Retraction Notice

Title of retracted article: **Direct Beam Solar Radiation Received by Parabolic Trough Collector with Dust Accumulated on Its Surface**

Author(s): Zheng Chang, Jing Ma, Suying Yan, Rui Tian

* Corresponding author. Email: yuanhao526829@163.com

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History

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X no

Correction:

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X no

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Free style text with summary of information from above and more details that can not be expressed by ticking boxes.

This article has been retracted to straighten the academic record. In making this decision the Editorial Board follows COPE's Retraction Guidelines. Aim is to promote the circulation of scientific research by offering an ideal research publication platform with due consideration of internationally accepted standards on publication ethics. The Editorial Board would like to extend its sincere apologies for any inconvenience this retraction may have caused.

Editor guiding this retraction: Prof. Elias K. Stefanakos (EIC of JPEE)

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Direct Beam Solar Radiation Received by Parabolic Trough Collector with Dust Accumulated on Its Surface

Zheng Chang[1*], Jing Ma[1], Suying Yan[1,2], Rui Tian[1,2]

[1]College of Energy and Power Engineering, Inner Mongolia University of Technology, Hohhot, China
[2]Key Laboratory of Wind and Solar Power Energy Utilization Technology Ministry of Education and Inner Mongolia Construction, Hohhot, China
Email: *ZZChang2015@foximail.com

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Abstract

Dust accumulation was part of the natural phenomena that adversely affecting the performance of the parabolic trough solar system. The parabolic trough solar concentrator was exposed to the ambient conditions. In this paper, the work was investigated experimentally and mathematically the effect of sand dust accumulation on beam light reflectance at a trough concentrator surface. The optical efficiency of the solar concentrator was analyzed theoretically and dust accumulation condition was simulated in this paper, in order to study the effect of dust on the optical efficiency of the solar concentrator and energy flux distribution of the metal tube. Moreover, energy flux density was generated via the Monte Carlo ray tracing method and the finite element volume method from the discussion of the heat transfer of the parabolic trough collector system. The results showed that the dust accumulated condition effected obviously a reflection path of the light and the energy flux density wall of the metal tube wall surface, and because of the dust accumulation energy flux density distribution of the wall also had a certain influence on circumferential temperature distribution.

Keywords

Dust Accumulation, Parabolic Trough Condenser Mirror, Reflectance Degradation, Energy Flux Density Distribution

1. Introduction

Nowadays, with depletion of fossil fuels and greenhouse effect, the utilization of solar energy has attracted increasing attention owing to the distinct advantages, including clean, sustainability, inexhaustibility, etc. For parabolic trough solar collector system, the condenser optical surface that was exposed to the environment would accumulate dust and dirt or otherwise degrade. The effects of this reflective degradation need to be included in any realistic prediction method. Also, suspended dust, whether fine or large in the atmosphere eventually would settle on the trough collectors and cover their surfaces and therefore reduce their efficiencies.

Mirror polluted and reflectance measurements were the most common activities and had a remarkable impact on the leveraged cost of energy. The fraction of these activities on the total cost of electricity produced by Concentrated Solar Power (CSP) plants was approximately 8% [1]. EI-Nashar [2] has studied the seasonal effect of dust deposition on a field of evacuated tube collectors of a solar desalination plant. The system is located near the city of Abu Dhabi, UAE, and the results are therefore relevant to this region. Dust deposition causes a monthly drop in glass tube transmittance of 10% - 18% with a large drop in plant production. The author evidences a transmittance decrease from an initial value of 0.98 (clean glass condition) to a low value of 0.6, corresponding to a very dusty glass condition. The production drops from 100% to 40% of the clean collector production level. Given a thermal energy loss production of 1.2% for each 1% point of reflectivity drop, the identification of the optimal balance between more and less in the Operation and Maintenance activities (cleaning) represents an important aspect for Concentrated Solar Thermal (CST) plant economic feasibility [3]. In recent years, the present study has been furthered by investigating the influence of the dust deposition on the efficiency of the photovoltaic (PV) module. Most scholars exposed the PV module in different environments, and analyzed the effect of the dust deposition by the comparison of experimental results [4] [5] [6]. Although numerous studies have been performed to study dust accumulation effect on the performance of different solar systems, very limited published studies on dust deposition effects are available for parabolic trough collectors of solar thermal power plants. So far, there were rarely research focus on the relationship between the dust deposition and sunlight reflectance of the condenser optical surface. This study focus on the optical surface of dust deposition affecting reflectance of the parabolic trough collector.

2. Methodology

2.1. Consider the Existence of Convergent Ray Equation for the Thickness of the Condenser Mirror

After concentrating solar trough system by adjusting the tracking device, solar rays reached the mirror, would undergo infinite reflection, refraction and transmission. But the actual trough solar concentrating system mirror was curved cylindrical, the upper and lower surfaces of thin curved mirror equidistant from each other. The main path through which the sunlight reached the mirror is given in **Figure 1**.

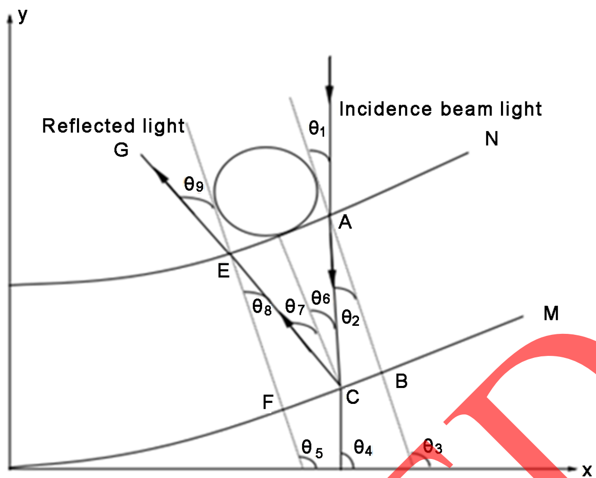


Figure 1. Main path of sunlight reaching the lower surface of parabolic reflector dust accumulation.

Theoretical calculation and analysis of the influence of glass thickness on reflective properties were by Fei Chen *et al.* [7]. The equation for refraction of the sunlight $\overline{EG}$ was:

$$y - y_E = k_{\overline{EG}}\left(x - x_E\right) \tag{1}$$

In the Equation (1), letted $x = 0$ could calculate the intercept l_y value of the $\overline{EG}$. The thickness of the condenser mirror caused the convergent light to deviate from the focal point of the longitudinal offset $\Delta Y = l_y - f$, and where $y = f$ could calculate the thickness of the condenser mirror to cause the converging light to deviate from the focal point of the lateral offset ΔX. Meanwhile, the Equation (1) was the principal path for the solar trough condensing system when the sunlight was paralleled to the solar light. In fact the sun has a 32' angle to the earth, except that θ_1 was replaced by $\theta_1 + 16'$.

The parallel light concentrating solar trough system had been calculated, the result was shown in Figure 2. When the condenser mirror thickness 4.6 mm, the distance from the optical axis incident light was 200 mm, ΔY could reach 0.85 mm; when the incident light rays from a distance of 2000 mm optical axis, ΔY was 1.46 mm. This was due to the presence of the condenser mirror glass thickness results converge shifted light direction, converging at a certain thickness of the mirrors, the incident light away from the optical axis, the larger the edge angle, the greater the optical path, and light converging more focal lengths deviate from the optical axis intercept. While converging the light at the focal position of the absorber, the same thickness glass mirror, the incident light from the farther from the optical axis, the larger lateral defocus offset ΔX. When the distance from the optical axis of the incident light incident ray of 200 mm, ΔX was 0.19 mm; distance from the optical axis of the incident light 2000 mm, ΔX could reach 7.73 mm. This was because the thickness of the condenser mirror leads light from reaching the convergence deviation occurs in the optical axis when the focal position of the receiver, and the farther the distance from the optical

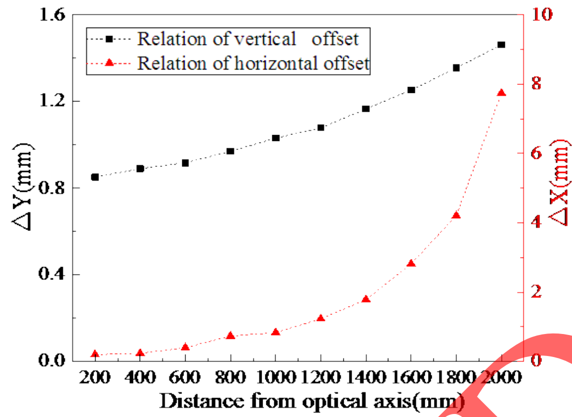


Figure 2. Location of incident light and relation of offset ΔY and ΔX.

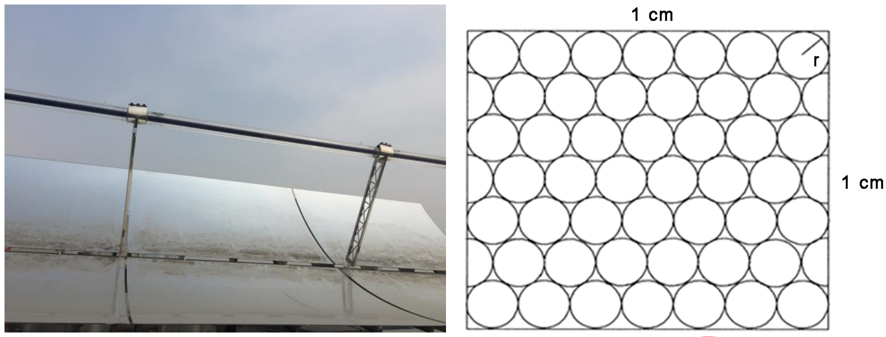
axis, the optical path shift more light when the light reaches the receiver convergence and focus position the more the optical axis deviation.

2.2. Reflectance Degradation for Dust Deposition Effected on Mirrors

Reflectance reduction was mainly embodied in the optical efficiency and energy flux distribution of the trough solar concentrator. In order to study the effect of dust deposition on the optical efficiency of the solar concentrator and energy flux distribution of the metal tube. The optical efficiency of the solar concentrator was analyzed theoretically and dust accumulation condition was simulated in this paper. Dust particle size was mainly taken into account the dust caused by the reflectance effected, using the equivalent projection area diameter was more appropriate. Applicable to simulate the actual problem simplification, assumed a uniform distribution of dust, shown in Figure 3.

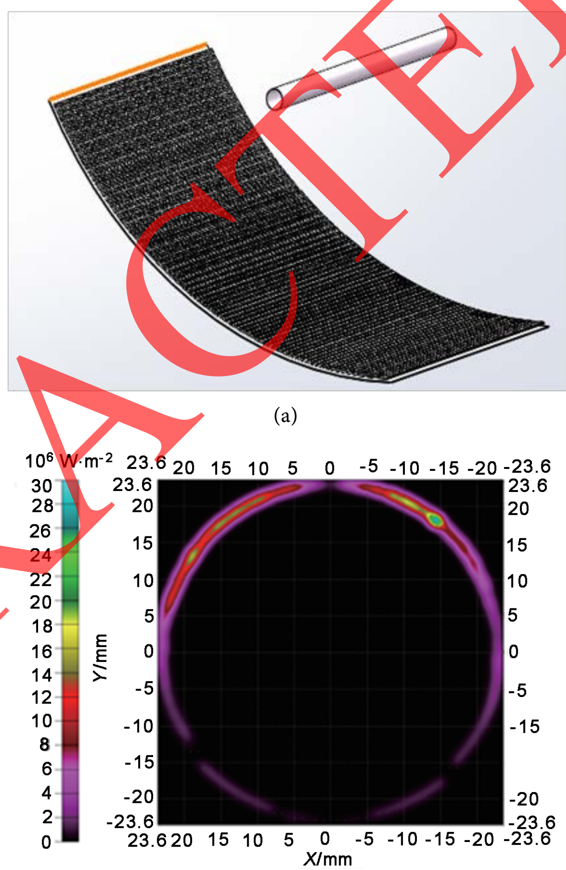
Dust deposition would not only result in the role of light shielding, but change the reflected light paths. Based on the theoretical study on the influence of dust on the optical performance of trough solar concentrator, the dust particles were simplified to the sphere, the physical properties were SiO_2 and the equivalent particle size of dust was 1 mm. In the Solidworks software, a three-dimensional model of the parabolic trough condenser was established and the 3D model with dust accumulation was imported into the TracePro software. The main parameters of the geometric model were shown in Table 1. Ray tracing was specified to rasterize the ray tracing mode, using the Monte Carlo method to trace all the light reflected by the condenser and the metal tube until the light overflows the condensing system or was completely absorbed and then tracks the next beam of light screening function, the total number of light was determined to 1×10^5.

Figure 4(a) was the establishment of the trough solar condenser dust in the three-dimensional model. Figure 4(b) was shown in the condenser mirror dust conditions, the metal tube wall along the circumferential energy flux distribution, where the peak was between the dust of the overlap caused by the light of the



(a) (b)

Figure 3. The photograph of the actual dust accumulation distribution for (a) and the arrangement of spheres when a whole for (b).



(a)

(b)

Figure 4. Three-dimensional model of the concentrator for (a) and circumferential energy flux distribution of the metal tube for (b).

Table 1. Main parameters of trough concentrating system.

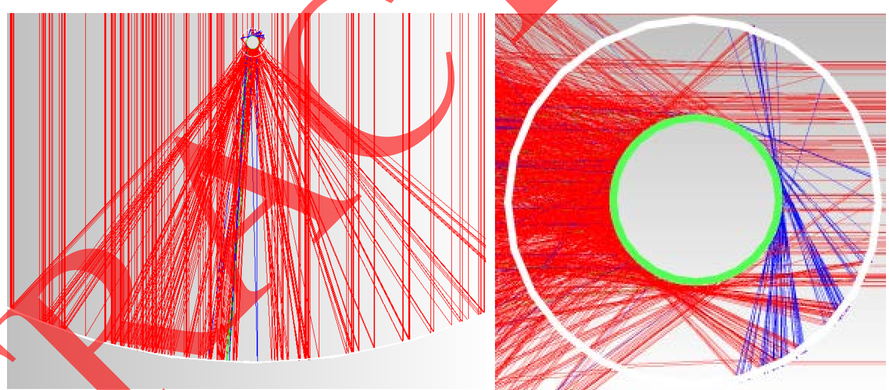
Condenser parameters		Absorber parameters		Optical properties	
Aperture width /m	5.000	Glass tube outside /m	0.115	Reflectivity	0.930
Focal length /m	1.840	Metal tube outside /m	0.110	Transmissivity of glass	0.950
Length /m	7.800	Metal tube inside /m	0.070	Absorptivity of metal tube	0.960

point of aggregation. The light paths under the dust accumulation were shown in Figure 5. Figure 6 was a metal tube wall along the circumferential direction of the energy flux value, compared the side of the half dust deposition and the whole dust deposition directly responded the influence of dust. In the cleaning condition, the energy flux density of the bottom of a metal tube was about 5 × 10^4 W/m^2, and the maximum energy flux density of a metal tube was about 1.2 × 10^4 W/m^2 in the whole dust accumulation condition.

In order to analyze the effect of dust accumulation on the energy flux value, Figure 7 was shown that the energy flux distribution of a metal tube under the dust deposition thickness of 3 mm, 2 mm, 1 mm. It could be observed in the figure distribution trends and values of the dust thickness of 2 mm and 3 mm were basically the same. When the dust thickness was 1 mm, the greater effected for the path of the reflected sunlight owing to the thin dust layer.

3. Test Experiment

To measure the amount of beam light reflected from the surface of as mirror which has different positions to different wavelengths in the visible region, a



(a) (b)

Figure 5. Optical simulation of TracePro in dust deposition condition of the condenser mirror (a) and the absorber (b).

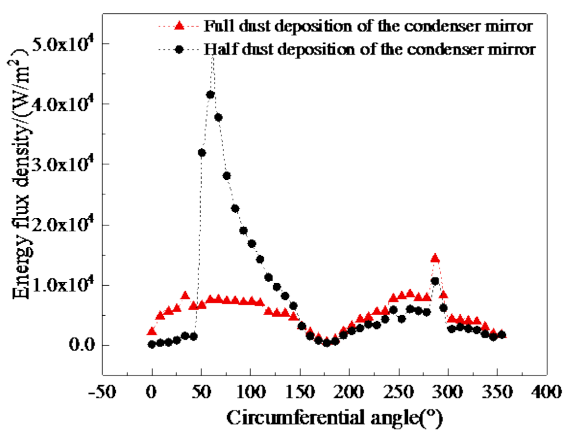


Figure 6. Circumferential energy flux distribution of the metal tube wall.

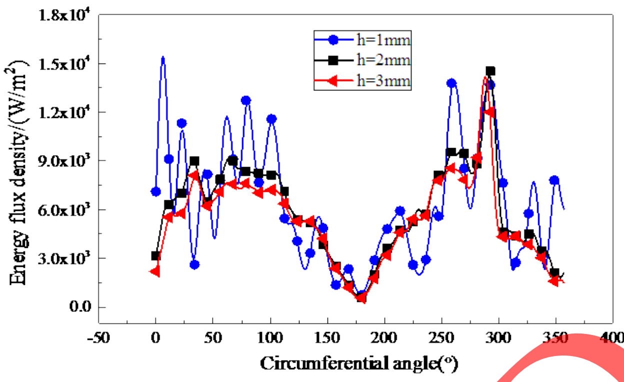


Figure 7. Energy flux distribution of the circumferential metal tube with different dust accumulation thickness.

UV3600 Ultraviolet Visible Near Infrared Spectrophotometer was used. The glass samples were exposed to the outdoor environment in Hohhot, China in different orientations, shown in Figure 8. The dust deposition was observed on the surfaces and monitored on a weekly basis. The building up of dust particles on the samples surface depended on the particle density and the particle aggregation. For a week of naturally dust accumulation, the different positions in the relative reflectance reduction at different wavelengths were plotted in Figure 9, which showed a clear picture of these results. The relative specular reflectance started to increase rapidly at shorter wavelengths. As the wavelength increased, the reduction value would start to decrease rapidly. Varying from 600 to 800 nm wavelengths, the relative reflectance reduction decreased at lower edge and the centre position of the mirror, which increased at the upper edge of the mirror. The reflectance reduction was more at longer wavelengths, which were related to the nature of the color of dust amounts. The color of the dust deposition was almost red or brown. This meant that dust accumulation particles started to form a brown layer over the mirror and so absorbed the smaller wavelengths.

4. Conclusions

Dust accumulation effected for the decreased reflectivity and reflected light paths changing with different thickness of reflector mirror had been examined experimentally. The theoretical analysis had been done for the solar parabolic trough system whose focal length was 1097 mm, and the refractive index of glass of the reflector was 1.5. For 4.6 mm thickness of the reflector, when the distance from the optical axis of the incident sun light was 200 mm and 2000 mm respectively, ΔX was 0.19 mm and 7.73 mm respectively, ΔY was 0.85 mm and 1.46 mm respectively. The optical efficiency of the solar concentrator was analyzed theoretically and dust accumulation condition was simulated. The result showed that the dust accumulated condition effected obviously the direction of reflected paths and the energy flux density of the receiver surface. In the cleaning condition, the energy flux density of the bottom of the receiver was about 5×10^4 W/m², and the maximum energy flux density of the receiver was about 1.2×10^4 W/m² in the whole dust accumulation condition.

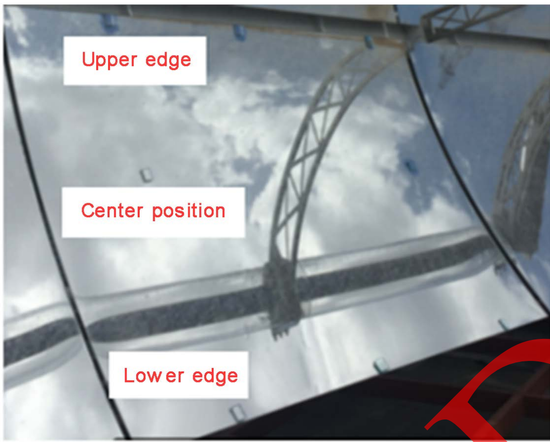


Figure 8. Measurement points at different locations of the mirror.

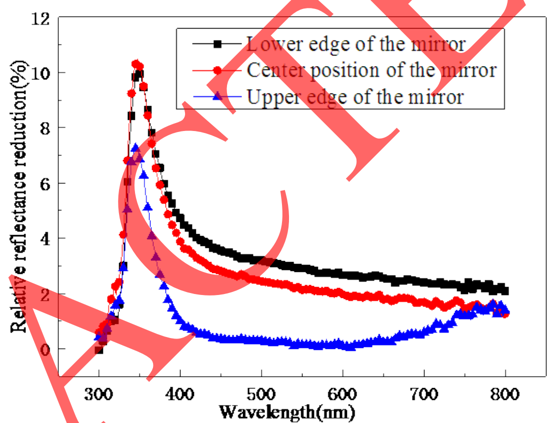


Figure 9. Relative reflectivity reduction with different positions of the mirror.

At the same time, the distribution of energy flux density of the receiver on different dust conditions with a thickness of 1, 2, and 3 mm was analyzed. It could be obtained that the distribution trend and the density value were almost the same for 2 mm and 3 mm of dust amounts thickness. With the more thin dust accumulation layer on the surface of the concentrator, the reflection path of the sun light had changed obviously, resulting in the density value fluctuation for 1 mm of dust deposition thickness. This decrease in light reflectance was not the same for all wavelengths in the measured region.

Acknowledgements

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