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DESALINATION OF SEA WATER BY USING SOLAR STILL WITH FRESNEL LENS

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Abstract— **Water scarcity is one of the major environmental problems facing today's world especially in dry regions. Depletions of fresh water resource availability mainly caused by urbanization and improper management of water. Solutions for this water scarcity includes conserving and managing of water resources and preventing them from getting pollution. Desalination is one of effective solution in providing water for domestic and agricultural purpose in coastal areas ad nearby. In current situation many desalination methods for large and small scale applications. Desalination by solar still is one of the simple method for desalination. Main advantage of this process lies in its simplicity in construction and working. And it needs no external power source for its operation except incoming solar radiation. Drawback this solar still is, its net output of distilled water is very low when compared to other desalination methods because of loss of energy. Many improvements are being made on solar still to minimize this energy loss and improving its performance by coupling with other desalination methods. This project work is aimed to study the solar still and minimizing the energy loss by implementing the Fresnel lens and increasing efficiency, net distillate output of solar still. First Theoretical analysis of solar still without Fresnel lens was done. Then Fresnel lens is implemented in solar still theoretical model and compared with results obtained from theoretical model of solar still without Fresnel lens. Then Fresnel lens installed solar still is fabricated and tested experimentally. Obtained experimental result of Fresnel lens installed solar still is compared with results obtained from theoretical model.**

Keywords— *Fresnel lens, solar still, vapourisation, optimization, sea water.*

1. Introduction

Increases are world population. The fresh water resources are getting low, about 71% of earth surface us covered with water, 97% of earth water is in ocean as sea water remaining 3% of water is available as fresh water. Population growth and urbanisation cause depletion and population of fresh water resources. Desalination and water recycling are carried out to overcome the water scarcity in many parts of the world. Distillation and membrane filtration are two important methods widely used for desalination many countries implement desalination technologies for fresh water. These countries include Saudi Arabia, USA, UAE, Spain. [1]-[4]. Solar distillation is type distillation method for desalination solar distillation is carried out in solar still. Many types of solar still are under development to increase its performance. Solar desalination systems have low operating and maintenance costs and require large installation areas and high initial investments. There are two different types of solar stills, those are; active solar still and passive solar still. The active type solar still, which contains the mechanical components like pump, valve etc. the passive solar still, which does not require mechanical components. Among active and passive solar stills, passive solar still gets more attractive compared to active solar still. Because, passive type solar still does not have moving elements, so no need of power consumption and no wear and tear problems. [4]. In this present work, focus is made on passive solar still. Passive type solar stills are more economic then active solar stills.[7]. Membrane distillation is methods of desalination process its hybrid of thermal distillation and membrane process.[5]. Study solar stull is integrated with fin represents performance is increased when the fin is implemented.[6].

In this paper we study sola still implemented with Fresnel lens, and compared with solar still without Fresnel lens. By implementing Fresnel lens heat loss to surrounding is reduced. And mass distillate output can be increased.

2. Material and Methods

2.1 Fresnel lens

Augustin Jean Fresnel developed the first Fresnel lens in the early nineteenth century. Fresnel lenses we first used in the 1800s as the lens that focuses the beam in lighthouse lamps. The design allows the construction of lenses of large aperture and short focal length without the mass and volume of material that would be required by a lens of conventional design. A Fresnel lens can capture more oblique light from a light source. Plastic Fresnel lenses are used as magnifiers when a thin, light lens is needed. Fresnel lens is moulded into many circular, concentric ridges. The symmetry of these concentric ridges is similar to that of a dart board. A lens, then, can be considered as a series of prisms of increasing apex angle as one moves away from the optical center of the surface. Indeed, Fresnel lenses are most commonly created by narrow, flat-surface prism grooves of increasing apex angle[8].

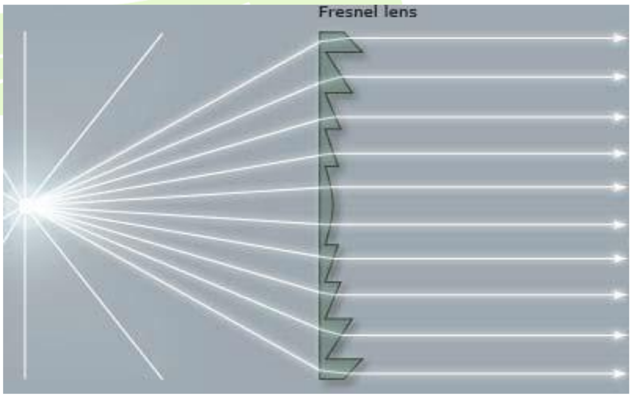

Fig.1. Fresnel lens

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2.2 Types of Fresnel lens

2.2.1 Linear Type Lens:

Linear Fresnel lenses focus sunlight in one dimension to a strip. They are used in Thermal Concentrated Solar (CSP) and Low concentration PV applications.

2.2.2 Radial Type Lens:

Radial Fresnel lens Focus as Spot. They are an attractive alternative to hot embossed or injection moulded lenses in High Concentration Photovoltaic (HCPV) applications.

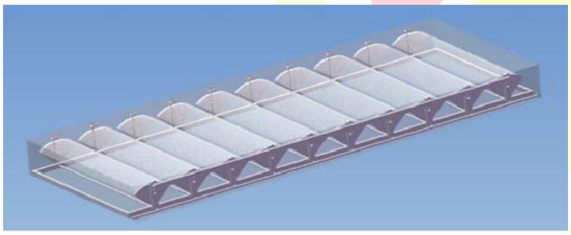

Fig. 2. Linear type Fresnel lens

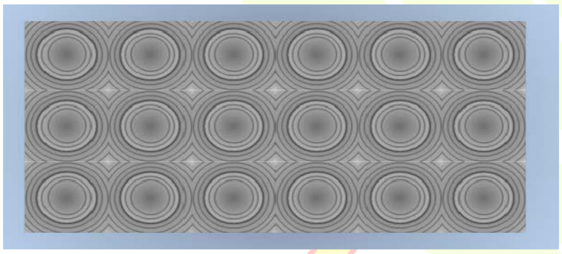

Fig. 3. Radial type Fresnel lens

2.3 Fresnel Lens Design

Insert Fresnel Lens dialog box allows you to enter:

1. Ring width or lines/unit length
2. Thickness of the substrate
3. Radius of the lens substrate
4. Material catalog, name, and design wavelength
5. Object distance
6. Image distance
7. Origin or location of the center of the part
8. Rotation angles specifying the orientation

Trace Pro interprets an object or image distance equal to zero as an infinite distance. Negative distances can also be entered for the case of a virtual object and image.

2.4 Advantages of Fresnel Lens

There is a big advantage to cylindrical lenses. If you arrange solar still in vertical stripes (e.g. covering 20% of the surface) and put vertically aligned cylindrical Fresnel lenses, as the sun moves from east to west (or west to east in the southern hemisphere). This is all ideal of course and there are other factors to consider: Heat accumulation. This should not be a tough one since you still have the same amount of light falling in your total solar still so if you mount the cells on a thermally conductive plate, you should be able to dissipate the energy just as with un concentrated solar panels, even more, if you make the space between the solar still columns a grooved surface like a radiator grid or a typical cooler you can probably cool it much better then in a fully solar still and the backing plate is a big challenge, I would say this probable has better thermal characteristics than non-concentrated solar still. Loses through the lens. Some lens material might not be highly transparent to the frequencies that your solar still is optimized for, so the lens and the solar need to be matched. Also, the lens has some loses due to reflection and imperfections in the surface. A Fresnel lens offer only near ideal characteristics from a straight on angle, so when light shines on it at a low angle e .g sideways in a vertically oriented cylindrical lens much higher loses can be expected[9].

3. Experimental setup:

The design specification of the solar sill is shown in the table 1

Table 1 Design Specification

Glassing cover	Fresnel lens
Lens thickness	1mm
Focusing length	240mm
No. of slope	Single
Angle	19°
Insulation material	Thermocool, wood
Absorbtion material	Aluminium
Aluminium thickness	0.5mm
Heat storage material	Sand
Basin area	629.13cm^2

Based on design specification experiment setup is fabricated for testing, Fresnel lens is fixed on top of solar still at angle

19° to fix focus point of Fresnel lens in the centre of base plate from centre of base plate heat is distributed to the other side of base plate.

The dimension of the setup is shown in the fig, 1

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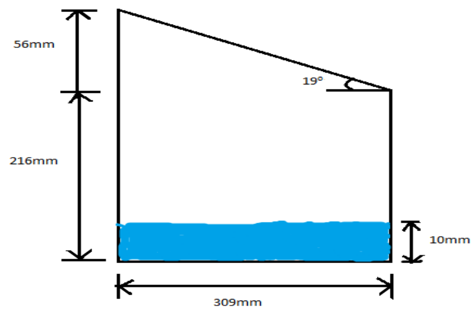

Fig. 4. Dimension of setup

Mild steel sheet was used to fabricate the solar still, which is show in fig.5. The basin is insulated with thermo cool, sand, and wood. The Sand is used or storing heat. Using adhesives wood panels are pasted in the surface of basin. And Fresnel lens edges are framed with metal, and edges are filling pasted with rubber feeding to prevent air leakage in basin

Fig. 5. Top view of set up

4. Theoretical Analysis of Solar Still with Fresnel lens

The theoretical analysis is performed using the energy balance mode on various components of the still system with Fresnel lens. To simplify the analysis, the following assumptions are made:

Table 2.Thermal properties of material

Material	Density Kg/m^3	Thermal diffusivity α = k/ρc	Specific heat c	Thermal conductivity k
Mild steel	7900	3.95x10^6	477	14.9

Table 3.Optical properties of material

Material	Reflectivity	Absorptivity	Tanmissivity
Fresnel lens	0.002	0.08	0.9
Sea water	0.02	0.96	0.02
Mild steel (painted block)	-	0.9	-

Table 4.Radiation properties of mild steel

Material	Solar absorptivity	Emissivity	Ratio
Mild steel	0.89	0.92	0.96

Above data from the table (2,3,4) is taken for analysis of evaporation rate, heat transfer rate, distillate output rate.

There is no vapor leakage in the still, and this is important to increase the productivity and efficiency.
There is no temperature gradient along the Fresnel lens thickness and in water depth. Also the absorbed energy by the Fresnel lens is negligible. The energy balance for different components of the still is as follows

a) Energy loss of base plate

$q_b = h_b(T_b\text{-}T_a)$------------------------------------(1)

b) Hourly distillate output Mass of evaporation water with Fresnel lens,

$m^{\cdot}_{ew} = (q^{\cdot}_{ewg}/L_f)*3600$---------------------------(2)

c) Evaporation of heat loss to water to Fresnel lens

$q^{\cdot}_{ewf} = h^{\cdot}_{ew}(T_w - T_f)$------------------------------(3)

d) Convective loss heat co efficient

$h_{ew} = 0.884\ [\ (T_w - T_f) + (p_w - p_f)\ (\ T_w - 273) / (268.9 * 10^{-3} - p_w)\ ]$-----------------------------(4)

e) Partial pressure of Fresnel lens

$p_f = exp[25.317\text{-}(5144/(\ T_f\text{+}273))]$----------(5)

5. Results and Discussion

The solar still was designed and fabricated and the test results were presented. The energy transfer occurs from glass cover to water mass and then basin layer as visible light. From

basin, visible solar rays are absorbed and emitted as thermal radiation based on its absorptivity and emissivity. The solar flux is reflected back to surrounding from glass cover and water basin is about 20 %. Steel sheet basin layer have less thickness and have less temperature gradient along thickness and well insulated at bottom using air as insulating material. So the conductivity of steel basin at the bottom is negligible. 80% of incoming solar radiation is utilized for heating water mass. The heat energy is utilized for heating sea water only until it reaches latent heat of vaporization of sea water by using Fresnel lens (7.11143 kJ). By using Fresnel lens in solar still, heat loss reduced (2505w/m^2) when compare to heat loss from solar still without Fresnel lens. The distillate output rate is increased up to 33% by using Fresnel lens in solar still.

Table.5. Distillate output and temperature with respect to per hour

S.No	TIME PER DAY (hr)	Temperature (˚C)	Distillate Water (ml)
1	10.00	64	25
2	11.00	73	45
3	12.00	75	90
4	13.00	79	100
5	14.00	70	80
6	15.00	64	70
7	16.00	60	30
8	17.00	58	25

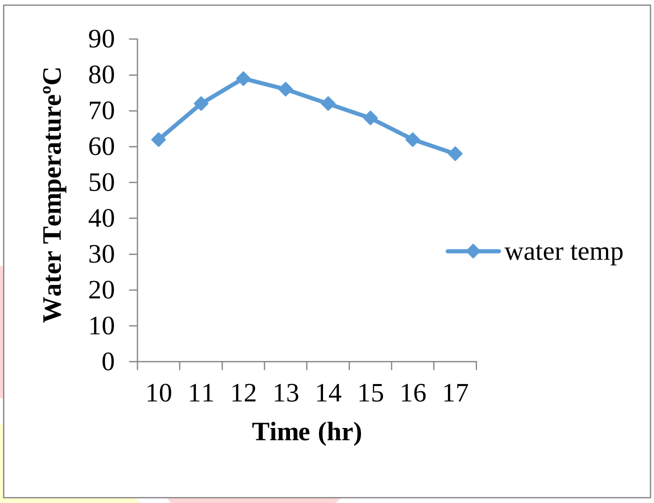

Fig .6. Water temperature with respect to temperature and time

Fig .6 shows that the effect of water temperature with respect to time with Fresnel lens. The temperature changes with respect to time.

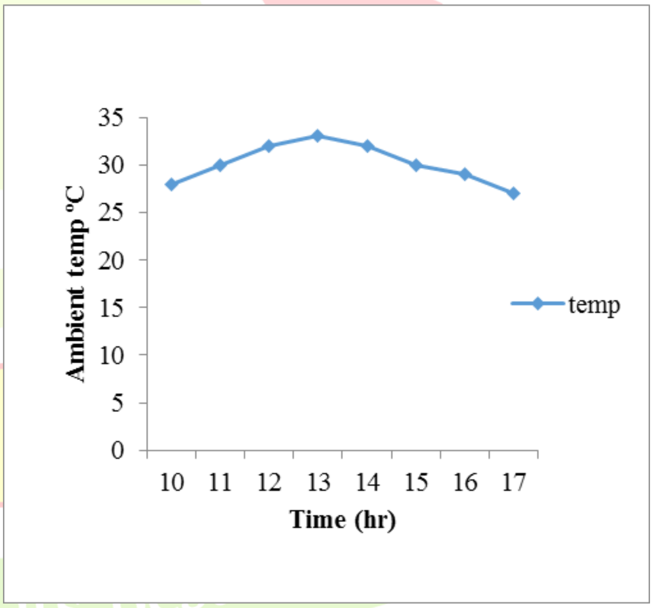

Fig. 7. Ambient temperature with respect to time (hrs)

Fig.7. shows that the effect of ambient temperature with respect to time with Fresnel lens. The surface temperature changes with respect to time.

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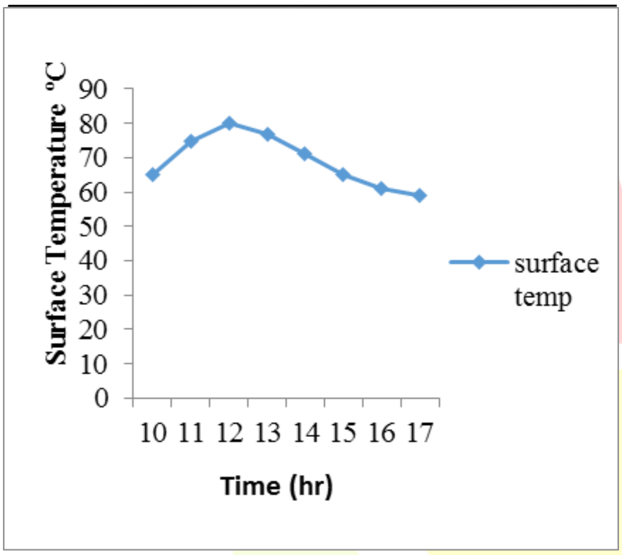

Fig .8. Surface temperature with respect to time (hr)

Fig.8 shows that the effect of surface temperature with respect to time with Fresnel lens. The surface temperature changes with respect to time.

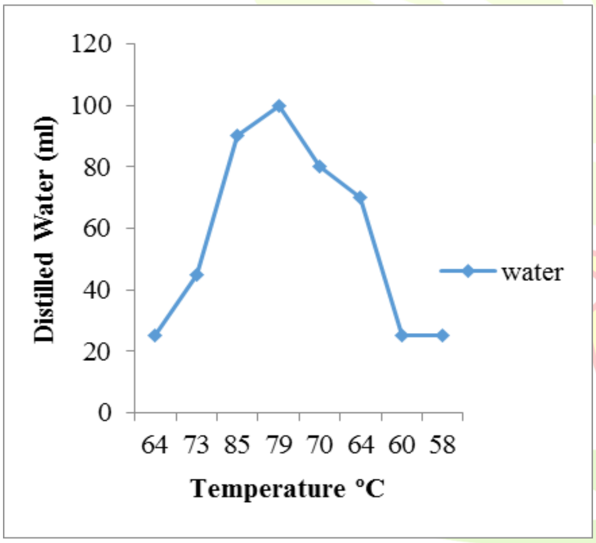

Fig .9. Distillate water rate with respect to temperature°C

Fig.9.shows that the amount of distillate water with respect to water temperature with Fresnel lens. The distillate water changes with respect to water temperature.

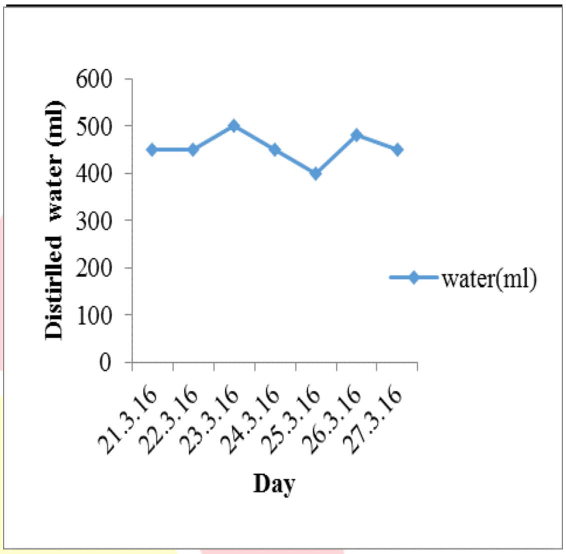

Fig.10. amount of distillate water with respect to per day (6hr)

Fig.10. shows that the amount of distillated water with respect to per day (6hr) with Fresnel lens. The distillated water with respect to temperature.

Nomenclature

q_{ca} : heat loss from cover to atmosphere by convection
q_{rga} : heat loss from Fresnel lens to atmosphere by radiation
q_{fa} : heat loss from Fresnel lens to atmosphere
F : shape factor depend on geometry, emissivity of water and glass cover.
σ : stefan boltzmann constant
C_f : heat capacity of Fresnel lens
Q_{fa}: heat loss from Fresnel lens to atmosphere
T_f : temperature of Fresnel lens
I : solar radiation on horizontal surface. 1020w/m^2
α_w: Water absorptivity
τ :transmittance of glass cover.
C_w: heat capacity of water basin 4186l/kg
$T_w$water temperature ;
t :time
U_b : overall heat transfer coefficient
Q_e : amount of heat utilized by solar still for obtaining (M_e) distilled water per m^2
$H_{T:}$ solar irradiation n horizontal surface
q_e : evaporative heat loasses from water to the transparent cover.
q_r : radiative heat losses from water to the transparent cover.
Qc: convective heat loasses from water to the transparent cover.
P_w: saturation partial pressure of water vapour at water temperature

L:latent heat of evaporisation the value is (2264 x 10^3J/kg
h_c:convective heat transfer coefficient

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