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Numerical Study of Natural Convection in Isothermal Open Cavities

Authors : Gaurav Prabhudesai, Gaetan Brill

Abstract : The sun's energy source comes from a hydrogen-to-helium thermonuclear reaction, generating a temperature of about 5760 K on its outer layer. On account of this high temperature, energy is radiated by the sun, a part of which reaches the earth. This sunlight, even after losing part of its energy en-route to scattering and absorption, provides a time and space averaged solar flux of 174.7 W/m^2 striking the earth's surface. According to one study, the solar energy striking earth's surface in one and a half hour is more than the energy consumption that was recorded in the year 2001 from all sources combined. Thus, technology for extraction of solar energy holds much promise for solving energy crisis. Of the many technologies developed in this regard, Concentrating Solar Power (CSP) plants with central solar tower and receiver system are very impressive because of their capability to provide a renewable energy that can be stored in the form of heat. One design of central receiver towers is an open cavity where sunlight is concentrated into by using mirrors (also called heliostats). This concentrated solar flux produces high temperature inside the cavity which can be utilized in an energy conversion process. The amount of energy captured is reduced by losses occurring at the cavity through all three modes viz., radiation to the atmosphere, conduction to the adjoining structure and convection. This study investigates the natural convection losses to the environment from the receiver. Computational fluid dynamics were used to simulate the fluid flow and heat transfer of the receiver; since no analytical solution can be obtained and no empirical correlations exist for the given geometry. The results provide guide lines for predicting natural convection losses for hexagonal and circular shaped open cavities. Additionally, correlations are given for various inclination angles and aspect ratios. These results provide methods to minimize natural convection through careful design of receiver geometry and modification of the inclination angle, and aspect ratio of the cavity.

Keywords : concentrated solar power (CSP), central receivers, natural convection, CFD, open cavities
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