Advances in Natural Science **ISSN 1715-7862 [PRINT]**
Vol. **3**, No. **2**, **2010**, pp. 338-347 **ISSN 1715-7870 [ONLINE]**
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The 3rd International Conference of Bionic Engineering

Primary Research on Bionic Design of Multi-surface Solar Concentrator Based on the Flower Structure

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Abstract: Plant can't grow and reproduce without sunshine. Flowers have an inseparable relationship with sunshine as an important part of the plants. Most studies on the relationship of the plant and sunshine focus on the influence that sunshine reacts to plant, such as photosynthesis. However, there is no much more special attention on the relationship between flower structure and sunshine. Through the observation and comparison, the outlines of many flowers contour have some similarities with the solar concentrator. This paper delves into the relation between flower structure and light, in order to get the new ideas of designing solar concentrator.

By means of extracting a contour line of flowers, their geometric structure models are got. Through simulation calculations of optical software, light-gathering performance of flowers is researched in the circumstance of different angle incident. Then based on researching the light-gathering process of the flowers, the innovative design ideas of bionics solar concentrators with excellent performance are presented. So in this way traditional thinking mode of single curve or surface used in solar concentrator design is expanded.

Key words: flowers; bionic; solar concentrator

1. INTRODUCTION

Plant can't grow and reproduce without sunshine. Flowers have an inseparable relationship with sunshine as an important part of the plants. Most studies on the relationship of the plant and sunshine focus on the influence that sunshine reacts to plant, such as photosynthesis. However, there is no much more special

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* Received 5 May 2010; accepted 26 July 2010

attention on the relationship between flower structure and sunshine. We need to study is how plants get solar energy efficiently. Through the observation and comparison, the outlines of many flowers contour have some similarities with the solar concentrator. This paper delves into the relation between flower structure and light, in order to get the new ideas of designing solar concentrator.

The blossoms of general plant are shorter than the period of plant growth. Such as the stylus, ovary and other key parts of reproductive organ need more light and heat. Therefore, in order to gain sufficient light and heat, flowers will derive high-efficiency condenser performance. The particularity of the pumpkin flower structure was found by preliminary studies. No matter which direction the incident entered into the flower, the light intensity was evenly distributed on the stylus, and there was no shadow on it. There are many other flowers have their special structure, which is very enlightening for studying other forms of solar concentrators.

Through observing and comparing a variety of concentrators and flowers, many similarities between solar concentrators and flower structures were found. Fig. 1 lists some the flowers, which are similar with some concentrators.

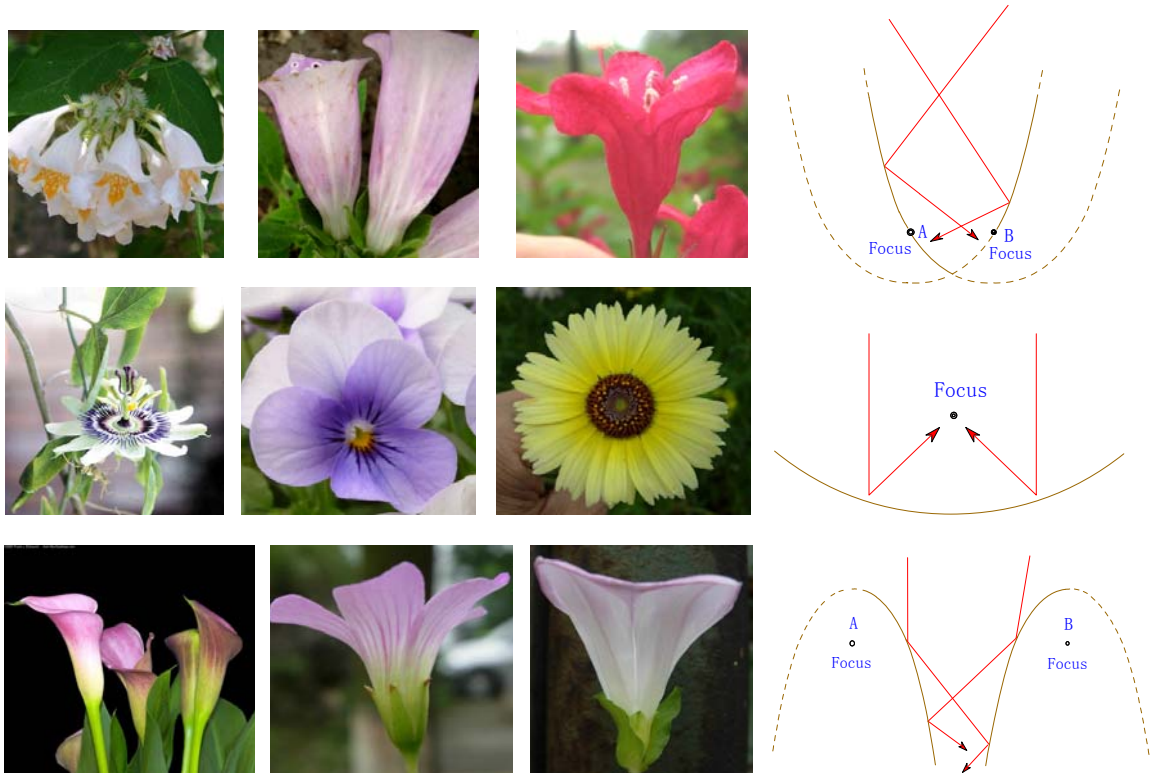


Fig. 1

2. THE RAYTRACE SIMULATION OF THE FLOWER STRUCTURE MODELS

Whether these flowers whose contour lines are similar with solar concentrators have condenser functions can provide sufficient light and heat to somewhere flowers need. Three flowers were chosen to analyze, their number are Flower A, Flower B and Flower C. Their photos are shown in Fig.2. Their outlines were analyzed simply and then one of their contour lines was picked up respectively. The flower structure models were established by their contour lines rotated around the symmetry axis. And the locations of the symmetry axis were much closed to the location of the pistil. The established flower structure models were

imported into the optical software to do the raytrace analysis. A cylindrical absorber Ⅰ whose dimensions approximately equal to the pistil was added on the symmetry axis and a plate absorber Ⅱ was added under the outlet in order to observe light gathering situation. The inner surface of the structure models was set as the mirror so as to analyze conveniently.

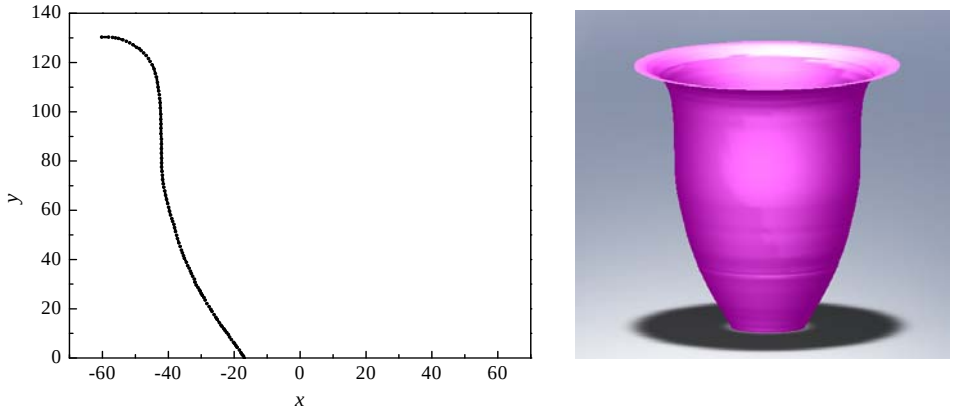
(a) (b) (c)

Fig. 2

2.1 The analyses of Flower A

The Flower A shown in Fig. 2 (a) looks like a compound parabolic concentrator. Based on the one of the contour lines extracted from the Flower A, a 3D model was established, and the results are shown in Fig. 3. Imported the 3D model into the optical software and then added the absorber. The wireframe structure is shown in Fig. 4. Ensure that the number of incident light is always 124, and the array map is shown in Fig. 5. Through the raytrace analysis, light gathering performance of the model was simulated on the condition of the incident deviate 0°, 2°, 5°, 10°, 20° respectively from symmetry axis. The simulation results are shown in Fig. 6.

The number of light received by two absorbers was counted, and the result is shown in Fig. 7. As can be seen from Fig. 7, the aggregate number of light received by absorbers decreased with the increase of the deviate angle of the incident from the symmetry axis. When the incident light deflection angle is less than 10°, with the increase of the incident light deflection angle, the number of light received by absorber I decreased; and the number of light received by absorber IIincreased. When the incident light deflection angle is more than 10°, with the increase of the incident light deflection angle, the number of light received by absorber I increased slightly; and the number of light received by absorber II decreased slightly.



(a) (b)

Fig. 3

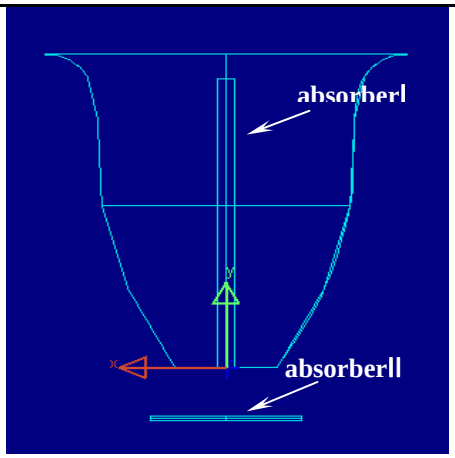


Fig. 4

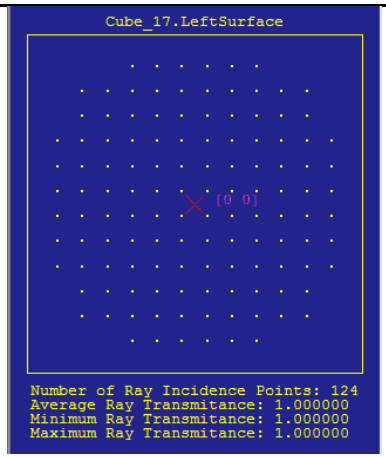
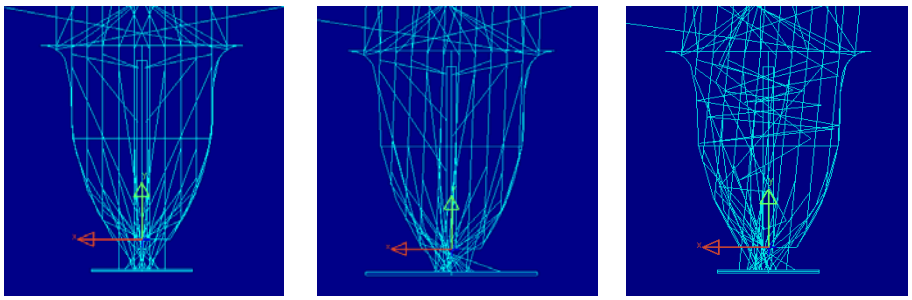


Fig. 5



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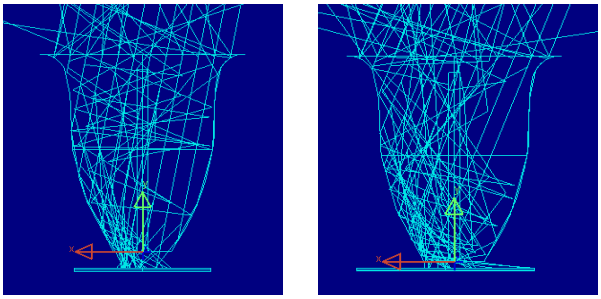


10° 20

Fig. 6

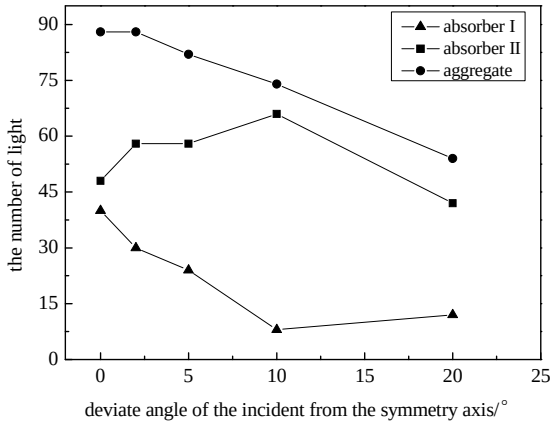
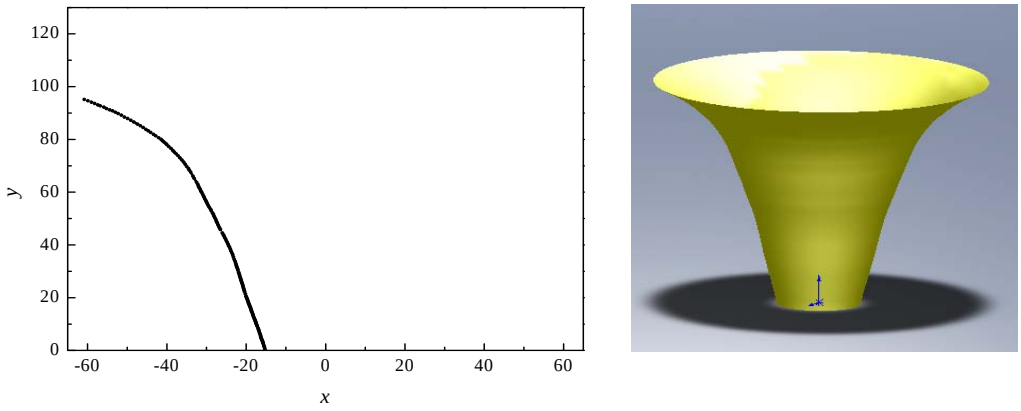


Fig. 7

2.2 The analyses of Flower B

Use the same method, the structure model of Flower B was analyzed. The results of the contour line and 3D model are shown in Fig. 8. Imported the 3D model into the optical software and then added the absorber. The wireframe structure is shown in Fig. 9. Ensure that the incident light array map is same with the Fig. 5. Through the raytrace analysis, light gathering performance of the model was simulated on the condition of the incident deviate 0°, 2°， 5°， 10°， 20° respectively from symmetry axis. The simulation results are shown from Fig. 10.

The number of light received by two absorbers of the Flower B was counted, and the result is shown in Fig. 11. As can be seen from Fig. 11, the changes of the aggregate number of light received by absorbers were relatively stable, only have some slight fluctuations. When the incident light deflection angle is more than 10°, the number of light received by absorber I decreased slightly; and the number of light received by absorber II increased slightly, along with the increase of the incident light deflection angle. There were not much distinction between the number of light received by absorber I and absorber II.



(a) (b)

Fig. 8

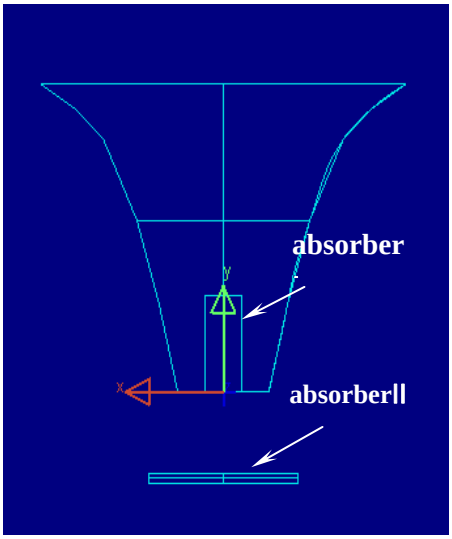


Fig. 9

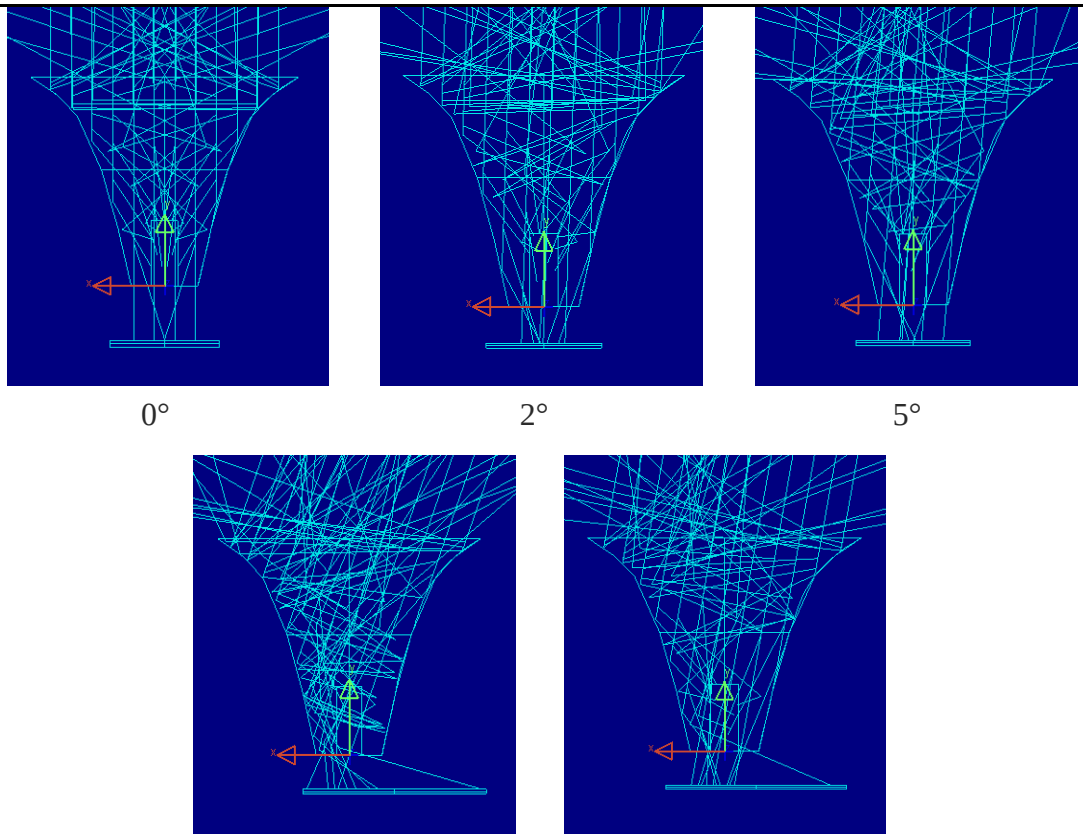


Fig. 10

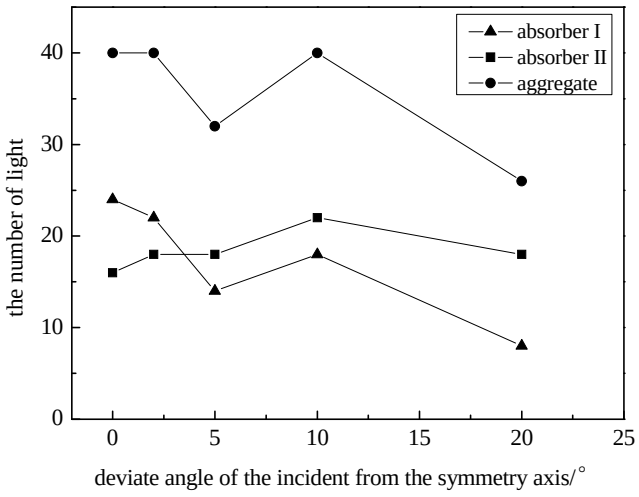


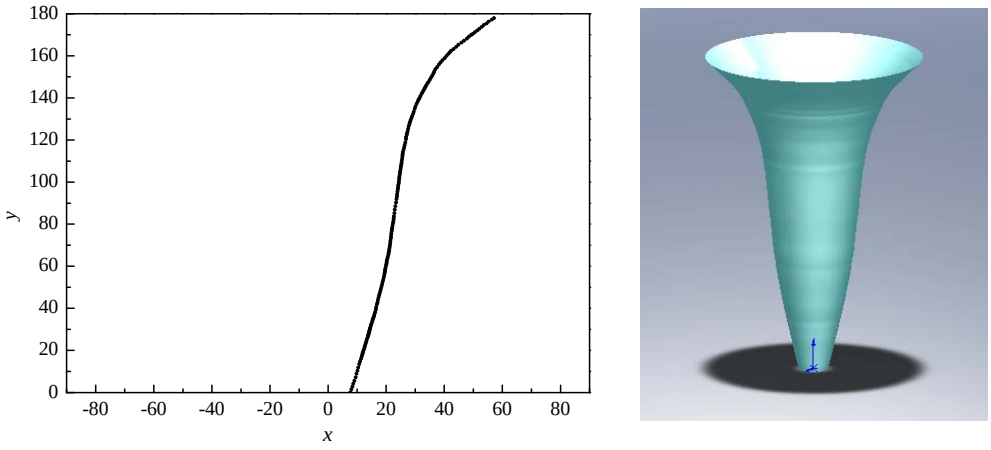
Fig. 11

2.3 The analyses of Flower C

Likewise, the structure model of Flower C was analyzed. The results of the contour line and 3D model are shown in Fig. 12. The wireframe structure in the optical software is shown in Fig. 13. Ensure that the

incident light array map is same with the Fig. 5. Through the raytrace analysis, light gathering performance of the model was simulated on the condition of the incident deviate 0°, 2°, 5°, 10°, 20° respectively from symmetry axis. The simulation results are shown from Fig. 14.

The number of light received by two absorbers of the Flower C was counted, and the result is shown in Fig. 15. As can be seen from Fig. 15, the number of light received by absorbers decreased rapidly along with the increase of the incident light deflection angle. There is not any light arrived at the absorbers when the deviate angle is 20°. The light that parallel to the symmetry axis is absorbed effectively by the absorber Ⅰ. However, the number of light decreased rapidly with the increase of the incident light deflection angle.



(a) (b)

Fig. 12

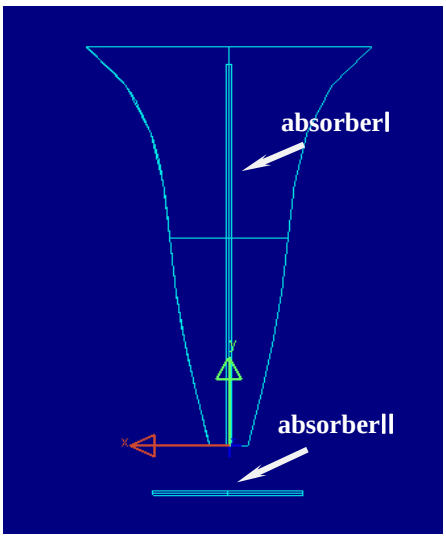


Fig. 13

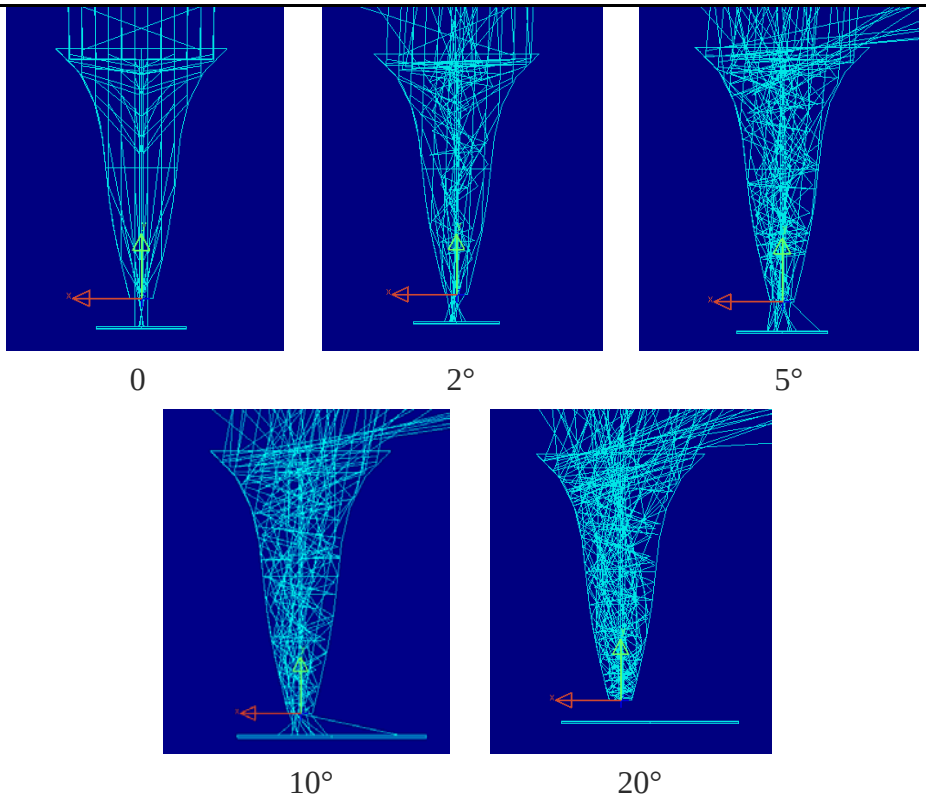


Fig. 14

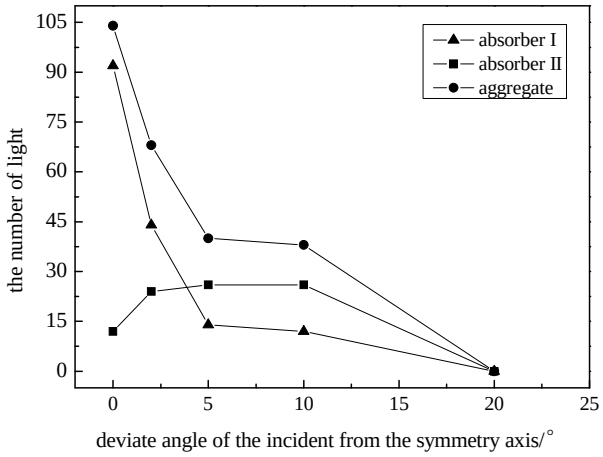


Fig. 15

3. THE ANALYSIS OF THE SIMULATION RESULTS

The results of raytrace simulation and statistical number of light received by absorbers indicated that these three flowers can provide sufficient light and heat to the stylus, ovary and somewhere else these flowers need. This demonstrated that derived condenser functions of the flowers after the choice of nature is a physiological significance.

(1) The calculation results of the Flowers A structure model shows that the number of the light received by the absorber Ⅱ is always more than the absorber Ⅰ. And these numbers tend to decline only when the

deflection angle is more than a particular angle. As long as keeping the deflection angle of the incident light within this particular angle, most incidents can be received by the absorber Ⅱ.

(2) The calculation results of the Flowers B structure model indicates that the number of light received by two absorbers don't fluctuate sharply although it is less the number of Flower A and Flower C. This character is very benefit for those receivers which are sensitive to changes of the energy.

(3) The calculation results of the Flowers C structure model indicates that when the incident parallel to symmetry axis enter into the structure of Flower C, the majority of incident is received by the absorber Ⅰ. However, this number decreased drastically when the incident light deflection angle changed. This means that the location of the absorber set on the symmetry axis is better than on the outlet. The absorber Ⅰ can receive most of the energy, but high tracking accuracy is necessary.

4. THE DESIGN OF MULTI-SURFACE SOLAR CONCENTRATOR

As can be seen from above analyses, the structures of the three flowers have condenser function. The concentration effects are different because of the different structures. How to get design inspiration of the concentrator from the flower structure? Here some design methods are listed to discuss.

First, the appropriate flower structure should be select as the imitation object, according to the requirements of concentrator. For example, the structure of like Flower A can be used if the concentrator need not to track the sun all the time just adjusted at regular intervals. The requirement of the tracking accuracy can be reduced significantly by using this structure. The receiver can receive most of the energy just ensure the incident within a particular deflection angle. If the receiver is sensitive to the changes of energy, the structure of like Flower B can be used. Because the energy absorbed by the receiver will be maintained a relatively stable state with the deviate angle of the incident changes. If the structure of like Flower C were used, high temperature will be got by the receiver, while high tracking accuracy is necessary.

Second, the curves with the concentrating function of the models should be judged and selected. The results of the raytrace analyses show that not all the curves of the models have an effect of concentrating. The incident will be reflected back to the inlet directly without contribution to the concentration, so this part of the invalid curve should be avoided when design the concentrator. Curves l_A, l_B, and l_C shown in Fig. 16 are invalid curves. There are some other curves of the structures make the light out of the inlet after reflecting many times. This part of the curves will be chosen or not according to the demands of the concentrator.

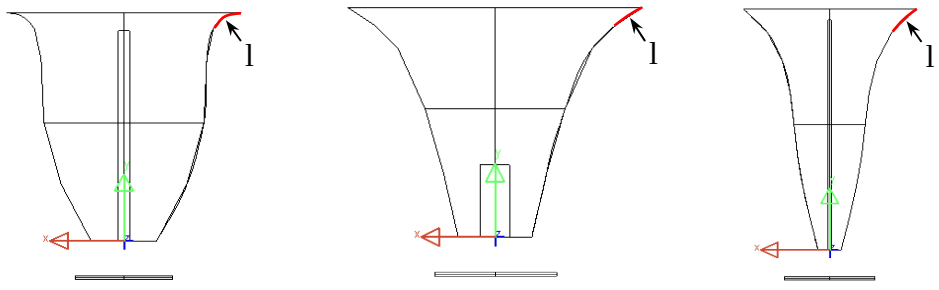


Fig. 16

Third, the selection curve should be combined and optimized. Diverse forms of concentrator will be obtained through different ways of combinations and optimization. Through further optimization and testing repeatedly, the concentrators with the better performance could be got.

5. CONCLUSION

In this paper, three different flower structures were simulated, and the light motion trajectory in the structures were analyzed. In addition, the design of the concentrator method was discussed.

(1) The results of simulating and analyzing flower structure models shows that part of flowers have the function of concentrating. Our thinking trying to get the well designed solar concentrator inspiration is worthy of further exploration.

(2) The results of simulating and analyzing flower structure models shows that the performance of different flower structures condenser is different, such as the location of the receiver, tracking accuracy, efficiency and so on are not the same. Based on the features of the flower structures, imitation object should be chosen according to the requirement when designing the concentrators. Therefore, enough flower structural models are important and the designer should be acquainted with the optical characteristics of the curves.

(3) Curves that compose flower structures are various and complex. When designing concentrators, the curves can be selected after judging whether they can meet the design requirements. Large amounts of data should be handled during this process, so design a set of effective methods to deal with the data is necessary.

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FIGURE CAPTIONS

Fig. 1 The comparison of flowers with concentrator structures
Fig. 2 The photo of flowers
Fig. 3 The result of the contour extraction and 3D model of the Flower A
Fig. 4 The wireframe structure of the Flower A in the optical software
Fig. 5 Incident array map
Fig. 7 The simulation result of the incident deviated different angles from the symmetry axis of the Flower A
Fig. 8 The statistical result of the number of light received by two absorbers of the Flower A
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Fig. 10 The wireframe structure of the Flower B in the optical software
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