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The wind-structure interaction analysis and optimization of parabolic trough collector

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Abstract

The mechanical properties and economic performance of solar collector have an important influence on solar thermal power generation system. The parabolic trough collector with torque-box is taken as the research object in this paper. Firstly, the geometric model is established with SolidWorks software. Then, the wind load of collector is simulated with ANSYS CFX software in order to achieve the more accurate result. Based on the work above, wind-structure interaction of collector is realized taking advantages of Workbench and the maximum deformation of the reflecting mirrors differs with the maximum deformation of single physical model about 30.3%. In the end, the cross-section sizes of the beam of torque-box and the cantilever beam are optimized based on the mechanical characteristics of variable cross-section beam. The simulation results show that the maximum deformation of the reflecting mirrors is reduced about 4.6% and the weight of the collector is reduced about 5.8% compared with the initial model. The methods provide the reference for the analysis and optimization of other solar collectors.

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Keywords: Parabolic trough collector; Fluid-structure interaction; Workbench; Mechanical optimization

Introduction

Although parabolic trough solar thermal power generation technology has been the most mature technology and realized commercial operation [1], the cost of solar collector is still the main factor to restrict the development

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of the technology. The collector is an important part of solar thermal power generation technology and accounts for over 30% of the total cost of the system which is different from the conventional power generation technology [2]. The reasonable structure design is the main way to improve the performance of collector and reduce the cost of system.

In the 1980's, the company LUZ had pioneered to develop the LS series collector with space truss structure and which has been applied in the United States SEGS parabolic trough solar power station [3]. In the 1990's, Schlaich et al. developed the parabolic trough collector with torque-box called Euro trough. Compared with LS-2 collector, the optical and mechanical performances are greatly improved while the weight of steel structure and cost are reduced [4-5]. The company Solargenix developed parabolic trough collector with whole aluminum frame which size and characteristic parameters follow the LS-2 collector [6]. This collector is not only lightweight but also more resistant to corrosion, convenient manufacture and installation. The results of wind tunnel test showed that Solargenix collector could meet the goal in terms of resistance to bending and torsion of the LS-2 collector. The Spanish company SENER proposed the cantilever arms of parabolic trough collector were made using stamping techniques and achieved the goal to reduce the cost [7]. IST (Industrial Solar Technology) with the support of plan of the USA national renewable energy laboratory (NREL) adopted galvanized steel instead of the original aluminum alloy structure and the thin glass mirror replaced the silver plated aluminum polymer reflector. The improved collector is reduced 15% of cost and the system performance improved by 12% [8]. In China, in order to reduce the weight of collector and improve the properties of resistance to bending and torsion, the state key laboratory of mechanical transmission of Chongqing university, school of mechanical and power engineering of Nanjing university of technology and school of mechanical and electrical engineering of Hohai university et al. optimized the parabolic trough collector bracket structure with optimization design technology and have obtained some research results [9-11].

Due to the non-uniform distribution of wind load on collector, in order to achieve the more realistic analysis results, wind-structure interaction of parabolic trough collector is studied with the Workbench software. The design method of variable cross-section size was proposed to optimize the small parabolic trough collector with torque-box and to realize the lightweight of collector and the improvement of concentrating accuracy.

1. The model of small parabolic trough collector with torque-box

The collector is the core component of concentrating solar power generation technology which includes parabolic reflecting mirrors, bracket of reflector, driving tracking device, installation bracket and receiver et al**.** For the convenience of subsequent wind tunnel experiment, this paper designs a small parabolic trough collector with torque-box. As shown in Fig.1, the collector is 3.1 m long, the parabolic trough aperture width is 2 m and the focal length is 1 m. The parabolic reflecting mirrors consist of six pieces of mirror, the size of mirror facets is 1045 mm×1020 mm×3 mm and has six support points. The section size of torque-box is 450 mm×450 mm. Torque-box is designed with L-shaped steel. The initial section size of L-shaped steel is 30 mm×30 mm×3 mm and the initial section size of cantilever beam is 30 mm×30 mm×3 mm. At the two ends of the torque-box two man-shaped plates are designed to install drive shaft respectively. The bolt is ignored in the model and the parts are connected by welding.

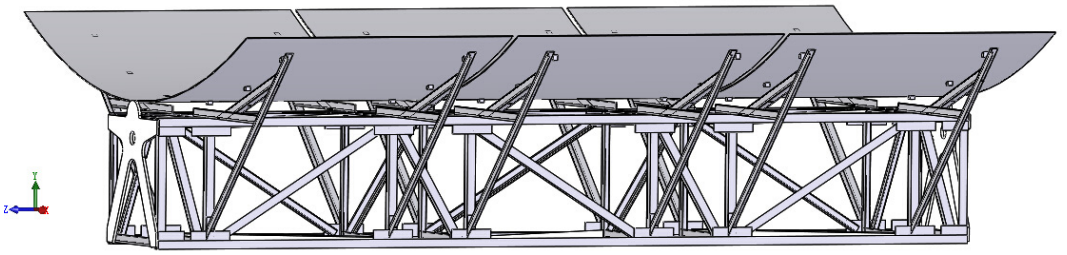

Fig. 1 The model of parabolic trough collector structure