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Numerical study and optimization of mirror gap effect on wind load on parabolic trough solar collectors

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Abstract

Parabolic trough collector (PTC) technology is currently the most proven and widely used solar thermal electric technology. These systems are usually located in open terrain where strong winds may occur and affect their stability and optical performance. As tiny deformation of collectors under the action of strong wind will influence the focusing accuracy and increase the structure demands of the collectors, it leads to the increase of the cost of collectors. It is particularly important to study the effect of wind load on parabolic trough solar collectors. In this context, different axial and radial gap sizes (0-0.06m) between the mirrors of PTC on wind load were studied numerically based on computational fluid dynamics (CFD). Wind load on collectors is decreased by around 13% with the axial gap extending from 0 to 0.06m while the effect of radial gap on wind load is small. Furthermore, the optimization model between the wind load and mirror gap was obtained by response surface methodology (RSM). The optimal gap size within 0m to 0.06m for a parabolic trough solar collector was predicted by particle swarm optimization (PSO). The result shows the optimum axial gap is 0.06m and the optimum radial gap is 0.02m.

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Keywords: Parabolic trough collector; CFD; Wind load; Mirror gap; RSM; PSO

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1. Introduction

Parabolic trough solar collectors (PTC) are currently one of the most mature and prominent solar technology for the production of electricity. Compared with other forms of solar power generation, it has the advantages of low cost and large scale. Parabolic trough solar collector systems are usually located in open terrain and subjected to the strong wind [1]. Deformation under combined effect of wind load and self-weight of collectors has an great influence on the focusing accuracy. How to decrease the effect of wind load and improve the stiffness of support structure of collectors has become an important part of the study of collectors. Simulation and analysis is the first premise for wind load of PTC.

The thermal performance and heat transfer characteristics of PTC have been studied by Several numerical and experimental studies [2-6]. The structure characteristics of PTC also has been studied. Geyer et al developed the

high-performance EuroTrough parabolic trough collector models ET100 and ET150 for the utility scale generation of solar steam for process heat applications and solar power generation [7]. However, only few studies of wind flow around the PTC have been published, especially in the gap effect on PTC. In the late of 1970s and early 1980s, Sandia National Laboratories sponsored some wind tunnel tests, which were published in different reports [8-11]. These reports provided mean wind loads coefficients for an isolated parabolic trough solar collector and for a collector within an array field. Schweitzer et al. [12] measured two trough collector models with conventional minimum gaps and with enlarged staggered mirror gaps in a wind tunnel in 2011. The results found that the enlarged staggered gaps have major effects on wind loads of trough collectors. Kotter et al. [13] studied the effects of staggered gaps on wind flow around a trough collector by means of Computational Fluid Dynamics simulations in 2012.

Because of the advances in fluid dynamics, numerical schemes, the rapid growth of computing power, and the urgently demand from aviation industry over the last 40 years, computational fluid dynamics (CFD) has achieved significant progress in both theory and numerical method and has boosted many industries [14-16]. Along with the wide spreading of commercial CFD software after the 1990s, numerical simulation was widely accepted and used in many industrial applications.

One prevalent idea of cutting the collector's cost was to construct it with a larger reflective surface [17]. But this design principle brought about the predicament of wind load. For better maintenance, performance and expectation of reducing the wind load acting on the collectors, the mirrors were designed with gap. But there is no definite value of gap size of the PTC. The objective of this paper was to know whether the gap size has an remarkable impact on PTC and obtain the optimum gap size for PTC. In this paper, both axial gap (0-0.06m) and radial gap (0-0.06m) between the facets of the collectors were studied numerically by CFD software FLUENT. The results showed that the wind load decreases with the increase of axial gap size (0-0.06m), but the effect of the radial gap size was very small compared with the radial gap on overall wind load. It is necessary to take into account the axial gap size effects on the wind load during the design process of PTC, while the effect of radial gap on wind load is negligible. The best gap sizes for a parabolic trough solar collector were predicted by response surface methodology (RSM) model where the axial gap is 0.06m and the radial gap is 0.02m.

Nomenclature

θ	Pitch angle of collectors
k	Kinetic energy
ε	Viscous dissipation rate of turbulent kinetic energy
D_1	Axial gap size of collectors
D_2	Radial gap size of collectors
PF	Pressure force
V	Wind speed