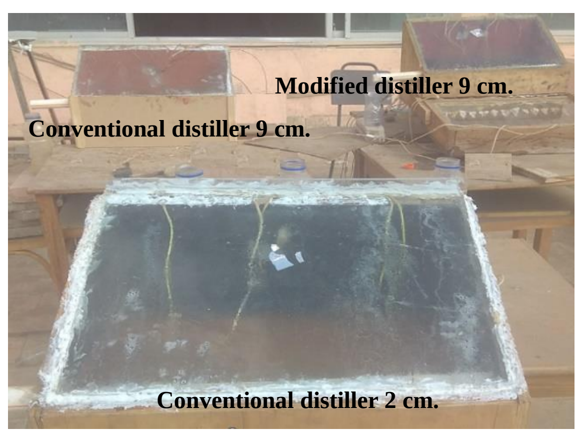


Fig. 4 Photo of the experimental set-up

2.2 Measuring procedure

An experimental investigation was performed in the solar energy laboratory of Mechanical Power Engineering Department (MPE), Menoufia University, Shebin El-Kom (30° 6' N latitude and 30° 98' E longitude), Egypt under actual weather conditions from Jun to and October 2021. The measurements were taken from 8:00 AM to 16:00 PM with a step time of 30 minutes. Solar radiation intensities, temperatures and hourly productivity were the most important variables to be measured.

2.3 Uncertainty and error analysis

Firstly, global solar radiation was measured throughout the day of experiments with a step time of half an hour. The measuring was carried out with EPPLEY PSP Pyranometer, which has a range of (0 to 2000 W/m2) and ±20 W/m2 mistake. Second measuring was the temperature which was measured by calibrated copper-constantan thermocouples (type T) with a range of (-200:200 °C). The thermocouples were attached to NI CDAQ-9174 data Acquisition with an error of ±0.05 °C. The data acquisition was connected to a laptop for reading and saving the data. The measuring was conducted at steady state condition. The hourly productivity was measured by Calibrated Flask with a range of 0.600 ml and an error of ±1 ml.

2.4 Samples of Error Analysis

$$Q=\frac{\text{Volume}}{\text{time}}$$

volume = 0.6 l, $w_{\text{volume}} = \pm\ 0.025$ l [45]

time = 120 sec, $w_{\text{time}} = \pm 0.5$ sec [45]

$$w_Q = \left[\left(\frac{\partial Q}{\partial \text{volume}} w_{\text{volume}}\right)^2 + \left(\frac{\partial Q}{\partial \text{time}} w_{\text{time}}\right)^2\right]^{1/2}$$

$$=\left[\left(\frac{1}{\text{time}} w_{\text{volume}}\right)^2 + \left(-\frac{\text{volume}}{\text{time}^2} w_{\text{time}}\right)^2\right]^{1/2} = 0.000139 \text{ l/sec}$$

$$\frac{w_Q}{Q} = 4.218\ \%$$

3 Results and Discussions.

3.1 Solar intensity distribution

Figure 5 presents the variation of global solar intensity during the daytime. The solar intensity increases until it reaches a max value at noon and after that, it decreases again to reach zero value at sunset.

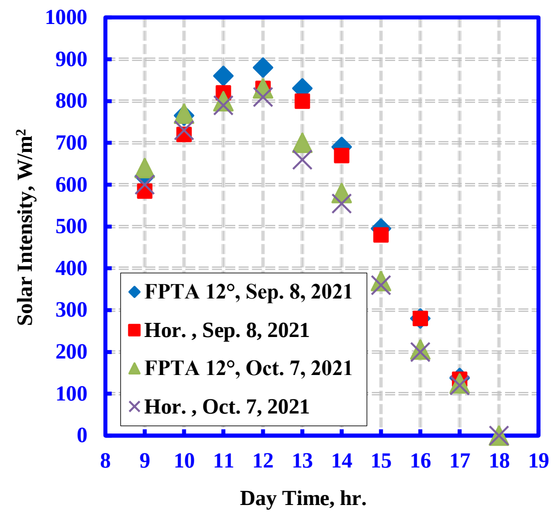


Fig. 5 Global solar radiation at Shebin El-Kom, Egypt (Lat. =30.5 °N, Lon. =31.01 °E)

3.2 Absorber plate temperature variation:

The variation of absorber plate temperatures with time for the 3 distillers was illustrated in **Fig. 6**. The same trend has been produced as the variation of the solar intensity since the absorber plate temperature increases till it has a maximum value, then it decreases to a minimum value. The absorber plate temperature of the conventional distiller with water depth 2 cm takes the lead till 4 PM then leaves it to the modified distiller which, in turn leaves it to the last distiller during night. This is because the solar radiation reaches the absorber plate of the conventional distiller with 2 cm water depth earlier than the absorber plates of the other distillers. The stored energy in water basin as the heat gained by solar radiation is stored in the 9 cm water depth for both distillers -modified and conventional distiller- with 9 cm water depth. The temperature goes down rapidly due to the heat released to the basin is more for the conventional one with 2 cm water depth during daytime.

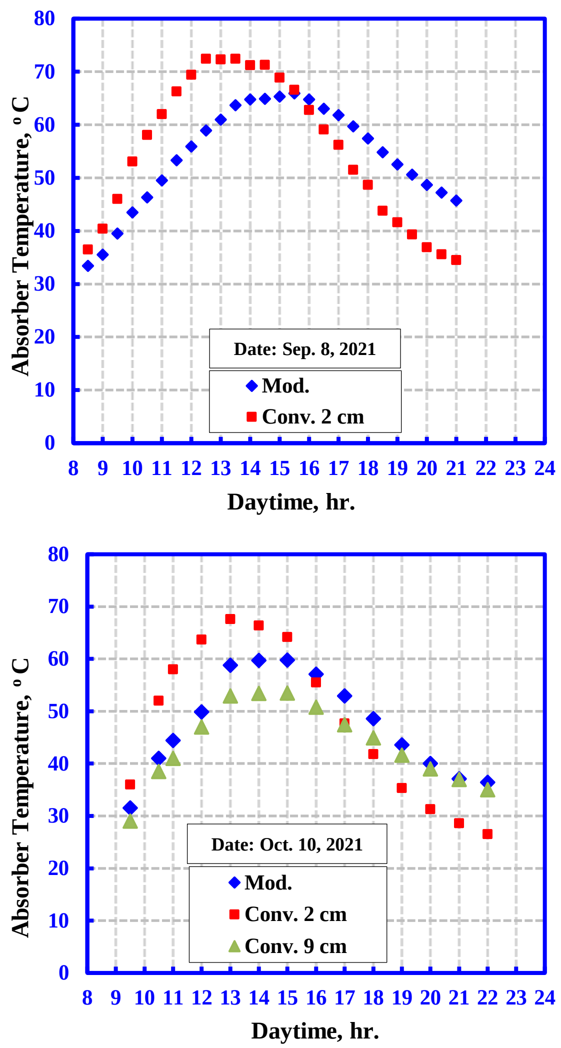


Fig. 6 Variation of absorber plate temperature with time for the three distillers

3.3 Glass cover temperature variation

Figure 7 represents the variation of glass cover temperature from outside with time for the three distillers. It can be noticed that the glass cover temperature variation has the same trend as the absorber plate temperature variation. Also, it can be noted that there is a small difference between the glass cover temperatures from inside and from outside as the glass cover thickness is 4 mm.

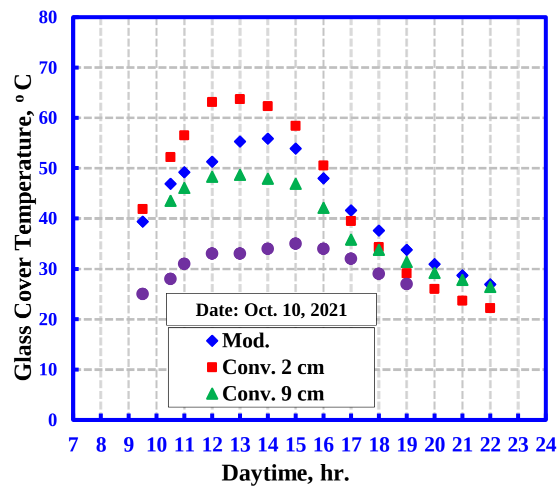


Fig. 7 Variation of glass cover temperature with time for the three distillers

3.4 Productivity

Figure 8 shows how the hourly productivity changes with time for the tested distillers. The hourly productivity changes according to the solar radiation profile. The conventional distiller with 2 cm water depth always has the largest productivity during daytime till 4 PM. This is due to two reasons, first, the shading effect which takes less place in it and the second is the less stored energy in the system and due to smaller water depth. The recovery of stored heat is more rapid for the modified distiller than the conventional distiller with water depth of 9 cm and the condensing section of the heat pipes releases its stored heat to the water basin rapidly. That's why the modified distiller's 9 cm water depth hourly productivity is more than the others after 4 PM till 7 PM. Then, after 7 PM the heat pipes inside the distiller have a reverse action as they cool the water basin and decrease the distiller's hourly productivity. The daily accumulated productivity with time for the three distillers was illustrated in Fig. 9. It is shown that the modified distiller with 9 cm water depth has the largest value.

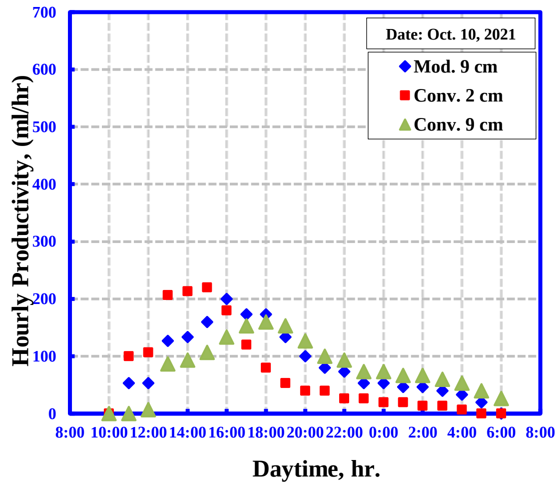


Fig. 8 Variation of hourly productivity with time for the three distillers

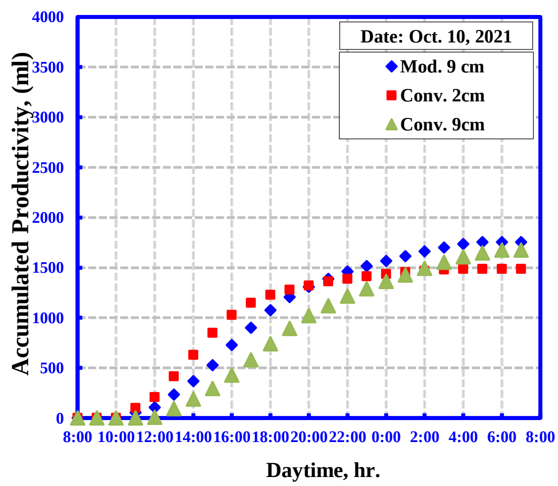


Fig. 9 Variation of accumulated hourly productivity with time for the three distillers

The comparison between the daily accumulated productivities of the three distillers for all the testing days in October is shown in **Fig. 10**. There is a clear rise in the daily productivity for the modified distiller with water depth of 9 cm over the conventional distiller water depth of 9 cm. **Figure 11** shows that the productivity of the conventional distiller with water depth of 2 cm is little higher than the modified one through the days of the experiments during October. There is an enhancement for the modified distiller with water depth of 9 cm over the conventional distiller with water depth of 9 cm of about 17.3%.

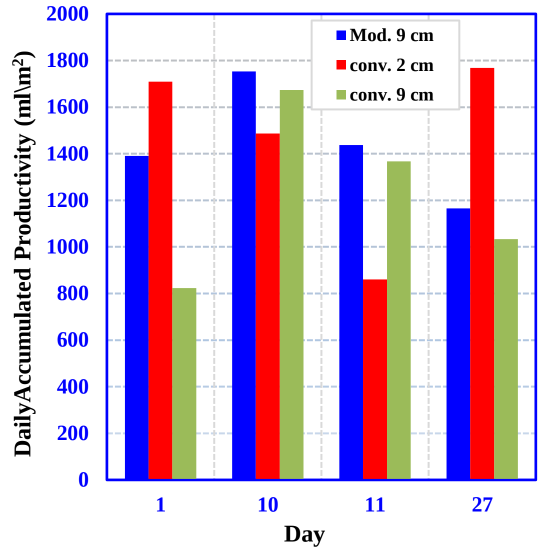


Fig. 10 Comparison between the distillers for accumulated productivity

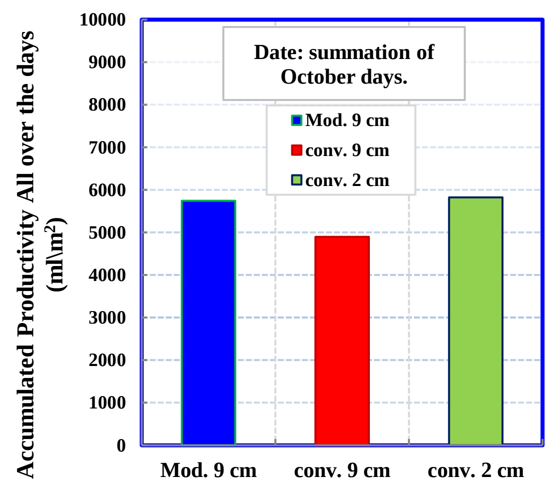


Fig. 11 Comparison between the distillers for average accumulated productivity in October

4 CFD Modeling

A CFD model was conducted to investigate the performance of conventional distillers. A 3-D geometry of the two single slope solar system, conventional distiller with 2 cm and 9 cm water depth were created by ANSYS Workbench. The geometric model of the two distillers with the dimensions of the designed experimental model are illustrated in Fig. 12 and Fig. 13.

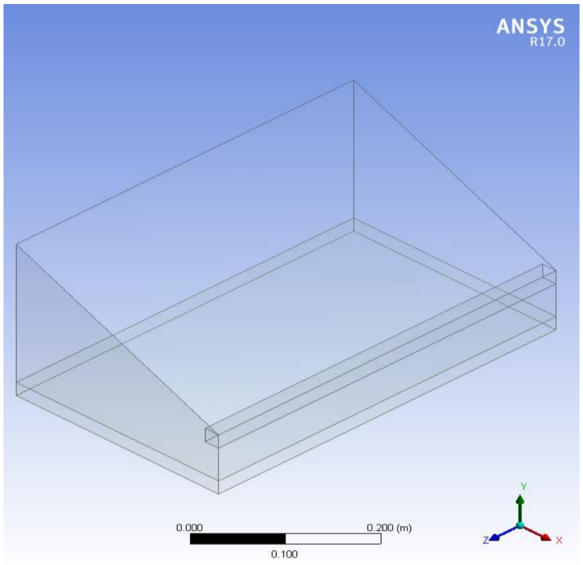


Fig. 12 Conventional SSSS with 2cm water basin

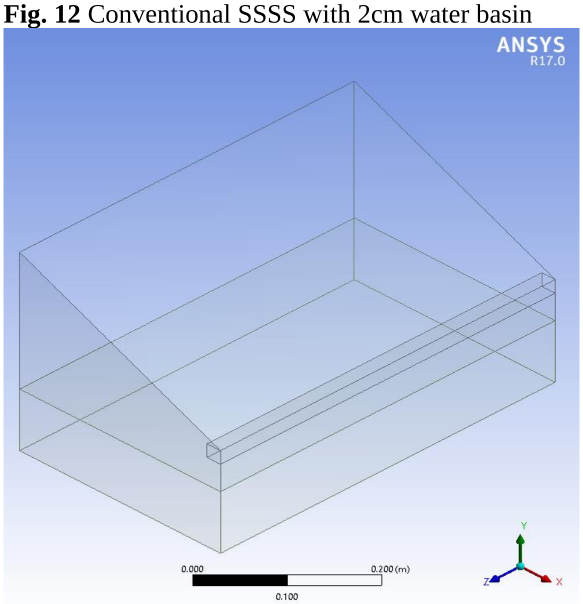


Fig. 13 Conventional SSSS with 9cm water basin

After construction of the geometric model, the next stage in CFD analysis is to create the meshing of the computational region. In mesh generation, the domain is partitioned into a vast number of small cells. Various calculations are solved by the CFD program for each cell to simulate its interior phenomena. The number of cells in the domain has a major effect on the simulation results. The number of cells in the region should be relatively large enough to record the physical phenomena by carrying out simulation. At the same time, increasing the number of cells increases the time needed by the solver for finishing the issue. So, there is always a requirement to get an optimum number of cells which may produce adequately precise results at smaller computational time for the simulation. In general, the appropriate number of cells for a domain varies with the complexity of the problem geometry.

The meshing of the computational domain for the conventional distiller with 2 cm and 9 cm water depth in 3-D view as shown in Fig. 14 and Fig. 15.

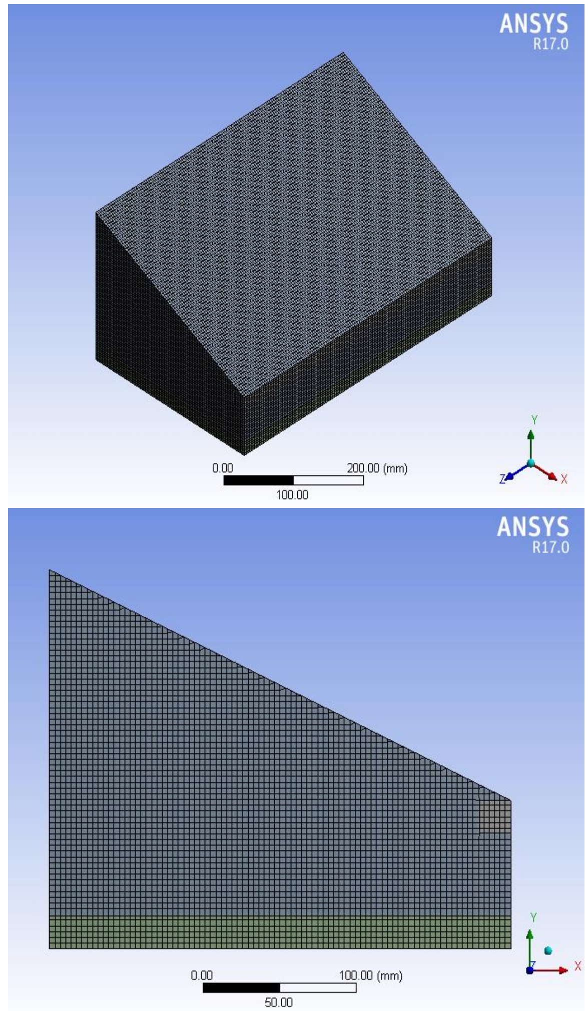
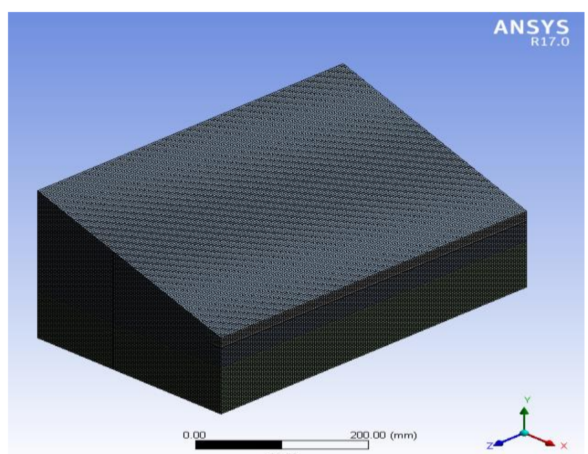


Fig. 14 Meshed CFD domain of 2 cm water depth and sectional view in X - Y plane



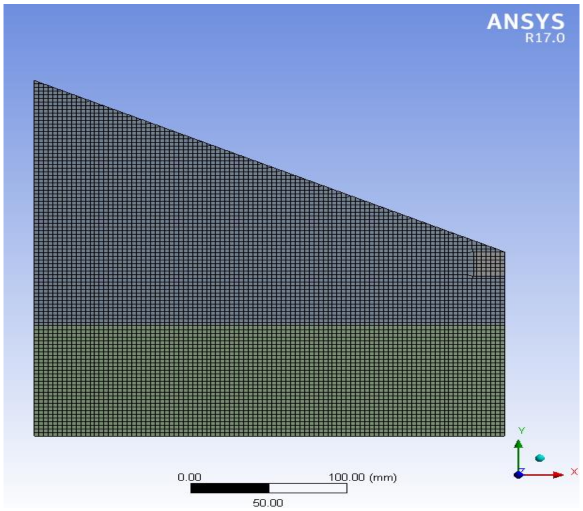


Fig. 15 Meshed CFD domain of 9 cm water depth and sectional view in X - Y plane

For accurate CFD analysis, a high-quality mesh is needed. In this study, Cut Cell technique is utilized for discretization. The Cut Cell technique for meshing is best suited since there are no curved surfaces in the geometries of the studied solar still patterns, which means it can produce correct results with little computational effort. There are 603504 and 1299144 nodes in the hexahedral meshed domains of the two conventional SSSSs with 2 cm and 9 cm water basin, respectively. According to the difficulty of the current challenge, the total elements' number in the meshed domain is sufficiently at 567998 and 1245488. There are many parameters available with ANSYS Workbench for checking the quality of the mesh, some of which are important parameters. Some of the parameters that are vital are Element Quality, Skewness, Aspect ratio, and orthogonal quality, among others. The two parameters, namely Skewness and Aspect Ratio of the generated mesh were tested.

According to the criteria for Skewness, an element with a Skewness value of zero is considered perfect. For a good quality mesh, the average value of Skewness always had to be less than 0.3. **Figure 16** of Skewness for the two conventional SSSSs demonstrates that most elements have a Skewness value less than 0.3 as the average values are 8.585×10^{-3} and 5.3643×10^{-3} for 2 cm and 9 cm, respectively, indicating that most of the elements in the mesh have good quality.

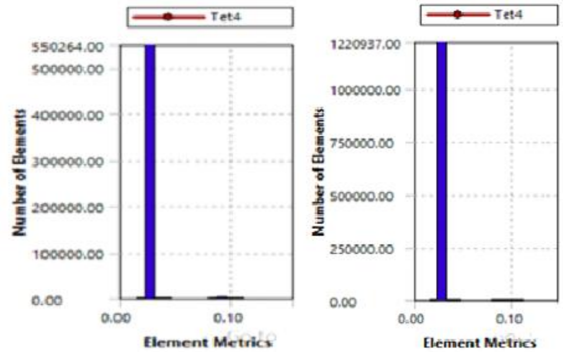


Fig. 16 Skewness of the elements for the 2 and 9 cm water depth of two solar distillers

Aspect ratio is another measure used to evaluate the quality of a mesh. For 3-D elements, the Aspect ratio measures the stretching of a cell and is defined as the ratio of the maximum distance to the minimum distance between the cell centroid and face centroids, or between the cell centroid and nodes. A good quality mesh should have an average aspect ratio value less than 2. **Figure 17** depicts the aspect ratio of the two conventional SSSSs meshes and demonstrates that most of the elements have an aspect ratio value less than 2. From the figure, the values were 1.0466 and 1.0303 for 2 cm and 9 cm, respectively. This indicates that the mesh, which is mostly composed of hexahedron elements, is of good quality based on both Skewness and aspect ratio criteria.

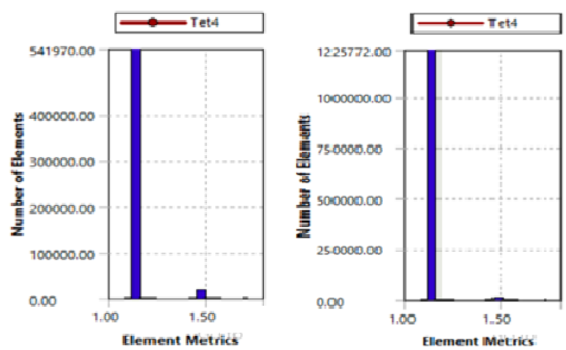
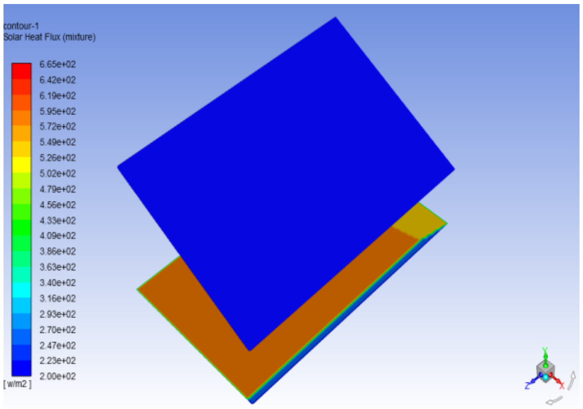


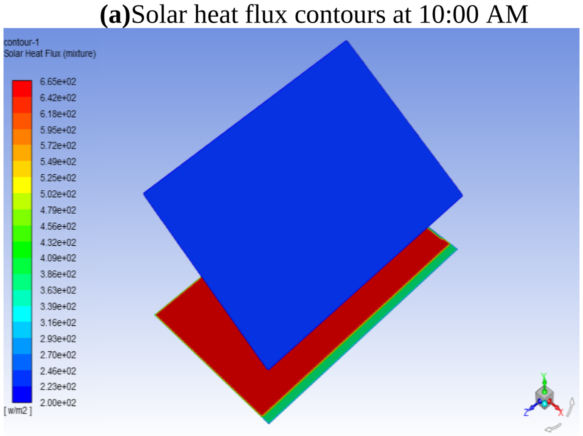
Fig. 17 Aspect ratio of the elements for the 2 and 9 cm water depth of two solar distillers

5. Simulation Results and Discussions

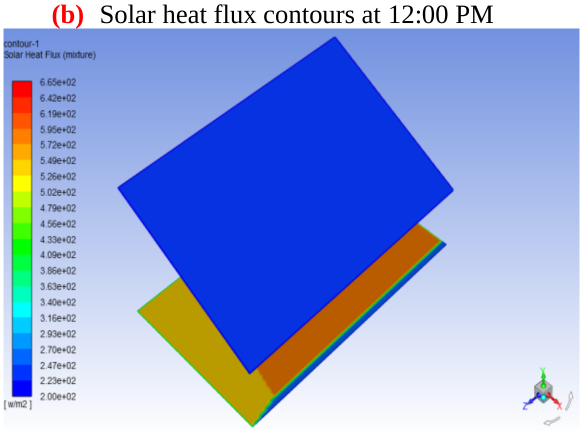
The contours of solar heat flux received by glass cover and absorber plate are shown in Fig. 18. There is a clear rise of the absorbed heat from solar radiation due to the absorptivity of the absorber plate till 12 PM as the solar radiation intensity rises and then it decreases till sunset. The absorber plate was given to ANSYS Fluent as a copper sheet with a high absorptivity and the glass cover was a transparent sheet; that's why the absorbed heat was higher for the absorber plate. The contours of temperature distribution over the glass cover and the absorber plate are shown in Fig. 19. The contours of vapor volume fraction for isometric view of the distiller are illustrated in Fig. 20. It is noticed that the evaporation rate is higher than the condensation rate at 12 PM due to the higher solar radiation over the absorber plate and after solar noon (at 2 PM) the situation changes because of the attenuation of the solar intensity.



(a) Solar heat flux contours at 10:00 AM

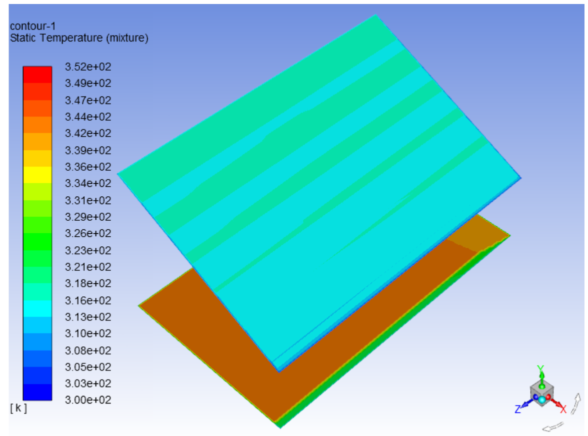


(b) Solar heat flux contours at 12:00 PM

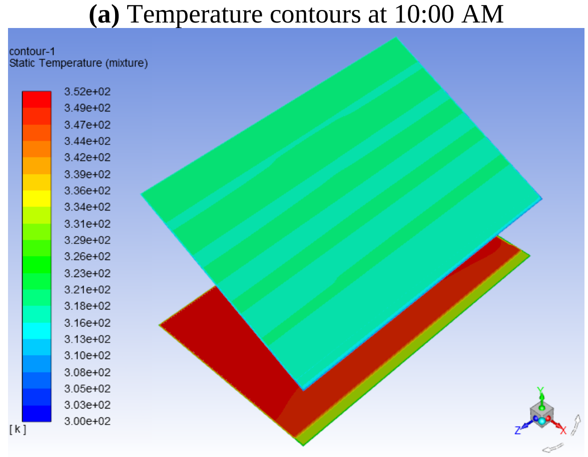


(c) Solar heat flux contours at 2:00 PM

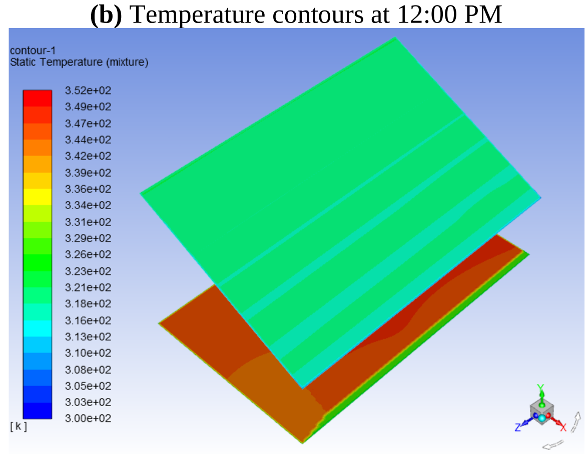
Fig. 18 Contours of solar heat flux received by absorber plate and glass cover



(a) Temperature contours at 10:00 AM

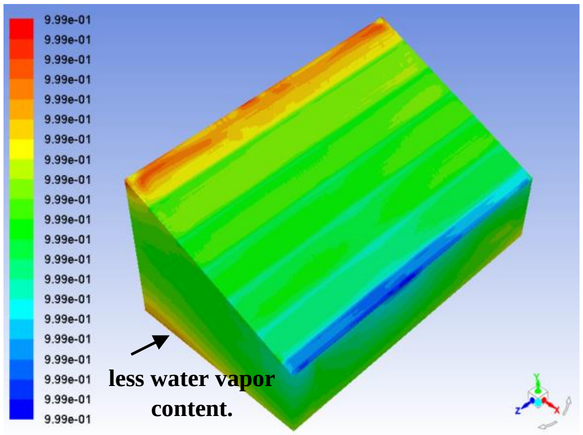


(b) Temperature contours at 12:00 PM

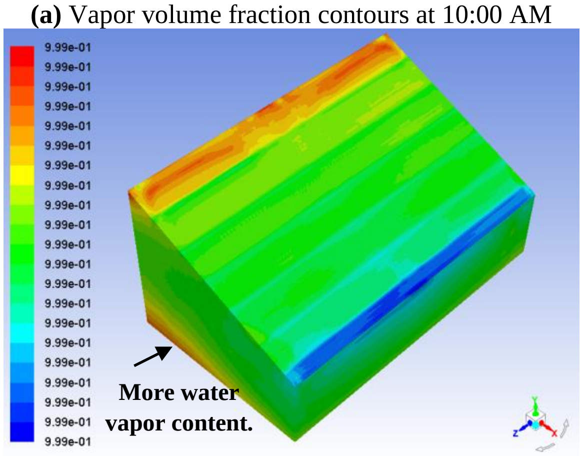


(c) Temperature contours at 2:00 PM

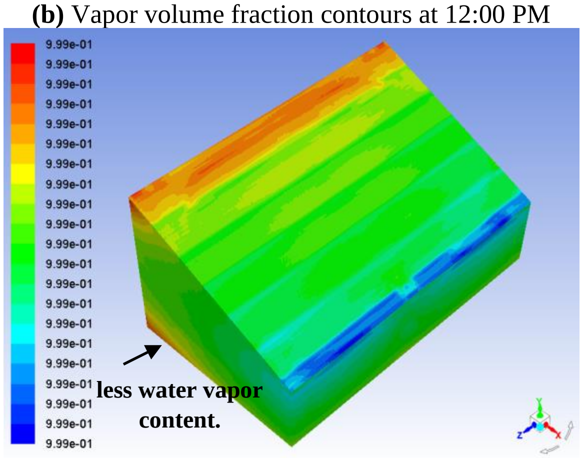
Fig. 19 Contours of temperature distribution over the glass cover and the absorber plate



(a) Vapor volume fraction contours at 10:00 AM

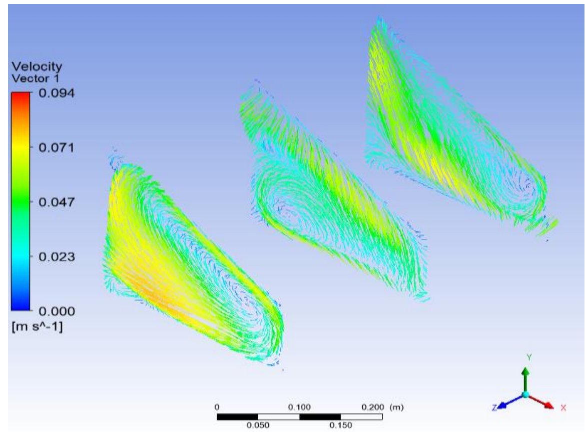


(b) Vapor volume fraction contours at 12:00 PM

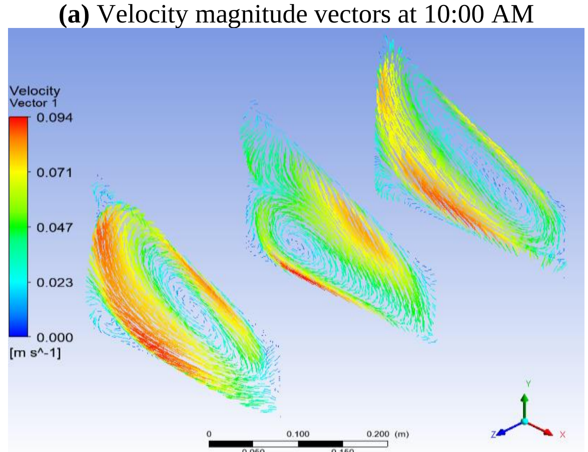


(c) Vapor volume fraction contours at 2:00 PM

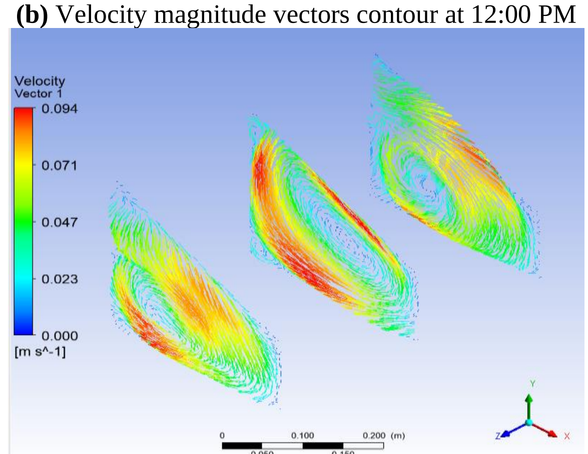
Fig. 20 Contours of vapor volume fraction for isometric



(a) Velocity magnitude vectors at 10:00 AM



(b) Velocity magnitude vectors contour at 12:00 PM



(c) Velocity magnitude vectors at 2:00 PM

Fig. 21 Velocity vectors of magnitude for 3 cross sections away from the west side of the distiller 4 cm, 25 cm, and 49 cm

For 3 cross sections away from the west side of the distiller -4 cm, 25 cm, and 49 cm-, **Fig. 21** indicates the vectors of velocity magnitudes. Until time reaches 12 PM the more movements were from the absorber plate; this shows that the evaporation rate is higher than the condensation rate. The situation reverses after solar noon due to the attenuation of solar radiation.

Figure 22 shows the experimental and numerical solar intensity variation during daytime. It can be noticed that the experimental solar intensity was higher than the numerical solar intensity due to taking fair weather conditions in the solar calculator options in Rosseland model. From the results, it can be observed that the daily average difference percentage related to the experimental results of 5.4%. The experimental and numerical temperature variations during daytime for absorber plate and glass cover were measured and illustrated in **Fig. 23**. It can be noticed, from numerical results, that the temperature distribution of the absorber plate is higher than that obtained from experimental measured. This is due to taking fair weather conditions in the solar calculator options in Rosseland model and sunshine factor of 1. We can observe from **Fig. 23-a**, the daily average difference percentage between the simulated and experimental absorber temperature related to the experimental results was 12.68%. But in **Fig. 23-b**, it was 11.2%.

The numerical results of the glass cover indicate that the temperature distribution is lower than that of the experimental measured. This is because of taking a convection heat transfer coefficient of 5 W/m^2.K for the simulation. Also, we can observe from **Fig. 23-a**, the daily average difference percentage between the simulated and experimental glass cover temperature related to the experimental results was 7%, but in **Fig. 23-b**, it was 7.46%.

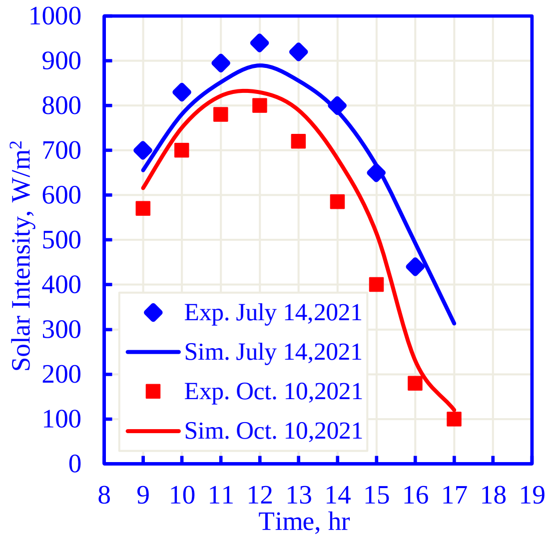
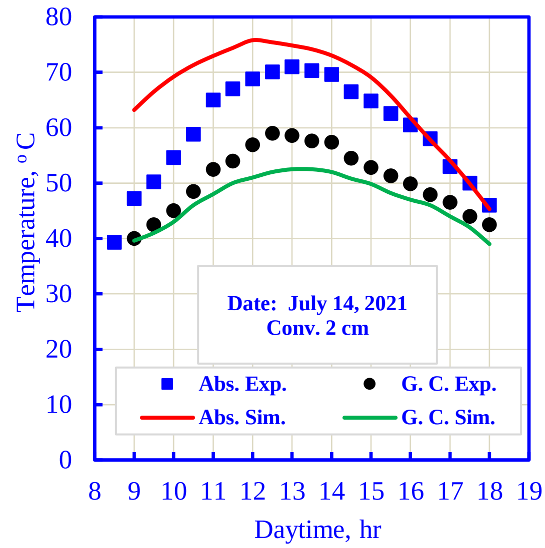
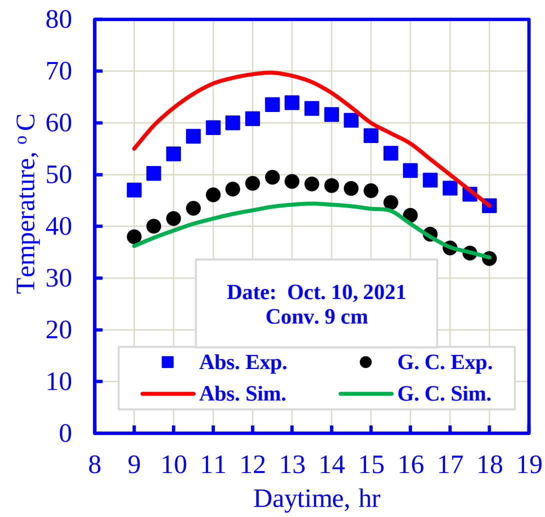


Fig. 22 Solar radiation intensity comparison for experimental and simulated data



(a) Conv. 2 cm



(b) Conv. 9 cm

Fig. 23 Conventional distiller absorber and glass cover comparison for experimental and simulated data

The experimental and numerical hourly productivity variation during daytime is shown in **Fig. 24**. The numerical hourly productivities were larger than the experimental one. This was due to the difference between the temperatures of the absorber plate and glass cover that was larger in the numerical than the experimental results. From **Fig. 24**, it can be noticed that the experimental distilled water began at 10:00 AM for 2 cm water depth and 12:00 PM for 9 cm basin water depth. The reason is that the greater the water basin depth, the more stored energy then more time to produce distilled water. We can notice from **Fig. 24-a**, the daily average difference percentage between the simulated and experimental hourly productivities related to the experimental one was 9%, and from **Fig. 24-b**, it was 30.9%.

The experimental and numerical accumulated productivity variation during daytime were illustrated in **Fig. 25**. The accumulated productivities show an acceptable comparison between experimental and numerical results.

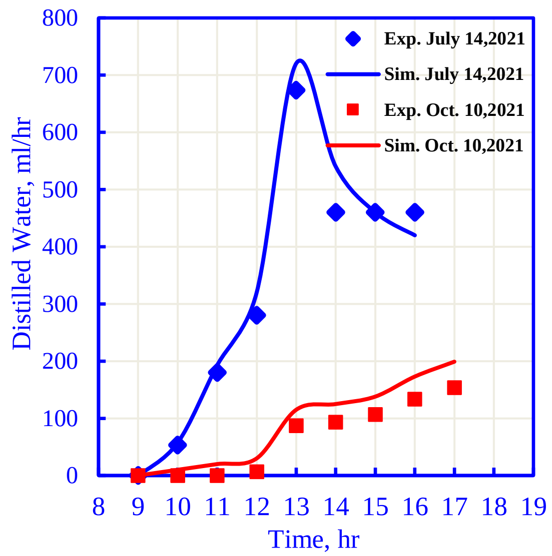


Fig. 24 Hourly productivity of experimental and simulated data for 2 and 9 cm water depth solar distiller

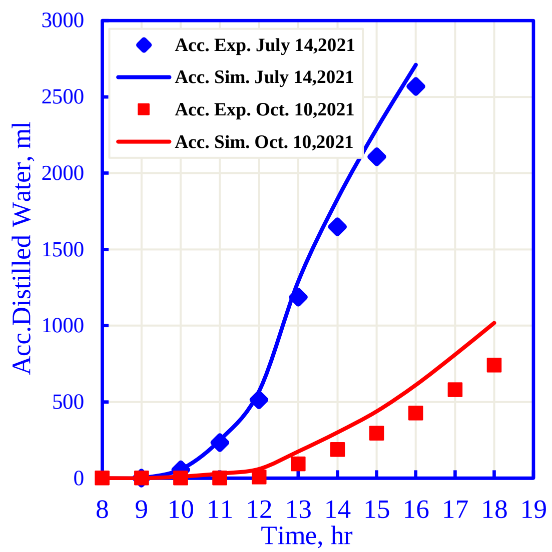


Fig. 25 Accumulated productivity of experimental and simulated data for 2 and 9 cm water depth solar distiller

6. Conclusion

There are two aims for this work. The first was studying the performance of the modified solar distiller with 9 cm basin water depth with flat plate collector using gravity assisted heat pipes and comparing its performance with the conventional solar distiller with 2 and 9 cm basin water depth. The second was making a comparison between simulated data by CFD and experimental results taken for the conventional distillers with 2 and 9 cm basin water depth.

The results are summarized as followings:

1. The productivity of the distilled water is better for the conventional solar distiller with 2 cm water depth until 4 PM, after that, the modified solar distiller has the highest productivity. The conventional solar distiller with 9 cm water depth is the best after 7 PM.
2. All over the days of experiments during October, there was productivity enhancement for the modified distiller over the conventional distiller with basin water depth 9 cm by about 17.3%.
3. The simulated solar intensity distribution from the CFD simulation showed the same trend as the experimental distribution with a daily average difference percentage related to the experimental results of 5.4%.
4. For the two conventional distillers with 2 and 9 cm basin water depth, the daily average glass cover temperature difference percentage between the simulated and experimental results was 7.6% and 7.46%, respectively.
5. For the two conventional distillers with 2 and 9 cm basin water depth, the daily average absorber plate temperature difference percentage between the simulated and experimental results was 12.68% and 11.2%, respectively.
6. For accumulated water productivity, there was an increase for the simulated over the experimental results. The daily average difference percentage between the simulated and experimental productivities related to the experimental one was 9% for 2 cm water depth and 30.9% for 9 cm water depth.

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