THERMAL STRESS AND FATIGUE LIFE ANALYSIS of MOLTEN SALT CENTRAL RECEIVER

Xin Li, Fengwu Bai, Xiaona Song, Chun Chang, Zhifeng Wang

Key Laboratory of Solar Thermal Energy and Photovoltaic System, Chinese Academy of Sciences,
Institute of Electrical Engineering, Chinese Academy of Sciences
Beijing, China; drlixin@mail.iee.ac.cn

Abstract

The heat transfer, thermal stress and fatigue characteristics in a molten salt receiver which are induced by high concentrating irradiation heat flux are studied. The average heat flux 200kW/m², 400kW/m², 600 kW/m², 800 kW/m² are applied for the external surface of two kinds of different receiver tubes. And inlet molten salt flow rate are 1.5m/s, 2.5m/s and 3m/s, the corresponding Reynolds numbers are 17987, 29978 and 41969. Based on finite volume method, the temperature distribution in the receiver tube and molten salt are simulated. The finite element method is used to compute the thermal stress fields. It is shown that when the molten salt inlet velocity is 1.5m/s, the allowable average heat flux is 600 kW/m². And for the receiver panel, the fatigue life is 20025 cycles under maximum allowable heat flux.

1. INTRODUCTION

The central receiver is one of the key equipments in solar tower power plant. The thermal stress of the receiver continuously influenced the development of CSP. In the 1980s, Solar One and CESA-1 superheated steam receivers were all damaged by thermal stress. In the following three decades, the researchers tried to solve the problem in two different ways. One is using better heat transfer fluids such as water and molten salt. PS10 is the example of using water to generate saturated steam. Until now, it is still working well. Solar Two is also the improved technology compared with Solar One. The other is using better anti-thermal stress and anti-thermal shock materials as absorber. For example, the air receiver using a ceramic foam absorber. While the solar irradiation on the receiver is nonhomogeneous and unstable following the sun’s behaviour. In fact thermal stress and thermal shock are inevitable in CSP. Therefore, it is necessary to analyse the stress mechanism of the receiver.

In the structure and heat transfer are the two important elements which influence the thermal stress of the receiver. Improving the ratio and avoiding the edges and corners of the receiver can reduce the thermal stress in the molten salt receiver (Hauike and Y.Yoshizawa, 2006). Controlling the flow rate in the receiver can adjust the temperature distribution in the working fluid and receiver to reduce the thermal stress (Verlotski and Schaus, 1995). Sandia National Laboratory have also done the molten salts receiver test in MSEE. The results showed that the thermal stress increased along the absorber tube radial direction when the convection heat transfer was dominant, decreased when the heat conduction was the dominant. The thermal stress became smaller as the temperature became uniform. According to the relationship between the maximum stress and flow rate, the minimum safe flow rate could be determined. Also some new kinds of materials which can reduce the thermal stress were researched. Because the Cu has a bigger thermal conductivity, therefore, the Cu-Fe metal alloy could lower the temperature gradient in the receiver. The results has been confirmed by Flores (Flores and Almanza, 2003). The pore size and distribution of SiSiC ceramic foam influence its mechanical performance. After the receiver was irradiated, the SiSiC became harder and its anti-thermal stress ability became stronger. In the paper, the FVM method and FEA method were used to analyse the temperature distribution in the absorber tube and panel and thermal stress and fatigue of the receiver.

2. MATHEMtical MODELLING