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DETERMINATION OF THE DIMENSIONS OF PARABOLIC-CYLINDRICAL CONCENTRATORS AND THE AMOUNT OF ENERGY INCIDENT ON THE REFLECTIVE SURFACE

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Abstract. *This paper examines the geometric dimensions of parabolic-cylindrical concentrators and determines the amount of solar energy incident on their reflective surfaces. The study considers the main parameters of the concentrator, including aperture width, focal length, depth, length, and reflective surface area. The amount of solar energy reaching the reflective surface is determined according to the intensity of solar radiation, the effective collecting area, and the angle of incidence. The relationship between the geometric characteristics of the concentrator and the amount of collected solar energy is also analyzed. Proper selection of the concentrator dimensions can improve the concentration of solar radiation and increase the efficiency of energy collection. The results of the study can be used in the design, calculation, and optimization of parabolic-cylindrical solar concentrators and solar thermal energy systems.*

Аннотация: *В данной статье рассматриваются геометрические размеры параболоцилиндрических концентраторов и определяется количество солнечной энергии, падающей на их световозвращающую поверхность. В исследовании рассматриваются основные параметры концентратора, включая ширину апертуры, фокусное расстояние, глубину, длину и площадь отражающей поверхности. Количество солнечной энергии, поступающей на отражающую поверхность, определяется с учётом интенсивности солнечного излучения, эффективной площади приёма и угла падения солнечных лучей. Также анализируется взаимосвязь между геометрическими характеристиками концентратора и количеством собираемой солнечной энергии. Правильный выбор размеров концентратора позволяет повысить концентрацию солнечного излучения и увеличить эффективность сбора энергии. Результаты исследования могут быть использованы при проектировании, расчёте и оптимизации параболоцилиндрических солнечных концентраторов и солнечных тепловых энергетических установок.*

Keywords: *parabolic-cylindrical concentrator, solar energy, solar radiation, reflective surface, solar collector, aperture width, focal length, concentrator dimensions, incident energy, solar radiation intensity, optical efficiency, thermal efficiency, solar thermal system.*

Ключевые слова: *параболоцилиндрический концентратор, солнечная энергия, солнечное излучение, отражающая поверхность, солнечный коллектор, ширина апертуры, фокусное расстояние, размеры концентратора, падающая энергия, интенсивность солнечного излучения, оптический КПД, тепловой КПД, солнечная тепловая система.*

Introduction

The increasing demand for renewable energy has led to growing interest in technologies that can efficiently utilize solar radiation. Solar energy is one of the most promising renewable energy sources because it is widely available, environmentally friendly, and suitable for a variety of thermal and electrical applications. Among the technologies used to collect solar radiation, parabolic-cylindrical concentrators are particularly important due to their ability to concentrate a large amount of solar energy onto a relatively small receiving area.

A parabolic-cylindrical concentrator consists of a reflective surface with a parabolic cross-section that directs incoming solar radiation toward a focal line. The geometric characteristics of the concentrator have a significant influence on its ability to collect and concentrate solar energy.

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Parameters such as aperture width, focal length, depth, length, and reflective surface area must therefore be selected carefully during the design process.

The amount of solar energy incident on the reflective surface depends primarily on the intensity of solar radiation and the effective aperture area of the concentrator. The position of the sun and the angle at which solar radiation reaches the reflective surface also affect the amount of energy collected. In addition, the reflectivity of the surface determines how much of the incident radiation can be directed toward the receiver.

Determining the dimensions of a parabolic-cylindrical concentrator is an important engineering task. An appropriately designed concentrator can maximize the collection of solar radiation while reducing optical and thermal losses. Accurate calculations of the aperture area and incident solar energy make it possible to evaluate the expected performance of the system and select suitable design parameters.

Parabolic-cylindrical concentrators are used in solar water heating, steam generation, industrial process heating, and other solar thermal applications. Their design and optimization can contribute to more efficient utilization of solar energy and reduce dependence on conventional energy sources.

The aim of this study is to determine the main dimensions of a parabolic-cylindrical concentrator and calculate the amount of solar energy incident on its reflective surface. The study also analyzes the influence of geometric parameters, solar radiation intensity, and the angle of incidence on the energy collection process. The results can be useful for improving the design and efficiency of parabolic-cylindrical solar concentrating systems.

Parabolic-cylindrical concentrators and their structure. Parabolic-cylindrical concentrators are solar thermal devices designed to collect and concentrate solar radiation onto a receiver located along the focal line of a parabolic reflective surface. They are widely used in solar energy systems because they can concentrate direct solar radiation and convert it into useful thermal energy. The basic principle of operation is based on the reflection of incoming solar rays from a curved reflective surface toward a common focal region.

The main component of a parabolic-cylindrical concentrator is its parabolic reflector. In cross-section, the reflective surface has a parabolic shape, while along its longitudinal direction it forms a cylindrical structure. When parallel solar rays reach the reflective surface, they are reflected toward the focal line. A receiver or absorber is usually positioned along this focal line to capture the concentrated solar radiation and transform it into thermal energy.

The concentrator generally consists of several main elements: a parabolic reflective surface, a receiver tube, a supporting structure, and a tracking or positioning mechanism when required. The reflective surface is commonly manufactured from materials with high solar reflectivity. Its purpose is to minimize optical losses and direct as much solar radiation as possible toward the receiver. The quality, cleanliness, and reflectivity of the surface have a direct influence on the performance of the concentrator.

The receiver is an important part of the system because it absorbs the concentrated solar radiation. Depending on the application, the receiver may contain water, thermal oil, air, or another heat-transfer fluid. As concentrated radiation reaches the receiver, the fluid is heated and can subsequently be used for hot water production, steam generation, industrial heating, or other thermal processes.

The supporting structure maintains the required geometric shape of the reflector and ensures that the receiver remains correctly positioned relative to the focal line. Mechanical stability is important because deformation of the reflective surface can cause solar rays to deviate from the focal region and reduce the amount of useful energy collected.

The operation of a parabolic-cylindrical concentrator depends strongly on the position of the sun. For maximum energy collection, the reflective surface should be oriented so that solar

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radiation reaches it as effectively as possible. Many systems therefore use a solar tracking mechanism that changes the position of the concentrator according to the apparent movement of the sun. Tracking can significantly increase the amount of direct solar radiation captured during the day.

The geometric design of the concentrator is also closely related to its optical performance. The aperture width determines the effective area available for collecting solar radiation, while the focal length influences the position of the receiver and the concentration characteristics. The depth and length of the parabola affect the total reflective area and the structural dimensions of the system.

One of the main advantages of parabolic-cylindrical concentrators is their ability to achieve higher temperatures than conventional flat-plate solar collectors. By concentrating solar radiation onto a smaller receiving area, the system can produce relatively high-temperature thermal energy. This makes parabolic-cylindrical concentrators suitable for applications where higher temperatures are required.

However, the efficiency of these systems can be affected by several factors, including the reflectivity of the surface, the accuracy of the parabolic shape, the position of the receiver, solar radiation intensity, tracking accuracy, and thermal losses. Dust, surface contamination, shading, and deformation of the reflector can also reduce the amount of solar energy reaching the receiver.

Therefore, proper design of the structure and accurate determination of the geometric parameters are essential for achieving efficient operation. The dimensions of the parabolic-cylindrical concentrator should be selected according to the required energy output, available solar radiation, receiver characteristics, and intended application. A well-designed concentrator allows a greater proportion of incoming solar radiation to be collected and effectively converted into useful thermal energy.

Geometric dimensions of parabolic-cylindrical concentrators. The geometric dimensions of a parabolic-cylindrical concentrator are fundamental parameters that determine its solar energy collection capacity and optical performance. Accurate selection and calculation of these parameters are necessary to ensure that the reflective surface collects the required amount of solar radiation and directs it toward the receiver. The main geometric characteristics include aperture width, focal length, depth, length, focal ratio, and reflective surface area.

The aperture width is the distance between the two outer edges of the parabolic opening. It represents the effective width through which direct solar radiation enters the concentrator. Increasing the aperture width increases the area available for collecting solar radiation and can therefore increase the total amount of incident solar energy. However, a larger aperture also requires a stronger supporting structure and may increase the overall dimensions and cost of the system.

The focal length is the distance between the vertex of the parabola and its focus. It is one of the most important parameters in the geometric design of the concentrator because it determines the position of the receiver relative to the reflective surface. For an ideal parabolic cross-section, the relationship between the focal length and the parabola can be described by the equation:

$$y^2 = 4fx$$

where f – focal length. This relationship is used to determine the shape of the parabolic reflector and to position the receiver correctly.

The depth of the concentrator is the vertical distance between the lowest point of the parabola and the aperture line. The relationship between aperture width, depth, and focal length determines the curvature of the reflective surface. A deeper parabola generally produces a different

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concentration geometry than a shallow one, and therefore the depth must be selected according to the required optical characteristics and construction conditions.

The length of the concentrator is measured along its longitudinal axis. Together with the aperture width, it determines the effective collecting area of the system. For a simplified calculation, the aperture area can be estimated.

Determination of solar energy incident on the reflective surface

The amount of solar energy incident on the reflective surface is one of the main factors used to evaluate the performance of a parabolic-cylindrical concentrator. The energy received by the concentrator depends on the intensity of solar radiation, the effective collecting area, the position of the sun, and the angle between the incoming solar rays and the orientation of the collector. Accurate determination of incident energy is therefore necessary for estimating the thermal potential of the system.

Solar radiation reaching the Earth's surface consists of direct and diffuse components. Parabolic-cylindrical concentrators primarily utilize direct solar radiation because the reflective surface is designed to redirect approximately parallel solar rays toward the focal line. The intensity of direct solar radiation changes during the day and throughout the year due to the position of the sun, atmospheric conditions, cloud cover, dust, and other environmental factors.

For a simplified calculation, the solar energy incident on the collector can be determined using the relationship:

$$E = G \times A \times t$$

Where E – the incident solar energy, G is the solar irradiance, A is the effective collecting area, and t is the exposure time. When the irradiance is expressed in watts per square meter and time in seconds, the resulting energy is obtained in joules.

The effective collecting area is an important factor in the calculation. For a parabolic-cylindrical concentrator, it can be approximated using the aperture width and the length of the collector:

$$A = W \times L$$

Where W – represents the aperture width and L represents the concentrator length. The greater the effective aperture area, the greater the amount of solar radiation that can theoretically reach the reflective surface under the same radiation conditions.

The angle of incidence also influences the amount of radiation intercepted by the concentrator. When solar rays are perpendicular to the effective collecting surface, the available radiation is at its maximum. As the angle of incidence increases, the effective projected area decreases. A simplified expression for this effect can be written as:

$$E = G \times A \times cos(\theta) \times t$$

Where θ – the angle of incidence between the solar rays and the normal direction of the effective collecting surface. The cosine term represents the reduction in effective radiation caused by non-optimal orientation.

The daily amount of collected solar energy is not constant because solar irradiance varies with time. In the morning and evening, the solar radiation intensity is generally lower, while around solar noon it is usually higher under clear-sky conditions. Consequently, the total daily energy should preferably be determined by integrating the instantaneous solar irradiance over the operating period:

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$$E = A \int G(t) \cos[\theta(t)]\, dt$$

This approach provides a more accurate estimate because it accounts for the changing solar radiation intensity and incidence angle throughout the day.

The optical properties of the reflective surface must also be considered. Not all radiation incident on the surface is reflected toward the receiver. A portion of the radiation may be absorbed by the reflector, scattered because of surface imperfections, or lost due to contamination. If the reflectivity of the surface is represented by ρ, the reflected energy can be estimated as:

$$E_r = E \times \rho$$

Where E_r - is the reflected solar energy and ρ is the reflectivity coefficient of the surface.

Additional optical losses can occur due to shading, tracking errors, surface deformation, imperfect reflection, and the finite size of the solar disk. These factors reduce the amount of energy that actually reaches the receiver. Therefore, the theoretical incident energy should be distinguished from the useful energy delivered to the receiving system.

For example, if a concentrator has an aperture width of 2 m and a length of 5 m, its effective aperture area is approximately 10 m². If the direct solar irradiance is 800 W/m² and the incidence angle is assumed to be zero, the instantaneous incident power can be estimated as:

$$P = G \times A = 800 \times 10 = 8000\ W$$

Thus, approximately 8 kW of solar radiation is incident on the effective collecting area under these conditions. If the reflective surface has a reflectivity of 90%, the ideal reflected power would be approximately 7.2 kW before considering other optical losses.

The calculated energy values can be used to estimate the expected thermal output of the concentrator. However, the final useful energy will normally be lower than the incident solar energy because of reflection losses, shading, tracking inaccuracies, thermal losses from the receiver, and atmospheric effects.

Conclusion

The analysis of parabolic-cylindrical concentrators shows that the geometric design of the concentrator plays a fundamental role in determining its ability to collect and concentrate solar radiation. The main parameters, including aperture width, focal length, depth, length, and reflective surface area, are closely related to the energy performance of the system. Accurate determination of these parameters is therefore essential for achieving effective concentration and ensuring that the reflected solar radiation is directed toward the receiver.

The amount of solar energy incident on the reflective surface is mainly determined by solar irradiance, the effective collecting area, the angle of incidence, and the duration of solar radiation. A larger collecting area allows more solar radiation to be intercepted under identical environmental conditions. However, the increase in collecting area must be balanced with structural requirements, material consumption, installation conditions, and economic considerations.

The study also demonstrates that the angle of incidence has a considerable effect on the amount of available solar energy. When the concentrator is correctly oriented toward the sun, a greater proportion of direct solar radiation reaches the reflective surface. As the deviation from the optimal position increases, the effective radiation received by the collector decreases. Therefore, solar tracking or appropriate orientation is an important factor in maintaining high energy collection throughout the operating period.

The optical properties of the reflective surface are equally important. Ideally, the reflective material should have high reflectivity and maintain its optical properties under outdoor operating

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conditions. Dust, moisture, surface contamination, scratches, deformation, and aging can reduce reflectivity and increase optical losses. Regular maintenance and appropriate selection of reflective materials can therefore improve the long-term performance of the concentrator.

In addition to optical losses, thermal losses influence the final useful energy output. Not all of the solar radiation reflected toward the receiver is converted into useful thermal energy. Heat can be lost through convection, radiation, and conduction from the receiver and other system components. For this reason, the evaluation of a parabolic-cylindrical concentrator should consider both the amount of incident solar energy and the amount of useful thermal energy obtained from the system.

The calculations of incident solar energy provide an important basis for estimating the expected performance of a concentrator. Using solar irradiance data together with the aperture area and incidence angle allows the theoretical energy input to be determined. More accurate calculations can be obtained by considering the variation of solar radiation during the day and throughout different seasons. Local climatic conditions, atmospheric transparency, and weather variations should also be taken into account when evaluating the practical performance of the system.

The results indicate that optimization of the concentrator requires a balanced approach to geometric design, optical performance, and operating conditions. Increasing the size of the concentrator alone does not necessarily guarantee a proportional increase in useful energy production. The focal geometry, receiver position, reflective material, tracking accuracy, and thermal insulation must be considered together to obtain the best overall performance.

Parabolic-cylindrical concentrators have significant potential for applications such as solar water heating, industrial process heating, steam production, and other solar thermal technologies. Their ability to concentrate direct solar radiation makes them particularly suitable for applications requiring higher temperatures than those normally achieved with conventional flat-plate collectors.

In conclusion, accurate determination of the dimensions of parabolic-cylindrical concentrators and the amount of solar energy incident on their reflective surfaces is essential for designing efficient solar thermal systems. Appropriate geometric parameters, high-reflectivity surfaces, accurate orientation, effective tracking, and reduction of optical and thermal losses can significantly improve system performance. Further research and optimization can contribute to the development of more efficient, reliable, and economically viable solar concentrating technologies and to the broader utilization of renewable solar energy.

References:

1. Kalogirou, S. A. (2009). *Solar Energy Engineering: Processes and Systems*. Academic Press.
2. Duffie, J. A., & Beckman, W. A. (2013). *Solar Engineering of Thermal Processes* (4th ed.). Hoboken, NJ: John Wiley & Sons.
3. Goswami, D. Y., Kreith, F., & Kreider, J. F. (2000). *Principles of Solar Engineering* (2nd ed.). Philadelphia: Taylor & Francis.
4. Fernández-García, A., Zarza, E., Valenzuela, L., & Pérez, M. (2010). Parabolic-trough solar collectors and their applications. *Progress in Energy and Combustion Science*, 36(1), 57–78.
5. Kalogirou, S. A. (2004). Solar thermal collectors and applications. *Progress in Energy and Combustion Science*, 30(3), 231–295.
6. Rabl, A. (1985). *Active Solar Collectors and Their Applications*. New York: Oxford University Press.
7. Price, H., Lüpfert, E., Kearney, D., Zarza, E., Cohen, E., Gee, R., & Mahoney, R. (2002). Advances in parabolic trough solar power technology. *Journal of Solar Energy Engineering*, 124(2), 109–125.

DOI: 10.65322/j.srd.04182026.21

8. Padilla, R. V., Demirkaya, G., Goswami, D. Y., Stefanakos, E. K., & Rahman, M. M. (2011). Heat transfer analysis of parabolic trough solar receiver. *Applied Energy*, 88(12), 5097–5110.

9. Burkholder, F., & Kutscher, C. (2009). *Heat Loss Testing of Schott's 2008 PTR70 Parabolic Trough Receiver*. National Renewable Energy Laboratory (NREL).

10. Lovegrove, K., & Stein, W. (Eds.). (2012). *Concentrating Solar Power Technology: Principles, Developments and Applications*. Woodhead Publishing.