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Performance Enhancement of a New Passive Solar Still Design for Water Desalination

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ABSTRACT: To produce pure water, it is known that the desalination of saltwater using solar systems and since a long time is a practical solution, especially in remote areas of rural, which suffer from the scarcity of drinking water due to poor infrastructure, many of which are not connected to the national water grid. The model was produced in ANSYS-CFD. The simulation was performed transient state to validate Practical experiments on solar distillation performance under the different climatic conditions of the city of Karbala, Iraq (latitude 32.6 °N and longitude 44.02 °E). The results of the ANSYS CFD simulation compared with the results obtained from conducting experiments, it showed a good agreement to solar still performance. Finally, it is clear that the simulation results are the ANSYS-CFD is a very important method for analyzing the solar still performance.

KEYWORDS: Solar still, CFD, distillation productivity, thermal energy storage.

INTRODUCTION

Many researchers around the world have conducted numerous studies aimed at improving solar desalination technology, by assessing the impact of some important factors on the performance of the system such as climate conditions, influence geographical of location, and influence operations on the productivity of water [1, 2]. Some researchers have published good results in improving the performance of desalination systems by solar still [3, 4]. Of the methods used to achieve this aim is to increase the condensation process using different methods [5].

In this research, the condensation process was increased, by increasing the rate of condensation, by the increased area of the surface, and the used of phase change materials to conserve and store thermal energy, and used them during the night to continue the process of distillation [6, 7], and preheat the water entering the solar distillation basin using different types of solar collectors [8, 9]. During all experiments, the following variables were recorded for each hour: productivity (quantity of distilled water), water temperature in distillation basin, the temperature of the internal glass, the temperature of the outer glass lid, ambient temperature, vapor temperature. Researchers [10-18] studied the effect of using PCMs on the energy storage and release applications. In this current work, recorded temperatures are compared and investigated validate of these temperatures using ANSYS CFD.

EXPERIMENTAL WORK

Figure (1) showed solar distillation basin made of (1.1 mm) thick stainless steel sheets with a length of (1.23 m), an active area of (1.23 m2), and measurement of width (0.98 m), The solar distillation basin shall be inside the phase change materials basin made of the galvanized iron with the same specifications of the distillation basin but with greater dimensions with measurement of width (1 m), and a length of (1.25 m), The solar distillation basin has been isolated from the PCM basin to avoid mixing water in the basin solar distillation, and PCMs and to avoid the effect of PCMs on the water productivity. The gap between the two basins is filled with 18 liters of phase change materials. The gap between two basins is maintained to be 10 mm by using small metal strips which are welded between two trays to hold them. In the second step, was the manufacture of the upper part of the solar still, which consists of transparent glass with a thickness of 6 mm with a slope of the four sides at the angle of 32°. Glass wool is used with a thickness of 5 cm to isolate the solar distillation basin from the bottom and the four sides and then put it in a wooden box to increase thermal insulation and reduce the loss of energy loss. A channel is placed along the perimeter of the upper edge of the solar still basin to assembles the resulting water, and send it to an external graded vessel to measure the water product. a floater is fixed inside the basin to maintain the water level is constant on 6 cm.

Figure 1. Solar still basin

RESULTS & DISCUSSION

Principle of solar distillation:

The principle of water desalination is simple, by using solar still, the distillation basin acts as a solar absorbing panel Which in turn heat salty or brackish water inside, thus water is only is that evaporates, leaving pollutants and dissolved metals which cannot evaporate. Water vapor begins to rise as a result of the creation of a driving force of convection streams Because of a different temperature among glass and water. Water vapor When in contact with the glass surface of the condensation surface is relatively cold, it will begin condensation in droplets of different size of distilled water. Move condense droplets and gravity along the sloping glass surface. Finally, the condensate water collects through a collection channel.

Different temperatures are recorded every hour taking readings of solar radiation intensity. Table 1 shows the result of solar radiation, productivity, water temperature in the distillation basin, internal glass temperature, external glass cover temperature, ambient temperature, vapor temperature.

Measurement Devices:

Solar power meter (TES- 1333) is utilized to measure the directly solar radiation, SD card data logger 12 channels, graduated vessel. Graduated vessel is utilized into measure a volume of fresh water distilled from a basin solar still. Thermocouples of type-K are used to measure a temperature at inside and outside surface glass cover, ambient and vapor temperature.

ANSYS CFD Results:

The Analysis was applied at various inlet temperatures and solar radiation for solar still. The simulation analysis was carried out using by The software ANSYS CFX 18.2, The Building geometry of the prototype using SOLIDWORKS 2016 The dimensions of the geometry are the same the experimental design. After that used software ANSYS CFX 18.2 to doing meshing for it and applied the boundary conditions to analyzing heat transfer, the structure of computational grids is Tetrahedral as shown in Figure (3). The mesh properties are shown in the table (1). Inflation is carried out in the underside of the solar still, and inflation shown figure (4), in which the number of layers in this place is increased to illustrate the heat transfer and condensation process more clearly.

The purpose of numerical CFD is to study the distribution of temperature and air volume fraction distribution through solar still Prototype, figures (5) to (10) show these behaviors.

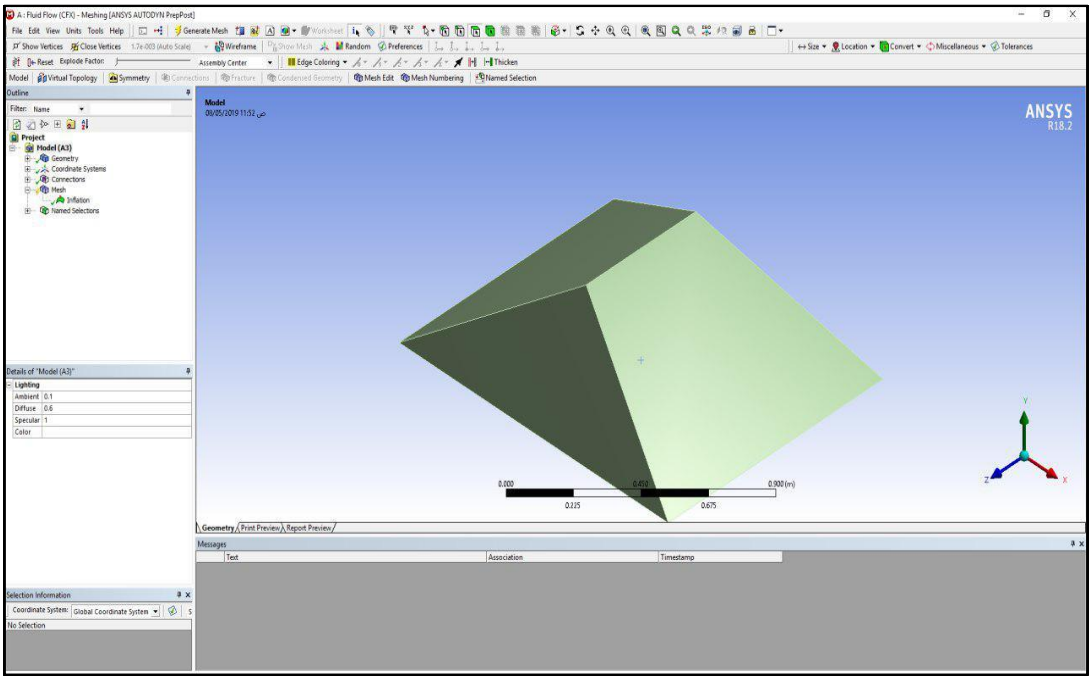

Figure 2. The 3D model of solar still

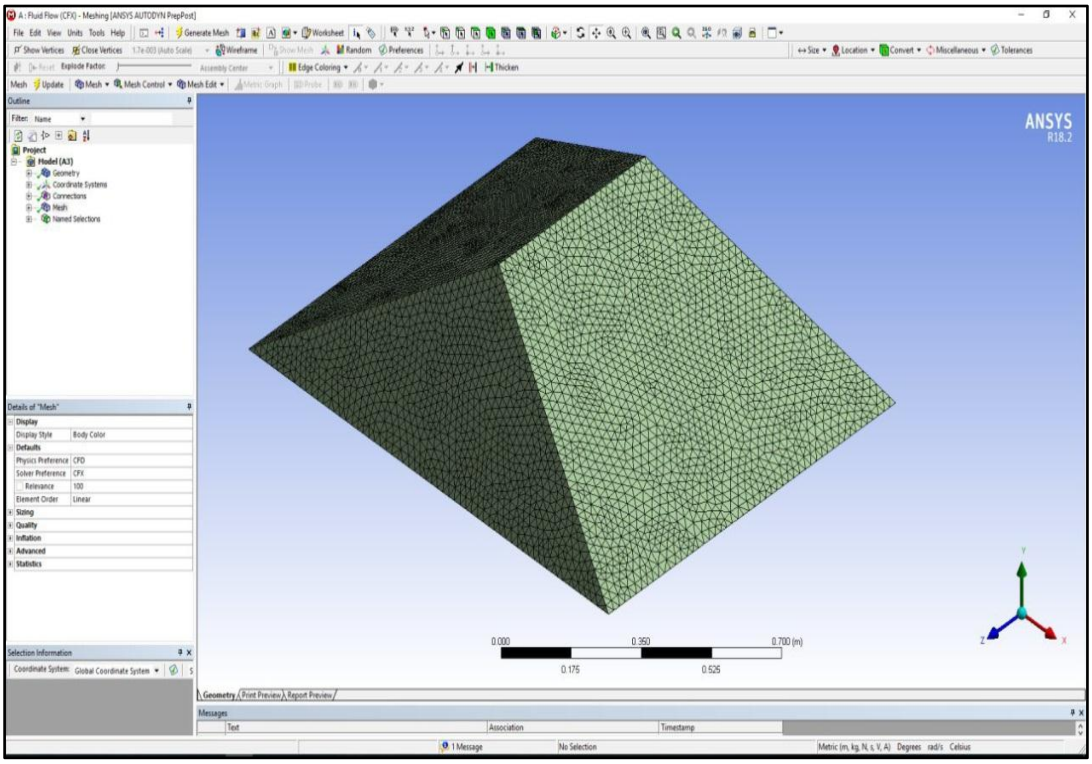

Figure 3. The mesh of prototype section in 3D

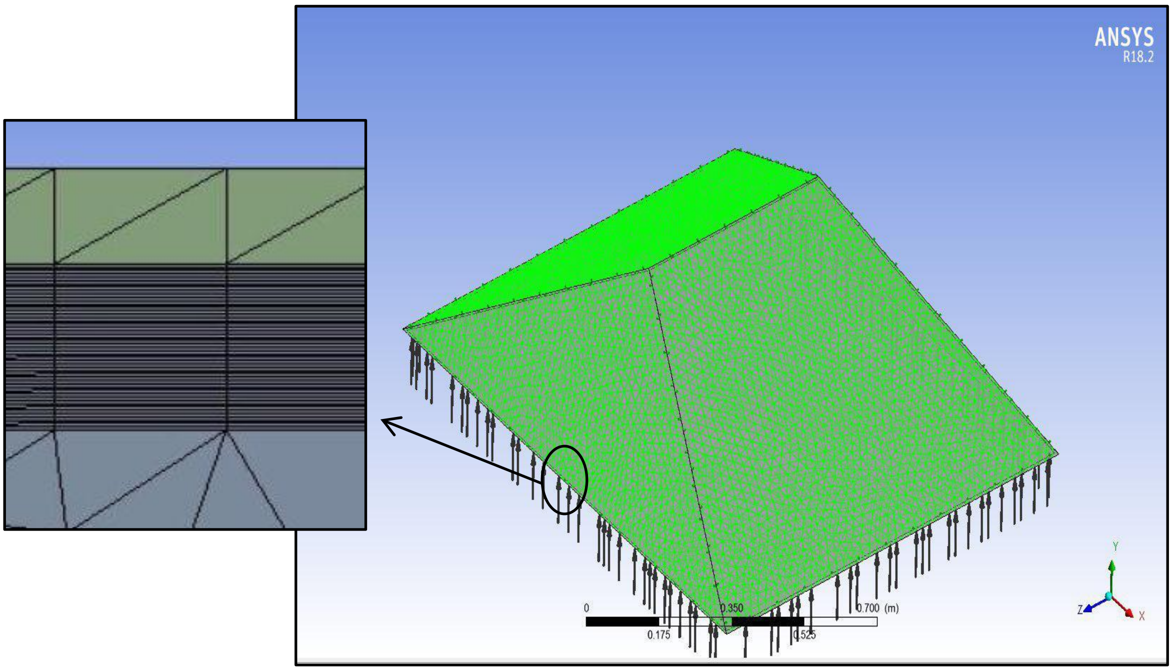

Figure 4. The inflation layers of solar still

Table 1. The Specifications of the mesh

Setup	Specifications
Physics Preference	CFD
Solver Preference	Ansys CFX 18.2
Growth Rate	Default (1.10)
Sizing	Fine
Min Size	1.6706e-004m
Max Size	3.e-002 m
Nodes	26053
Elements	598343
Transition	Slow
Shape of the mesh	The structure of computational grids are Tetrahedral

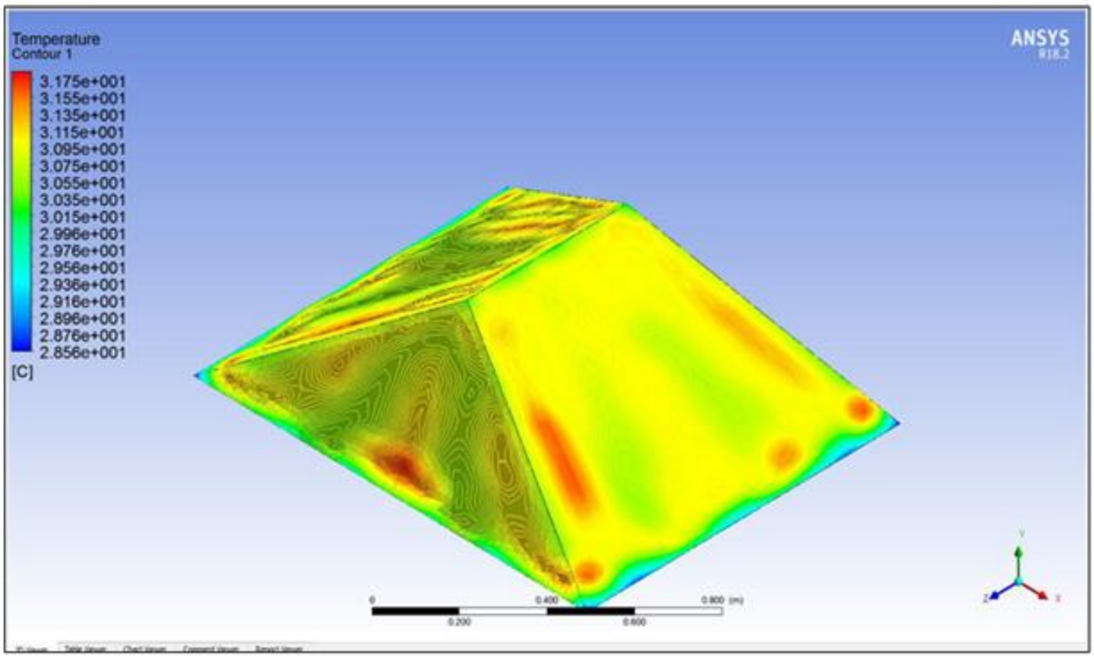

Figure 5. Temperature distribution of solar still at time 2 PM

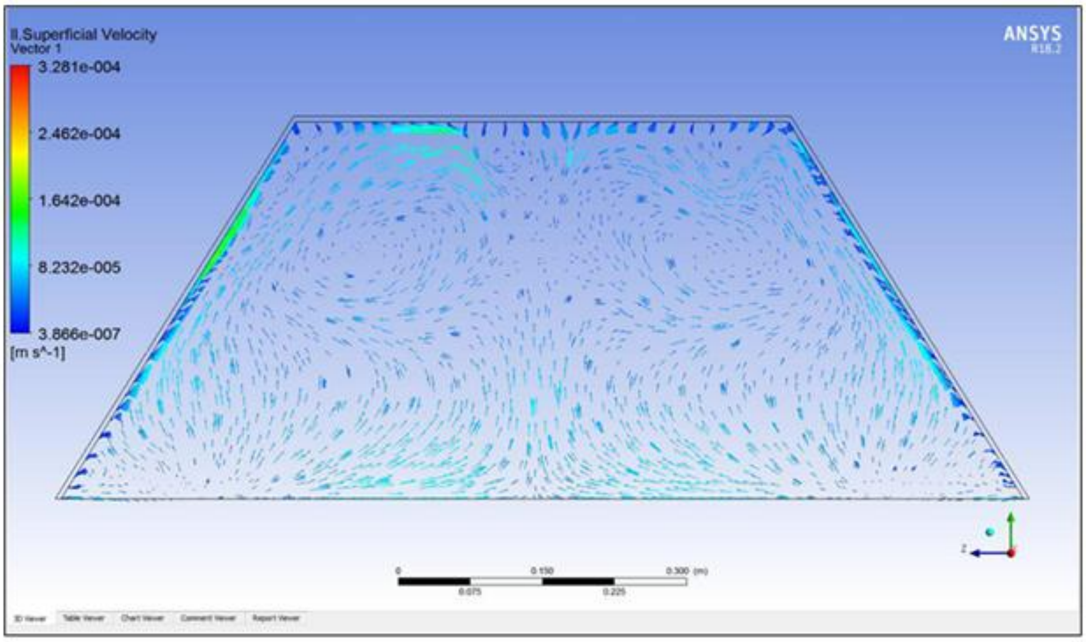

Figure 6. The velocity vector of solar still at time 2 PM

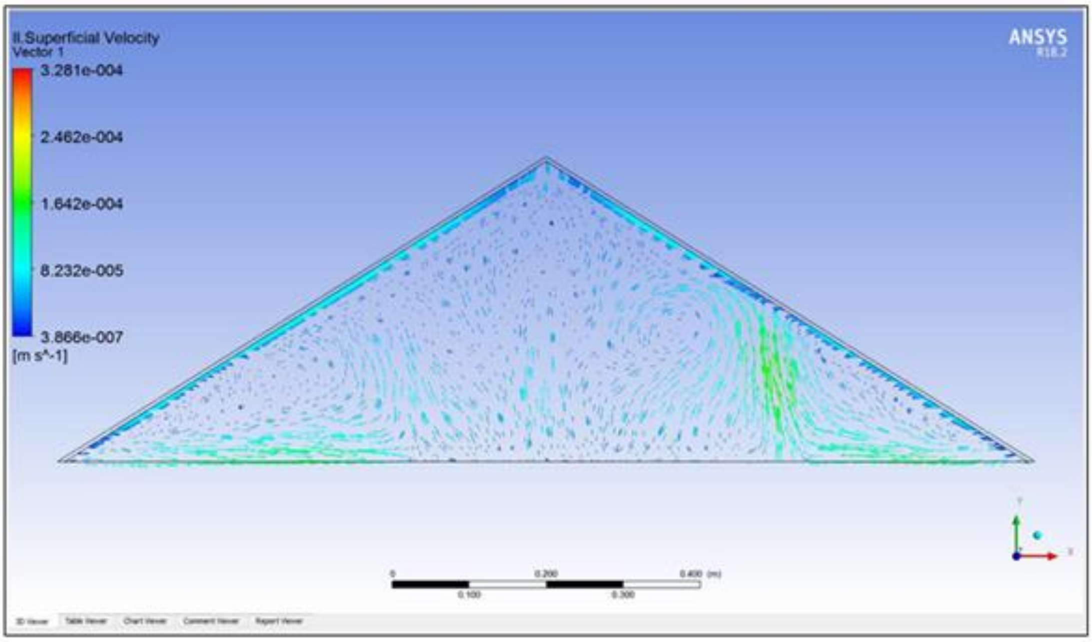

Figure 7. The velocity vector of solar still at time 2 PM

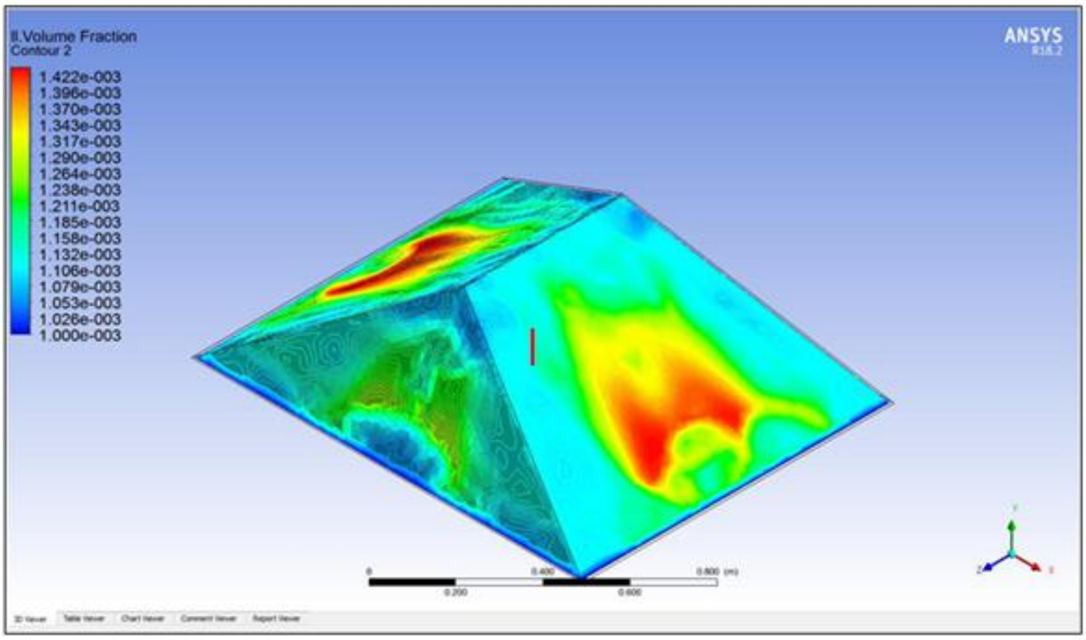

Figure 8. The volume fraction of solar still at time 2 PM

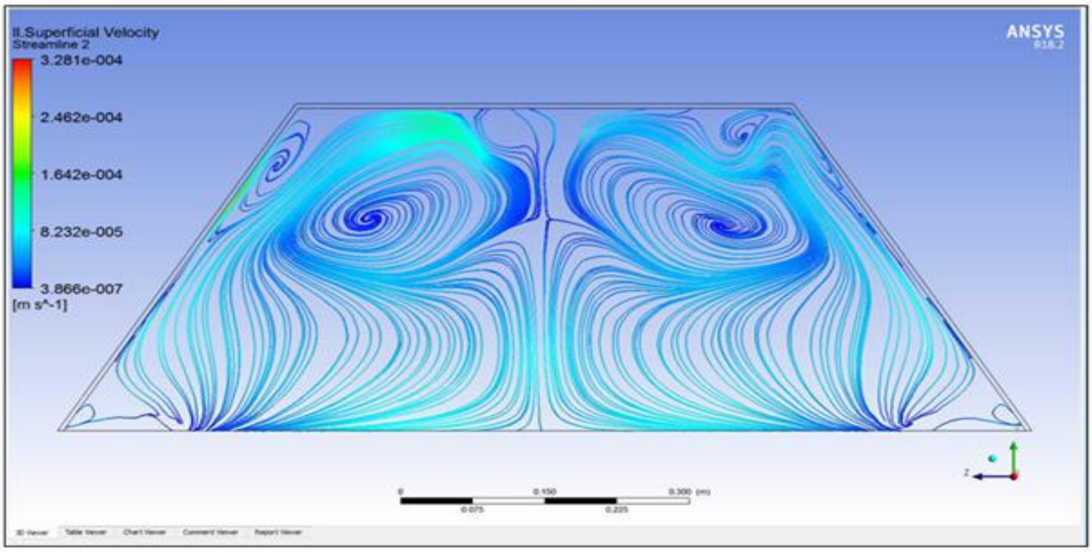

Figure 9. The stream function of solar still at time 2 PM

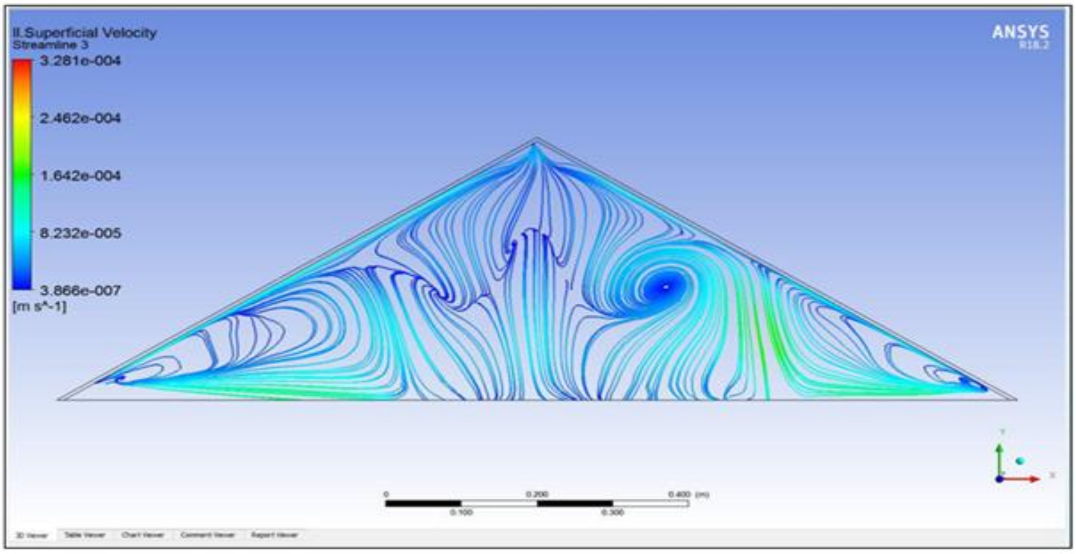

Figure 10. The stream function of solar still at time 2 PM

Comparison of experimental and simulation results:

The numerical results for the (3D) CFD model were validated with experimental work results. It is observed through the curves that there is an accepted the assent among the CFD results, and experimental results for the temperature basin solar distillation, water basin solar distillation and the water vapor, as well as the internal and external temperature face of the glass lid where the maximum error was (3.6 %). Figures (11) to (15) show the temperature basin solar distillation, the water basin solar distillation and the water vapor, as well as the internal and external temperature of the glass lid, between CFD and experimental work results with time for water. It is observed that the small difference in temperature due to the experimental temperature was recorded in one specified position of the solar still, whilst at CFD, the temperature of the working fluid flow during the solar still was indicated. Illustrates the comparison among the experimental results and the simulation results of the CFD a good agreement.

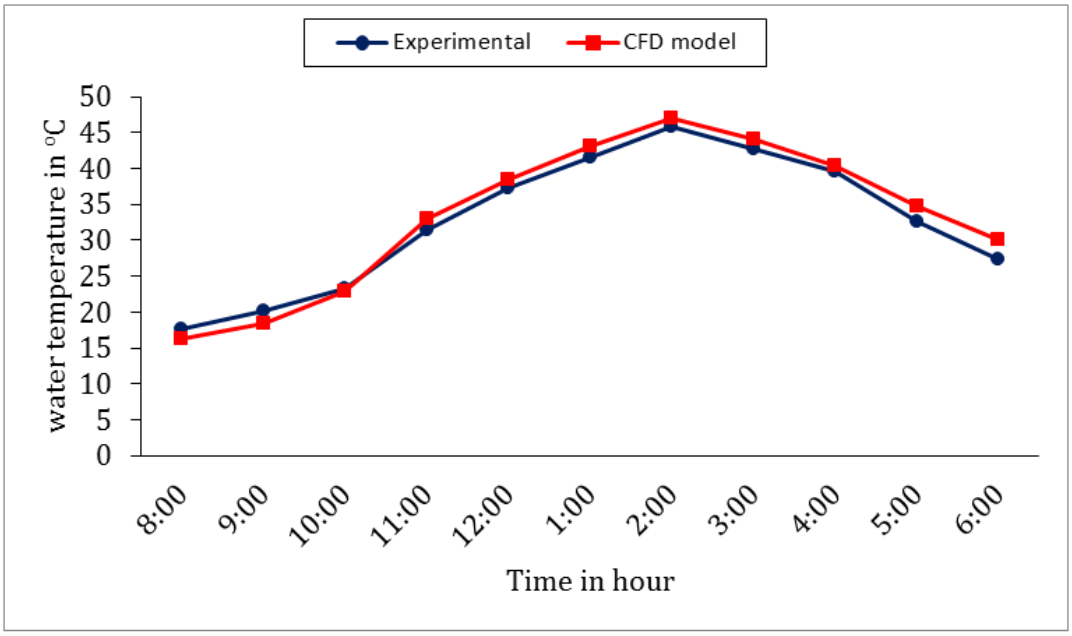

Figure 11. Validation of the water temperature for CFD model and experimental for solar still

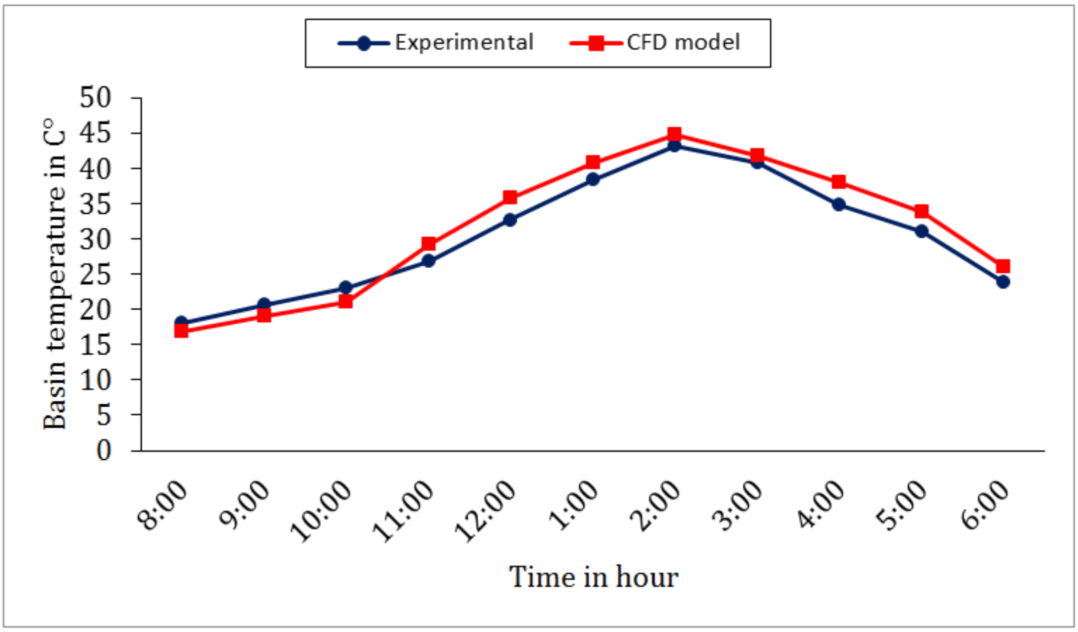

Figure 12. Validation the basin temperature for CFD model and experimental for solar still

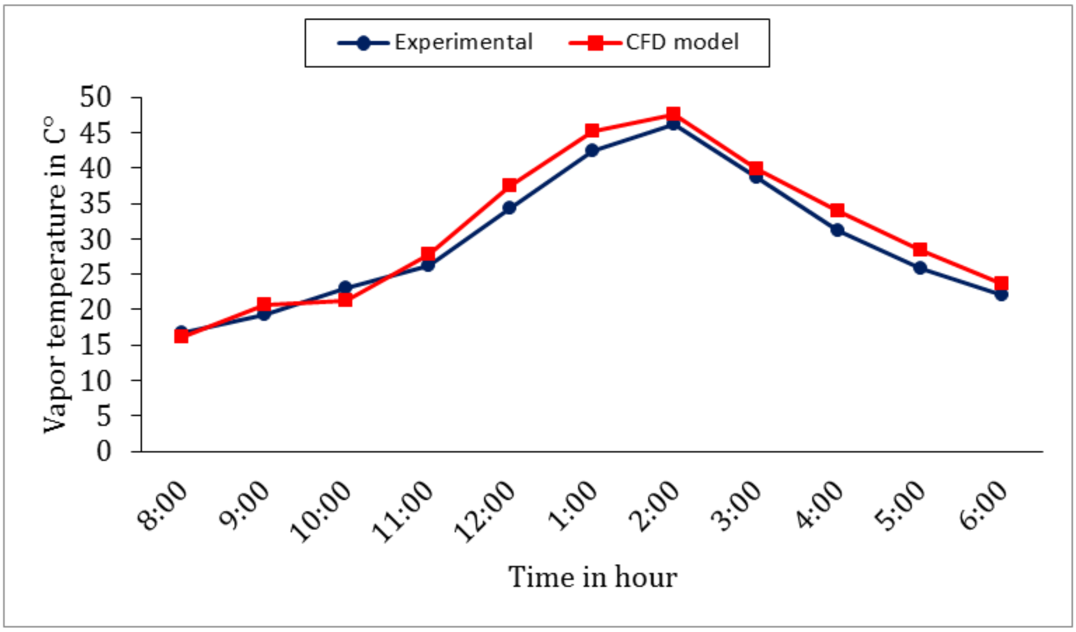

Figure 13. Validation of the vapor temperature of CFD model and experimental for solar still

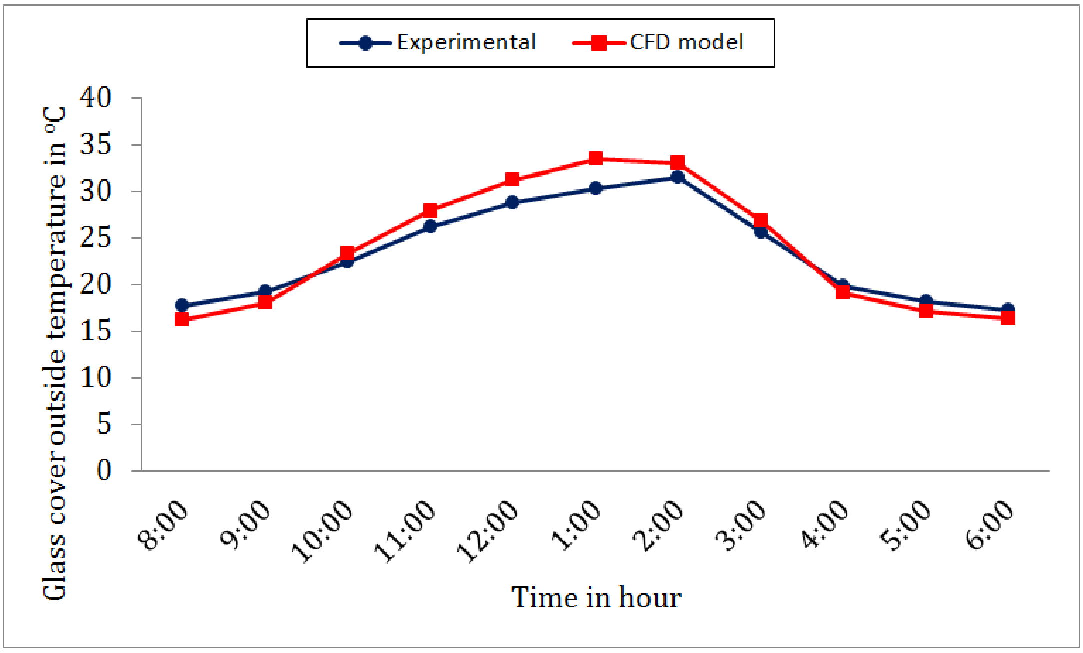

Figure 14. Validation of the glass cover outside temperature of CFD model and experimental for solar still

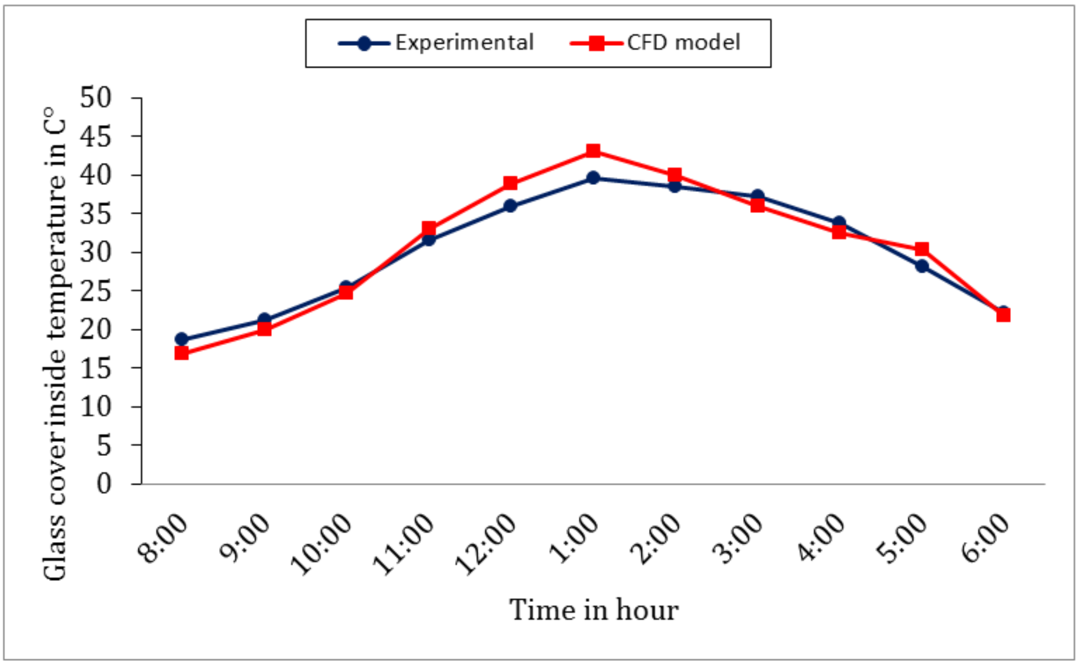

Figure 15. Validation of the glass cover inside temperature of CFD model and experimental for solar still

CONCLUSION

The main objective of this study is to develop a model of a CFD and through some analyzes used to improve solar still performance. The numerical simulation CFD has given results comparable to the results of the experimental used to estimate the temperature of the basin water solar still, the vapor temperature, and the internal surface temperature of the glass lid. A comparison was made between the experimental results and the numerical results. The comparison showed a clear and good correlation, with the difference in temperature ranged from (7 °C-15 °C). it is obvious, the user of the ANSYS CFX 18.2 provides the effort and time to overcome the difficulties that can occur when using solar distillation.

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