Numbering-up of Parallel Microchannel Arrays to Megawatt Scale Supercritical CO_2 Solar Thermal Receivers

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Abstract

Concentrated solar power (CSP) plants have the potential to reduce the reliance on nonrenewable energies such as coal and natural gas and provide 24 hour, renewable electricity. A CSP system consists of a large field of heliostats that concentrate the sunlight on a centralized receiver, in this receiver a working fluid absorbs the incident flux and then either directly or indirectly supplies energy to a power cycle. Current CSP systems have high capital and operational costs which makes the levelized cost of electricity uncompetitive with conventional techniques. Recent experimental research has shown the potential of small unit cells (up to 2 × 2 cm) containing micropin arrays (DH < 1 mm) to operate efficiently (> 90% thermal efficiency) at high incident flux (>100 W cm^{-2}) using supercritical carbon dioxide. Applying this technology to CSP systems would result in a smaller central receiver which would reduce thermal losses, increase thermal efficiency and reduce the capital cost of the receiver component.

In this thesis, we will investigate and address the practical thermal hydraulic, manufacturing, and materials issues in numbering-up these small unit cells into numerous parallel cells within an integrated module design. A thermal hydraulic network model is developed to quantify the distribution of the working fluid within an integrated module and the effect on overall thermal efficiency. This model is used to specify maximum allowable unit cell size and header dimensions to maintain acceptable thermal performance and pressure loss. Manufacturing constraints on minimum feature size and diffusion bonding surface area, and material limitations on allowable pressure and temperature were considered in specifying the final design. Once a module design was finalized, parametric studies were performed to study the effects of varying incident flux on flow distribution and thermal performance of the module. The results show that an integrated module design can be achieved with less than 5% flow maldistribution and a reasonable pressure drop (< 4 bar).

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