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SIMULATION OF THE EFFECT OF THE COVER GLASS ANGLE INCLINE ON A SINGLE SLOPE SOLAR DISTILLATOR

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Abstract

Distillation is a water purification process through evaporation and condensation. Research on solar distillation was developed using the Computational Fluid Dynamic (CFD) method to obtain an overview of the transmission of solar radiation heat by the cover glass for variations in the angle of the glass inclination of 10^0, 20^0 and 30^0. The water height in the basin is 100 mm. The simulation results show that the heating process with variations in the angle of the cover glass affects the distillation results. The smaller angle of the cover glass inclination, the higher heat flux entering the basin so that the evaporation process becomes higher which ultimately increases the amount of distillate water production produced. The highest heat flux entering the distillation system was achieved by the system with a cover glass inclination angle of 10^0 with a value of 388.525 W / m^2, while the lowest was at an angle of 30^0 with a value of 379.792 W / m^2. In addition, the highest distillate production was obtained on the cover glass with an inclination angle of 10 ° of 1.078 cc. For operational hours at 13.00 WIB and simulation time 180 seconds.

Keywords: Distillation, simulation, single slope solar distillation.

Abstrak

Destilasi merupakan proses pemurnian air melalui proses penguapan dan pengembunan. Penelitian terhadap distilasi tenaga matahari dikembangkan dengan menggunakan menggunakan metode Computational Fluid Dynamic (CFD) untuk mendapatkan gambaran mengenai transmisi panas radiasi matahari oleh kaca penutup untuk variasi sudut kemiringan kaca 10^0, 20^0 dan 30^0. Ketinggian air dalam basin 100 mm. Hasil simulasi menunjukkan bahwa proses pemanasan dengan variasi sudut kemiringan kaca penutup mempengaruhi hasil destilasinya. Semakin kecil sudut kemiringan kaca penutup semakin tinggi fluks panasyang masuk kedalam basin sehingga proses penguapan menjadi semakin tingga yang pada akhirnya meningkatkan jumlah produksi air destilat yang dihasilkan. Fluks panas yang masuk kedalam system destilasi tertinggi dicapai oleh system dengan kemiringan sudut kaca penutup 10^0 dengan nilai sebesar 388,525 W/m2, sedangkan yang terendah pada sudut 30^0 dengan nilai sebesar 379,792 W/m2. Selain itu diperoleh produksi distilat tertinggi pada kaca penutup dengan sudut kemiringan 10° sebesar 1,078 cc. Untuk waktu operasional pada jam 13.00 WIB dan waktu simulasi 180 detik.

Kata kunci: Destilasi, simulasi, Single Slope Solar Distilator

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1.0 INTRODUCTION

Water is one of the basic needs of humans and also all other living things on this earth. Especially for drinking water, special requirements are needed that are free from germs, bacteria and other dangerous substances. The availability of clean water today is increasingly rare and in some areas the availability of clean water is almost impossible to find.

Data from the Central Statistics Agency (BPS) states that the current achievement of access to clean water in Indonesia has reached 72.55 percent. This figure is still below the Sustainable Development Goals (SDGs) target of 100 percent. Efforts to distribute clean water to coastal areas have not been carried out evenly. On average, coastal areas use brackish water for daily life. However, with the increasing environmental damage, the use of brackish water without further processing is very risky. One way to process brackish water into drinkable water is by distillation, which is to purify water through evaporation and then condensation.

This research was conducted through a single slope solar distillation simulation using the CFD (Computational Fluid Dynamic) method to determine the effect of the angle of the cover glass on the productivity of the clean water produced.

2.0 METHODOLOGY

The study was conducted by simulation using a single slope distillation system. In this simulation, single slope solar distillation is modeled in 3D with a horizontal block geometry and has one roof, this is a simplified form of the solar distillation device by modeling the inside of the basin and the glass roof only. In the basin section with a height of 300 mm, a width of 600 mm and a length of 500 mm. With a height from the bottom of the basin to the top of the glass roof on one side adjusting to the angle of the glass roof, with variations in angles of 10^0, 20^0 and 30^0 at 13.00 WIB with a simulation time of 180 seconds.

The simulation was carried out by utilizing solar energy entering through a transparent glass roof and then heating the water in the basin with a water height from the bottom of the basin of 100 mm, after which evaporation occurs where there will be steam droplets on the glass roof cover so that the steam on the glass roof condenses. The simulation was carried out with dynamic conditions and also took into account the heat flow from inside to outside the distillation device. The heat flow that occurs is a combination of radiation and convection. Figure 1-3 shows the geometry of the single slope solar distillation that will be used in the simulation process.

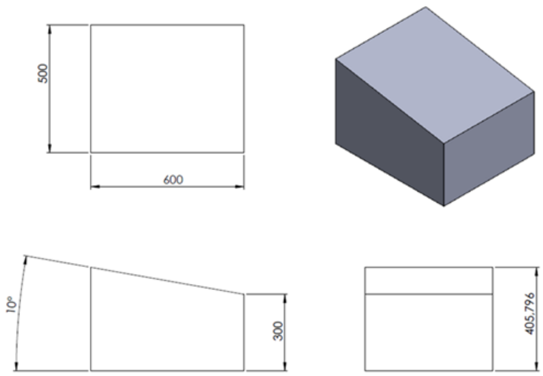

Figure 1. Single slope solar distillator with 10˚ glass cover slope

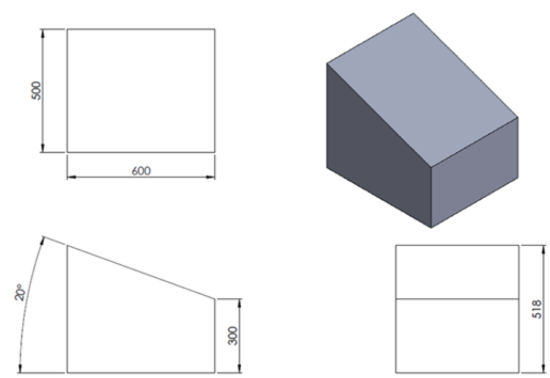

Figure 2. single slope solar distillator with 20˚ glass cover slope

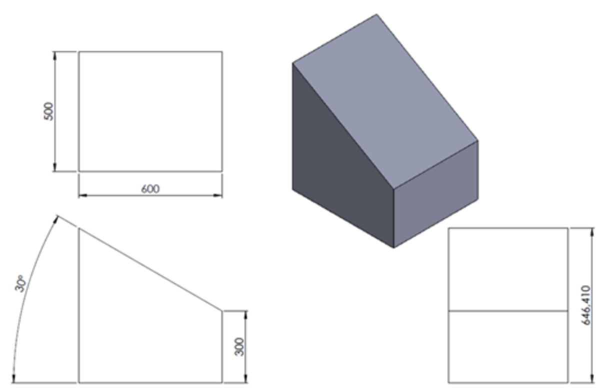

Figure 3. single slope solar distillator with 30˚ glass cover slope

The 3D geometry in the simulation was created using GAMBIT 2.4.6 software, which provides a design modeler as a design tool to develop geometric models of physical problem domains. The geometric model used has dimensions of 500 mm in length, 600 mm in width, 300 mm in basin height, and the height from the bottom of the basin to the roof of the glass cover is adjusted. While for the simulation, a 1:10 scale of the geometric model is used. This is because simulations with a 1:1 scale require a fairly large amount of MESHING so that they require a computer with super specifications or what is commonly known as a Super Computer. The type of mesh used is hexahedral, with a geometric scale of 1:10 which can provide accurate results with the computing time as needed with the help of Ansys Fluent v19. Figure 4 shows the meshing results for variations in the angle of inclination of 10˚, 20˚ and 30˚.

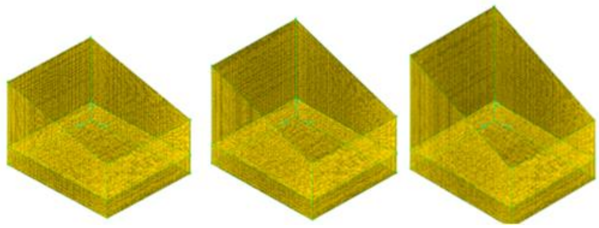

Figure 4. Hexahedral Mesh Geometry for 10˚, 20˚ and 30˚ Angles

Determining the boundary conditions and initial conditions is a step that must be taken to ensure the data needed before running the simulation. After creating the geometry, the next step is to define the right boundary conditions and types because they are very important for an accurate solution. Most of the boundary conditions are determined by the phenomena that occur, but some are determined by the Ansys Fluent simulation software. Table 1. shows the boundary conditions and types for various parts of the studied domain.

Table 1. Boundary Condition Settings

Name	Type	Thermal Conditin	Description	Wall Thickness (m)
Glass Wall	Wall	Heat Flux=274 W/m^2	Semi-transparent	0.005
Ground Wall	Wall	Adiabatic Wall	Opaque	0.005
Front & Back Wall	Wall	Adiabatic Wall	Opaque	0.005
Side Wall	Wall	Adiabatic Wall	Opaque	0.005

After determining the boundary conditions on the wall, proceed to the next step, which is to define the water conditions at the bottom of the basin. With the initial condition of water in the liquid phase as thick as 100 mm at the bottom of the basin, so that the value of the water volume fraction is 1.

Material Characteristics

The characteristics of the materials used in the study are described in Table 2 below.

Table 2. Material Characteristics

Cover glass	
Density Specific heat Thermal conductivity Thickness	2500 kg/m^3 790 J/(kg.K) 1.15 W/(m.K) 0.005 m
Copper plate	
Density Specific heat Thermal conductivity	8978 kg/m^3 382 J/(kg.K) 387.6 W/(m.K)
Wood	
Density Specific heat Konduktivitas Thermal	700 kg/m^3 2310 J/(kg.K) 0.173 W/(m.K)

Simulation Parameters

Simulation parameters are important and must be set properly so that the results of the simulation run are in accordance with what is needed. The more parameters that are set and entered, the more accurate the results of the simulation run, because they are closer to the actual conditions. The simulation parameters in this study are shown in Table 3.

Table 3. Radiation parameters in simulation

Solar Calculator			
Global Position		Mesh Orientation	
Longitude (deg)	106,03	North	Axis Z = 1
Latitude (deg)	-5,99	East	Axis x = -1
Time zone (GMT)	+7	Solar irradiation methode	Fair wheather condition
Starting Day		Starting time	
Day	21	Hour	1 pm
Month	6	minute	0
Fair Weather Conditions			
Sun direction vector		X:-0.2466747 ; y : 0.8374572 ; z : 0.876782	
Sunshine farction		1	
Direct normal solar irradiation (at earth surface)		852.99 W/m^2	
Diffuse solar irradiation vertical surface		100.62 W/m^2	
Diffuse solar irradiation horizontal surface, Ground reflected solar		114.301 W/m^2	
Irradiation vertical surface		83.287 W/m^2	

3.0 RESULTS AND DISCUSSION

3.1 Water Vapor Phase Productivity

In this three-phase simulation using the VOF method. To find out the position of the evaporated water vapor, it can be seen in the position of the volume fraction of water vapor in the solar distillation process of one glass roof against the variation of the angle of the glass roof cover within 180 seconds shown in Figure 5.

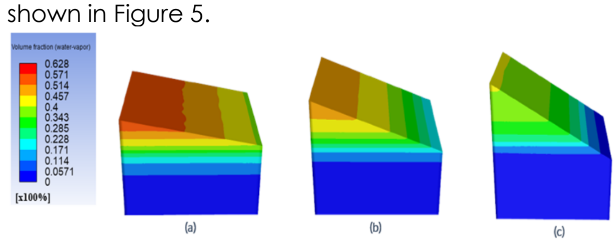

Figure 5. Volume fraction of water vapor in 180 seconds of simulation for glass cover angles of (a) 10°, (b) 20° and (c) 30°

From the visualization above, it can be concluded that along with the small angle of the glass roof, the results obtained are that the volume of water vapor in the distiller increases and slowly the top of the distiller glass cover is covered by water vapor so that it reaches uniformity. The volume fraction of water vapor from the three variations of the slope of the glass cover roof is at a minimum-maximum average of 0% - 62.8%. However, at an angle of 100, the volume fraction of water vapor has covered all the inner surfaces of the glass cover and the space in the upper basin is filled with the volume fraction of water vapor on the dark red-orange contour with a volume content value of the water vapor fraction of 40% - 62.8%.

3.2 Heat Transfer Analysis

Radiation heat transfer from the sun to the glass cover roof of the distiller occurs through the mechanism of conduction on the cover glass to the inside of the distiller, in addition to the mechanism of solar radiation and convection from the surface of the cover glass to the top of the basin.

The heat flux transmitted by the glass cover from the solar heat radiation it receives towards the basin is shown in Figure 6. From the figure, it can be seen that the highest value of heat flux transmission is at a glass cover slope of 10°. Table 3. Shows the average value of heat flux transmission from the glass cover for each angle of inclination of the glass cover.

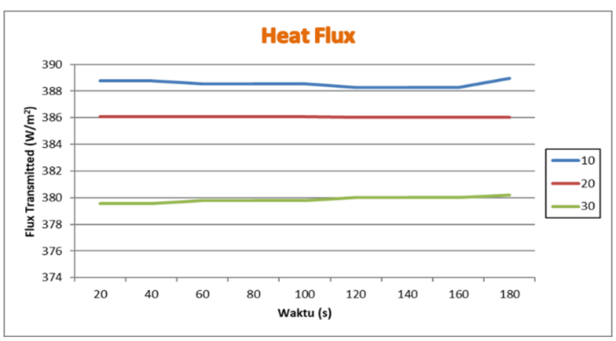

Figure 6. Transmission of radiation flux by cover glass with varying inclination angles.

Table 3. Average Value of 1s – 180s Transmitted Flux by Glass against Variation of Glass Roof Cover Angle

Heat Flux (W/m²)		
10^0	20^0	30^0
388,525	386,083	379,792

It can be seen from the table data above that the highest transmitted heat flux value is at an angle of 10° of 388.525 W/m2 and the lowest flux value is at an angle of 30° with a flux value of 379.792 W/m2. Because it causes steam production which is also greater than other angle variations. Therefore, it can be concluded that the greater the angle of inclination on the glass roof cover, the lower the heat flux transmission value, this is because the shape of the 100 angle of inclination of the glass surface directly faces the sunlight so that the direction of the sunlight radiation enters directly, compared to other angles that do not directly face the glass surface of the sun.

3.3 Mass Transfer Analysis

The simulation results for mass transfer that occurs during the distillation process using solar radiation in terms of the amount of water evaporated during 180 seconds are shown in Figure 7.

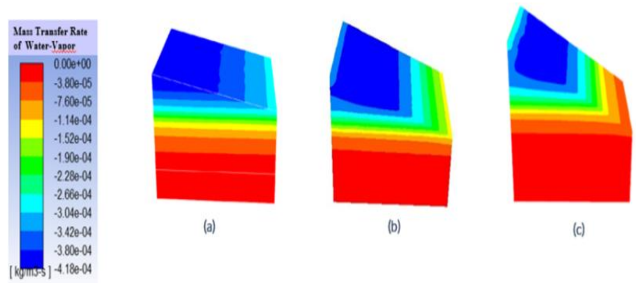

Figure 7. Mass transfer of water vapor against variations in the angle of the cover glass for 180 seconds (a) 10°, (b) 20°, (c) 30°

It can be concluded that the greater the slope of the glass roof cover angle, the smaller the value of the water vapor mass transfer. At the variation of angles 10° and 20° of the water vapor position and the value of the water vapor mass transfer are not too different from the maximum evaporation rate of 4.18x10-4 kg/m3.s the difference is in the position of the largest evaporation rate. For an angle of 10° the position of the largest evaporation rate is located in the middle to the end of the glass roof while at an angle of 20° the position is located in the middle of the glass roof.

At the angle variation of 30°, the lowest value of water vapor mass transfer is obtained. It can be seen from the blue contour that represents the highest value of each of the angle variations, from the image above that the light blue to blue zone that is widest is seen at the angle variation of 10° so that the highest value of water vapor mass transfer in accumulation when viewed from the contour of the image above is the angle variation of 10° which has a larger volume of water vapor produced compared to the other 2 angle variations.

Figure 8 shows the evaporation rate distribution graph for various angles of the cover glass.

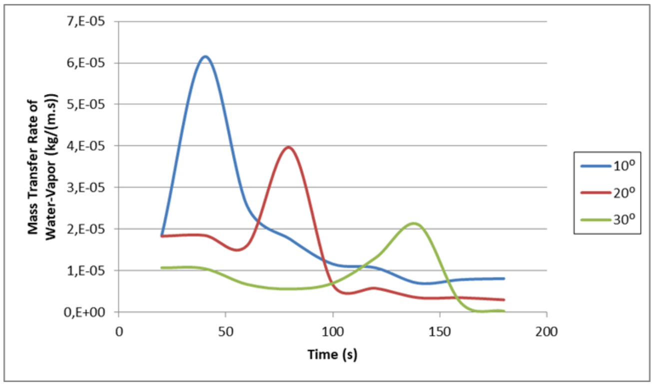

Figure 8. Distribution of evaporation rate against variations of cover glass inclination

The simulation results in the graphic data above show that the variation of the slope angle of 10° has the highest evaporation rate distribution value and the one with the lowest evaporation rate distribution value is the angle of 30°. And it can be seen from the angle variations that when it reaches the highest evaporation rate distribution value, then along with the increase in time the evaporation rate will slowly decrease, both angles 10°, 20°, and 30°. The smaller the surface area of the glass, the faster the water that has condensed in the distillate glass produced will flow to the distillate place so that the productivity of the distillate becomes large, but if the surface area of the glass is wider, even though the evaporation rate is high, it takes time to flow to the distillate place. With the increasing evaporation rate produced, the more condensation processes occur so that the greater the volume of condensate produced.

3.4 Water Vapor Production Analysis

The simulation results show the production of water vapor for single slope solar distillation as shown in Figure 9. The production time starts at 13.00 for 180 seconds as obtained from the simulation results.

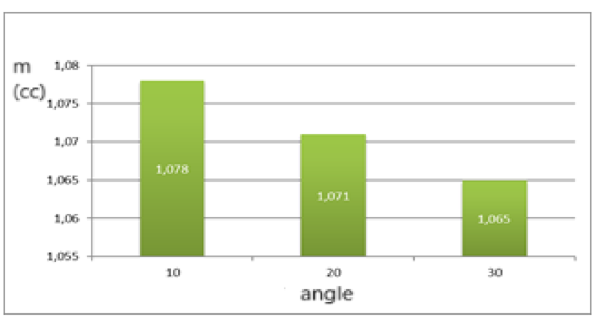

Figure 9. Water vapor production within 180 seconds at 13.00 local time.

It can be concluded that the highest water vapor production is produced by a distiller with a glass roof slope of 10° and the lowest water vapor production is produced by an angle of 30°. From the results of this simulation, it can be concluded that the greater the angle of the glass roof slope, the less water vapor production will be produced.

4.0 CONCLUSION

After conducting CFD simulation on single slope solar distillator with variation of glass cover angle slope of 100, 200 and 300, it can be concluded that variation of angle slope greatly influences the heating process, this can be proven from the values of evaporation rate that occurs. Heat transfer and mass transfer that occur in 3 variations of glass cover angle prove that the smaller the variation of angle, the higher the temperature distribution value, the highest heat transmission occurs in the glass cover with a slope of 100 with a value of 388.525 W/m2, and the lowest at an angle of 300 with a value of 379.792 W/m2. In addition, the production of water vapor for solar distillation with a glass cover slope of 100 is 1.078 cc, an angle of 200 is 1.071 cc, and an angle of 300 is 1.065 cc.

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