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The Effect of Variation of the Solar Azimuth Angle on the Flux Distribution Spread over the Receiver

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Abstract

Obviously, one of the greatest challenges facing the world today is breaking fossil fuel dependence and promoting the development of new and renewable sources of energy that can supplement and, where appropriate, replace the diminishing resources of fossil fuels. Solar energy is clearly one of the most promising prospects to these problems since it is non-pollutant, renewable, and available everywhere in the world although with varying intensity. Ray tracing is an important tool for the design of the receiver elliptical–hyperboloid concentrators (EHC). However, the information about ray tracing, and flux distribution on the receiver of the EHC determines the size of the receiver using OptisTM Ray-trace software.

The present study concerns the effect of variation of the solar azimuth angle on the flux distribution on the receiver area of the EHC is examined by moving the solar energy source along the x-y plane of the aperture major axis from 0° to 90° with an increment of 15° intervals. For each azimuth angle variation, one maximum optical efficiency is observed in those variations. The maximum optical efficiency observed for each angle decreases, as the solar source is moved from 0°-90°. Results presented also show the distribution of the concentrated radiant energy over the receiver/absorber.

Keywords: *Azimuth angle, flux distribution., ray tracing, optical efficiency*

1. Introduction

Many studies on the optimization of tilt angles have considered the effect of cloudiness [1], wind-speed cooling [2], maximizing radiation on flat-plate collectors [3], the clearness index optimization method [4], the radiation- transfer method [5], the maximizing different solar radiations in changed geographical locations [6, 7]. These methods were used to draw a relevant map for PV installation tilt and azimuth angles and, improve the generation of the annual energy of PV systems analyses the impact of the azimuth angle on the energy production of PV installations. Two different PV sites. These analyses were based on the cumulative density function modelling technique as well as the normal distribution function.[8]. Presented the photovoltaic systems performance in obtaining the maximum power efficiency with various azimuth angles and solar array tilt positions [9] shows that how power generation is affected due to variation of azimuth angle. and also depicts that how solar irradiation is varied with respect to time duration. Highlights the influence of azimuth angle on the BIPV application considering temperature issue [10]. One of the important parameters that affect the performance of a solar collector is its solar azimuth angle on the flux distribution on the receiver area. The variation of solar azimuth changes the amount of solar radiation reaching the receiver surface. Flux distribution on the receiver area for different incident angle using Optis™ rays tracing were considered [11]. The magnitude of the peak and area averaged flux decreases as the incident angle increases. The overall magnitude of the flux was significantly reduced for the incidence angle of 30° [11].

In the present paper, the flux distribution on the receiver area of the Elliptical–Hyperboloid Concentrators (EHC), which is according to the variation of solar azimuth that changes the amount of solar radiation reaching the receiver surface, and to determine the optimum tilt angle and orientation (surface azimuth angle for the solar collector at any latitude. Never the less the Optis™ software ray-trace technique was used to determine the maximum optical efficiency .it was examined by moving the solar energy source along the x-y plane of the aperture major axis from 0° to 90°. The maximum optical efficiency observed for each angle decreases, as the solar source is moved from 0°-90°.

2. Optical Study of Elliptical Hyperboloid Concentrator

2.1 Ray Tracing of EHC at Different Incidence Angles

The source rays have been modelled to follow a similar path to that of the sun for a typical daily cycle. Using the ray tracing method described in [11], the following results were obtained for the 3-D EHC. Figure 1 shows the ray tracing diagram for the different incident angles of 0°, 15°, 30° and 60°. Based on these preliminary models, it can also be observed that the maximum number of rays reaching the receiver occurs when the radiation source is directly above the concentrator (θ is 0º). The number of rays reaching the receiver decreases as the angle of the incidence increased; no rays are absorbed by the receiver when the incident angle is ± 60º.

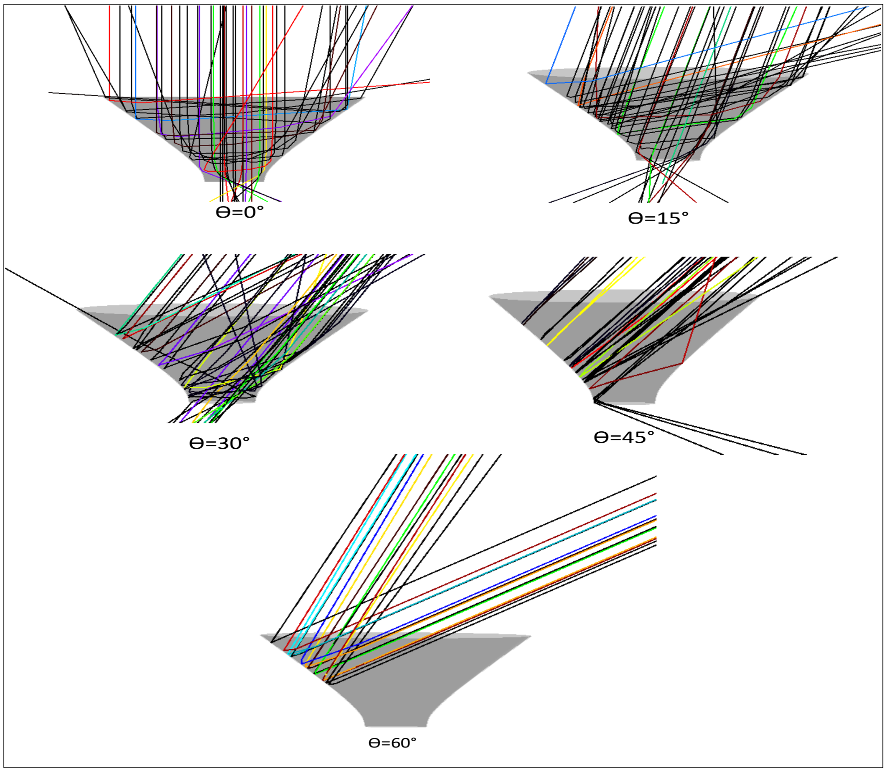

Figure1: Ray Tracing of EHC for Different Incidence Angles (0°, 15°, 30°, 45° and 60°)

2.2 Effect of the Variation of the Solar Azimuth Angle

Using the ray tracing model, the effect of the variation of the solar azimuth angle (*Ψ*) on the optical efficiency of the EHC was investigated. The solar azimuth angle is the angular deviation of the sun from true south [6]. By moving the solar source along the xy plane of the major axis aperture through angular variation from 0° to 90° with an increment of 5°, for teach angle of interval the solar incidence angle is varied from 0° to 60°. The geometry considered for this simulation with variation of major axis aperture is shown in figure 2.

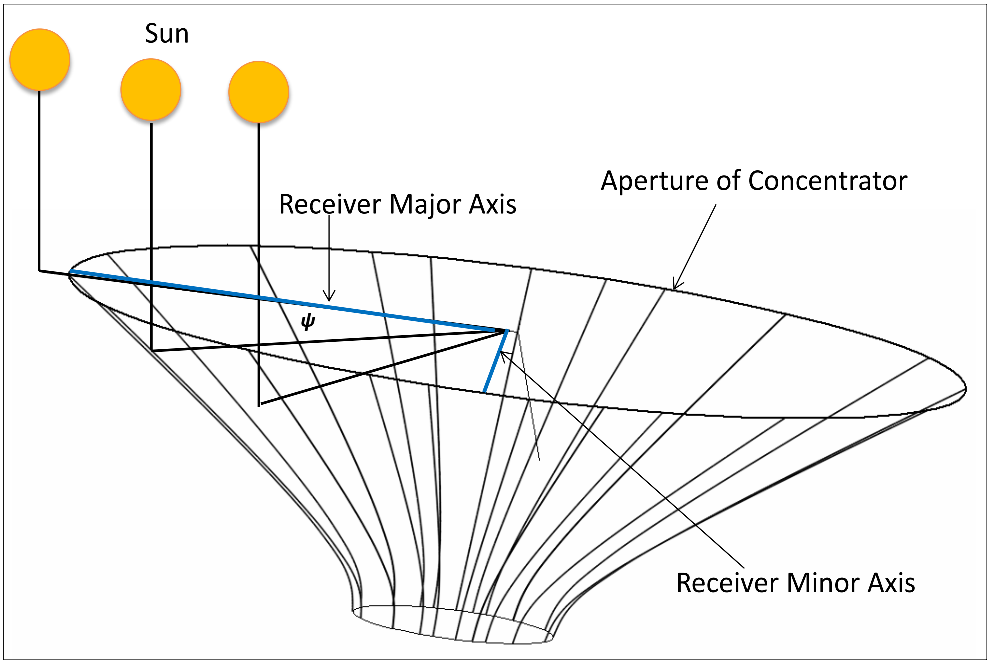

Figure 2: EHC with Variation of Major Axis Aperture

Next, the effect of variation of the solar azimuth angle on the optical efficiency was investigated. The variation of the optical efficiency with azimuth angle variation and incidence angle is shown in figure 3. It was observed that as the solar azimuth angle was increased from 0°-90°, that is the solar source was moved from the south to the north, the acceptance angle decreases from approximately 30° in the south to less than 5° as the solar source approaches the north. For each azimuth angle variation, one maximum optical efficiency is observed in those variations. The maximum optical efficiency observed for each angle decreases, as the solar source is moved from 0°-90°.

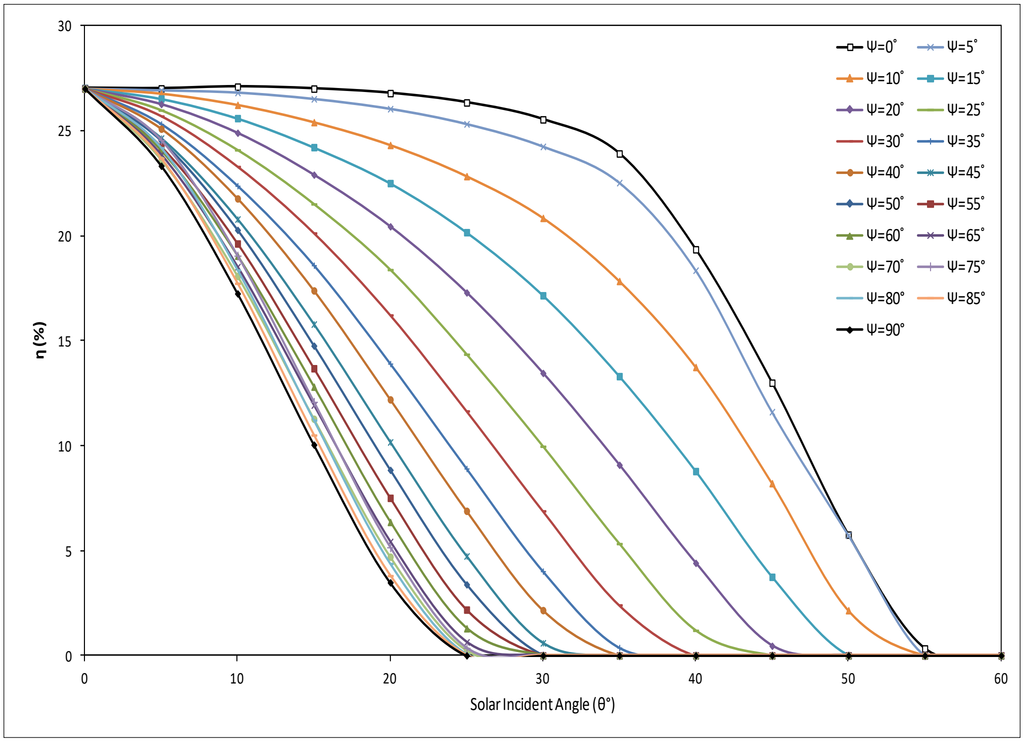

Figure 3: Variation Of Optical Efficiency with Azimuth and Incident Angles

2.3 Flux Distribution on The Receiver Area for Different Azimuth Angle

Using the 3-D tracing simulation, the effect of variation of the solar azimuth angle on the flux distribution on the receiver area of the EHC was examined by moving the solar source along the x-y plane of the aperture major axis from 0° to 90° with an increment of 15° intervals. The results obtained are shown in figures 4 to 6 respectively. It was observed from figures 4 and 5, at solar azimuth angle of 0° and 15°; the flux is uniformly distributed and spread over the receiver for the solar incidence angle of 0° to 30°. In the same figures, at 45° incidence angle, the flux is not uniformly distributed. The distribution is scattered non-uniformly over the receiver. And at one end of the receiver, it is concentrated, the flux value is higher. Similarly, from figures 6 and 7, at solar azimuth angle of 30° and 45° the distribution of the flux on the receiver area were uniformly spread when solar source incidence angle was 0 and 15, but when the solar source incidence angle of 30, the total flux measured on the receiver was concentrated at one side of the receiver, while at angles above 30° no radiation flux was observed at the receiver. Similarly, variation is observed for solar azimuth angle of 75° and 90°, as shown in figures 8 and 9. Furthermore, the variation of the flux distribution along the receiver major axis and receiver minor axis; are also shown in figures 10 to 15.

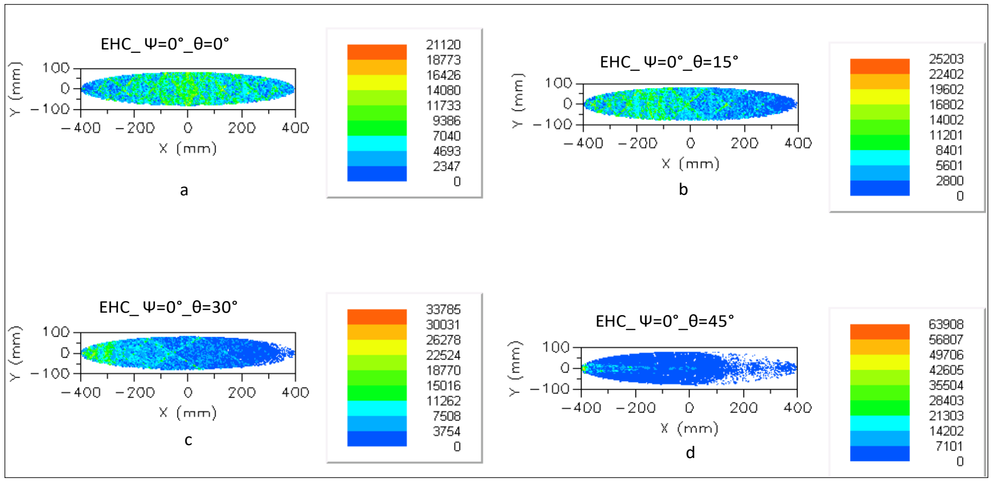

Figure 4: Flux Distributions on Plane Angle is 0° and Incidence Variation for 0°-45°

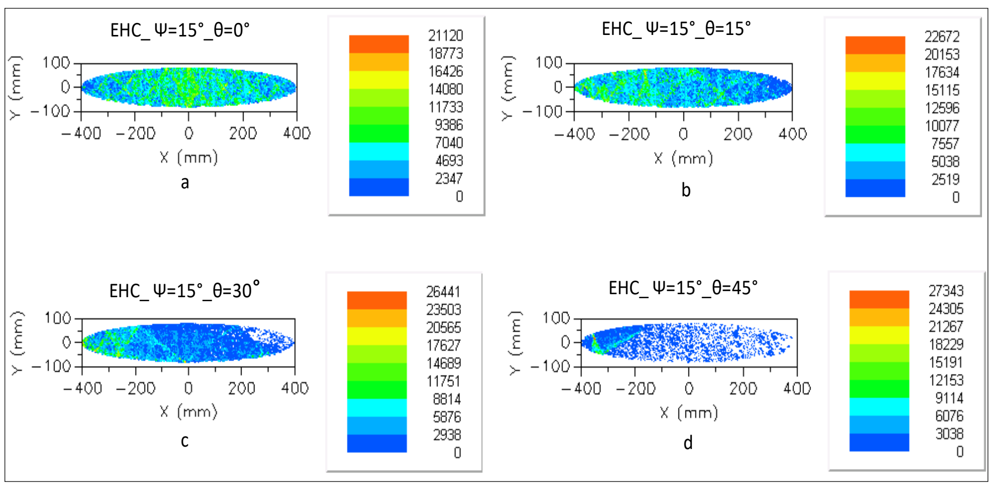

Figure 5: Flux Distributions on Plane Angle is 15° and Incidence Variation for 0°- 45

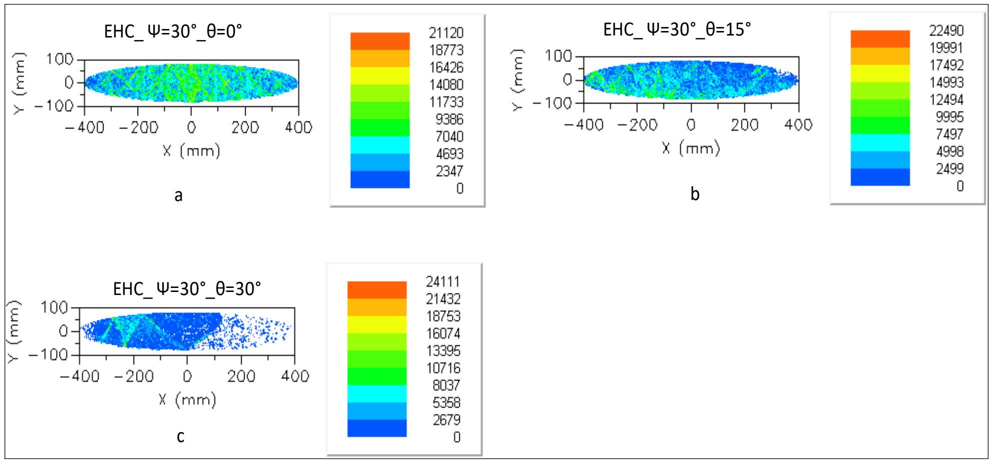

Figure 6: Flux Distributions on Plane Angle is 30° and Incidence Variation for 0°-30°

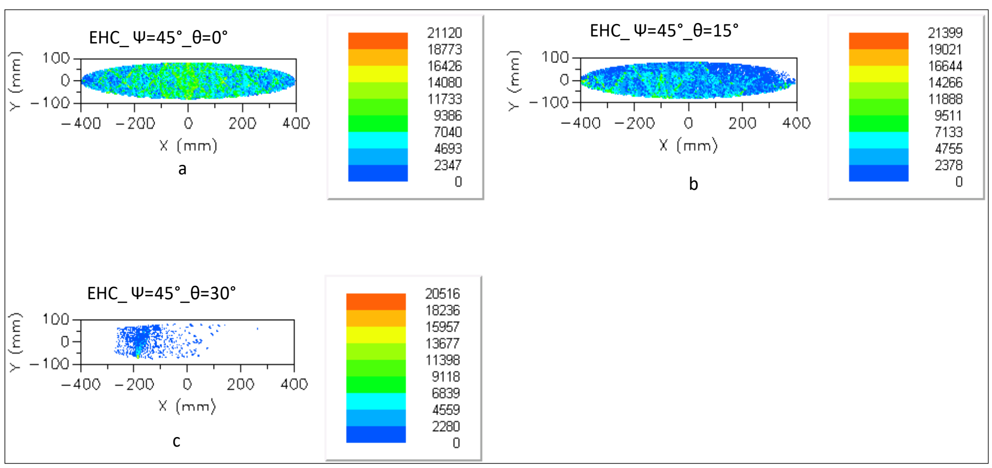

Figure 7: Flux Distributions on Plane Angle is 45° and Incidence Variation for 0°-30°

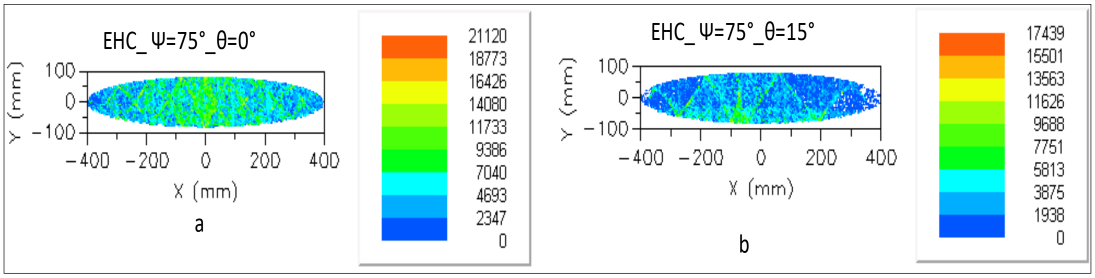

Figure.8: Flux Distributions on Plane Angle is 75° and Incidence Variation for 0° -15°

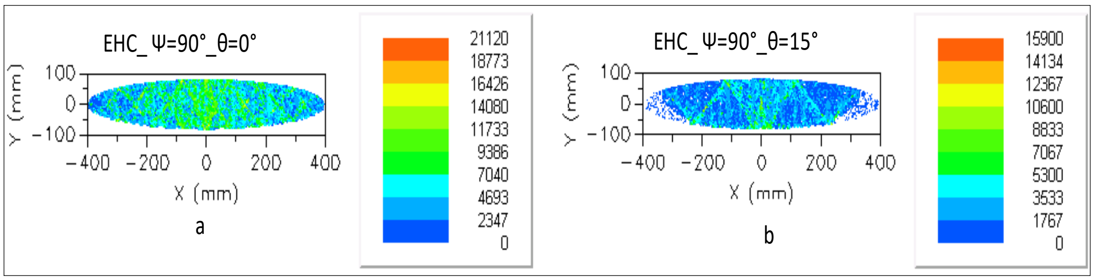

Figure.9: Flux Distributions on Plane Angle is 90° and Incidence Variation for 0° -15°

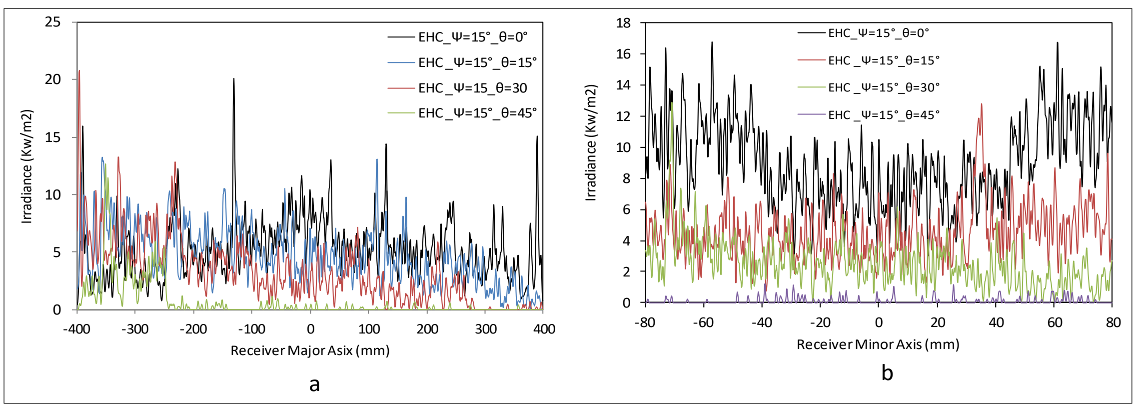

Figure10: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=15°) and Different Incident Angle

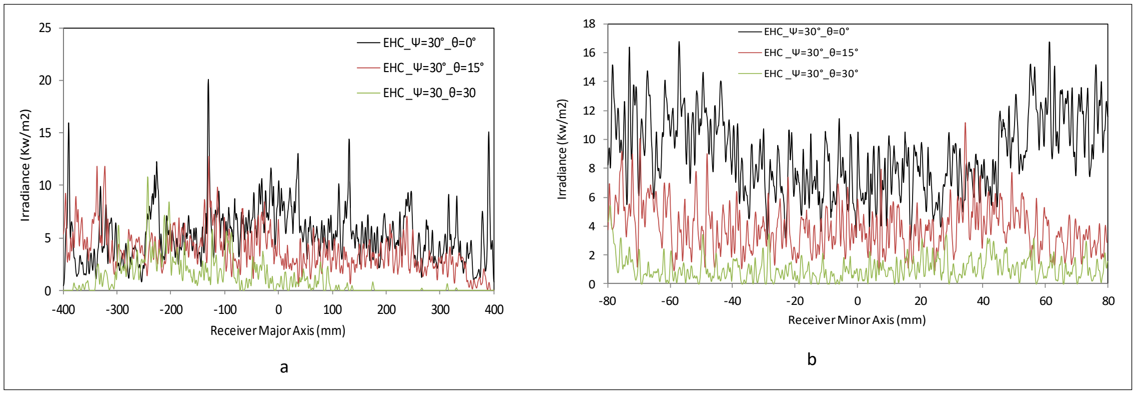

Figure11: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=30°) and Different Incident Angle

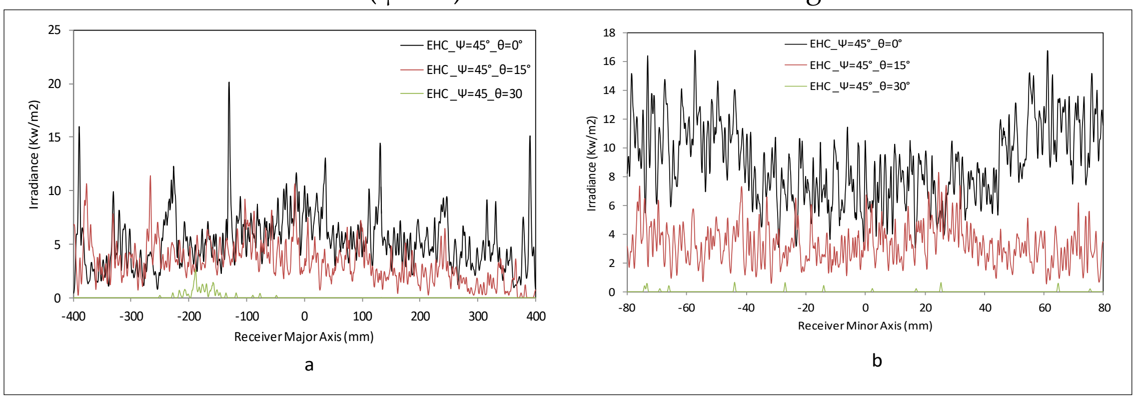

Figure 12: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=45°) and Different Incident Angle

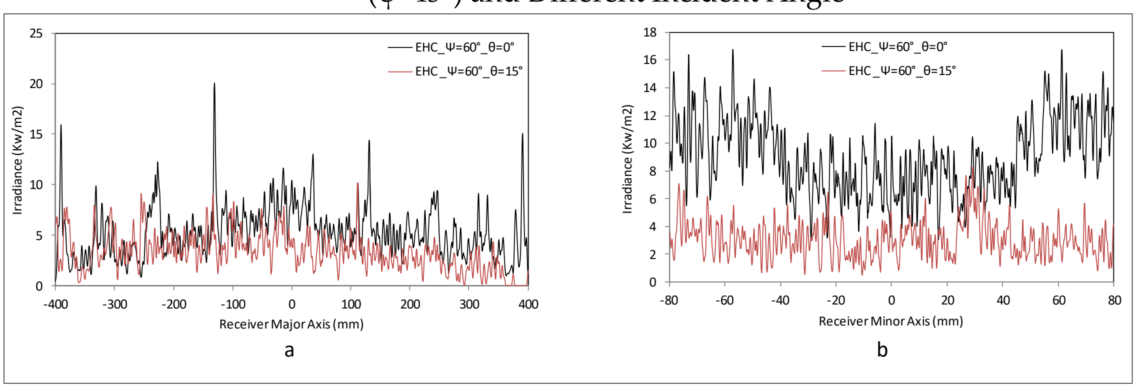

Figure13: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=45°) and Different Incident Angle

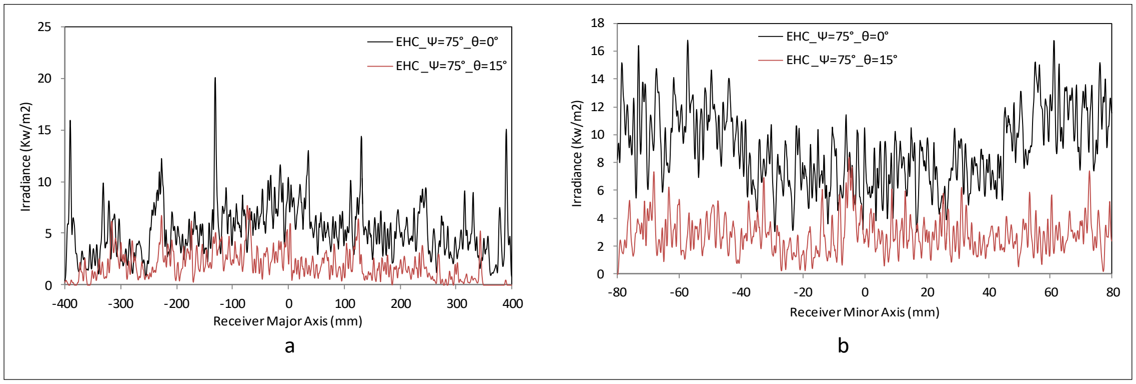

Figure14 1: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=75°) and Different Incident Angle

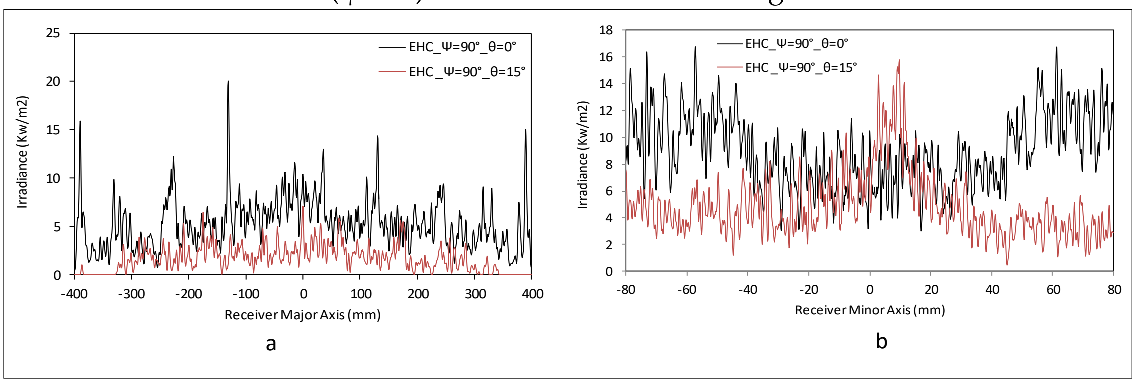

Figure15: Flux Distributions on Centre Line of a) Major Axis and b) Minor Axis for Different Plan (ψ=90°) and Different Incident Angle

Conclusion

The evidence is observable that this paper has shown clear and promising results of the optical study of Elliptical Hyperboloid concentrator (EHC) based on ray tracing at different incidence angles and orientations. Centered on the present study of the effect of variation of the solar azimuth angle on the flux distribution on the receiver area of the EHC has been examined by moving the solar energy source along the x-y plane of the aperture major axis from 0° to 90° with an increment of 15° intervals.

The maximum optical efficiency observed for each angle decreases, as the solar source is moved from 0°-90°. Moreover, Using the 3-D tracing simulation, the effect of variation of the solar azimuth angle on the flux distribution on the receiver area of the EHC was also examined and illustrated. Whereas, at 45° incidence angle, the flux is not uniformly distributed. The distribution is scattered non-uniformly over the receiver. However, at one end of the receiver, which is concentrated, the flux value is higher.

References

[1] Armstrong S, Hurley WG. A new methodology to optimize solar energy extraction under cloudy conditions. Renew Energy 2010; 35:780–7.

[2] Cludius J, Hermann H, Matthes FC, et al. The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: estimation and distributional implications. Energy Econ 2014; 44:302–13.

[3] Stanciu C, Stanciu D. Optimum tilt angle for flat plate collectors all over the world: a declination dependence formula and comparisons of three solar radiation models. Energy Convers Manage 2014; 81:133–43.

[4] Rawat R, Kaushik SC, Lamba R. A review on modeling, design methodology and size optimization of photovoltaic based water pumping, standalone and grid connected system. Renew Sustain Energy Rev 2016; 57:1506–19.

[5] Smith CJ, Forster PM, Crook R. An all-sky radiative transfer method to predict optimal tilt and azimuth angle of a solar collector. Sol Energy 2016; 123:88–101.

[6] Dhimish M, Holmes V, Mather P, et al. Preliminary assessment of the solar resource in the United Kingdom. Clean Energy 2018; 2:112–25.

[7] Stanciu D, Stanciu C, Paraschiv I. Mathematical links between optimum solar collector tilts in isotropic sky for intercepting maximum solar irradiance. J Atmos Sol-Terr Phys 2016; 137:58–65.

[8] Mahmoud Dhimish, Santiago Silvestre, 2019, Estimating the impact of azimuth-angle variations on photovoltaic annual energy production, Clean Energy, Vol. 3, No. 1, 47–58

[9] Banu Poobalan, Haziah Abdul Hamid, Noor Hasnizam Hanafi and Wooi Chin Leong, 2020 The study of photovoltaic systems performance using various azimuth angles and solar array tilt positions. Journal of Physics: Conference Series 1432 012050

[10] Suman Chowdhury, Md. Abul Bashar, Md. Nazmul Hossain, Anik Talukder. 2013 Temperature and Azimuth angle variation effect on the Building Integrated Photovoltaic Application in Bangladesh, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 8, Issue 2, PP 42-46

[11] I.M. Saleh Ali, Tadhg S.Reddy, K. S. Mallick, Tapas K., An optical analysis of a static 3-D solar concentrator, Solar Energy, 88 (2013) 57-70.