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Printed Circuit Heat Exchangers as a Highly Efficient Alternative for CSP Plants

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Abstract

Supercritical CO_2 (sCO_2) has been proposed as a heat transfer fluid for the Brayton cycle to achieve a high efficiency in power generation from concentrating solar power (CSP) plants. A major component in such a plant is the heat exchanger transferring thermal energy from the solar field to the power block. Compact printed circuit heat exchangers (PCHE) have been proposed for the heat exchange between two streams of sCO_2 (as the primary and secondary fluids) as a regenerator in a CSP plant [1]. Further research work has been conducted for nuclear energy applications [2-6].The main advantages are the high ratio of heat transfer area to volume (compactness), the lowest achievable pinch (as small as 2 K), and the highest strength due to the diffusion bonding between the platelets.

However, there is a need to expand the research in the scope of PCHE using liquid sodium at high temperature and sCO_2 at high temperature and pressure (700 °C and 20 MPa). In this study, a PCHE is proposed to transfer heat from liquid sodium as the heat transfer fluid of the upstream cycle to sCO_2. In the work presented here, the thermal and hydrodynamic characteristics of a recently proposed airfoil-fin channel [7] is compared to the more conventional straight channel with semi-circular profile. The advantages and disadvantages of each concept is also discussed. The capacity of the system (800 kWth), operating temperature and pressure are adopted from the design criteria for an integrated test facility (ITF) proposed to be constructed by the Australian Solar Thermal Research Institute (ASTRI).

Methodology

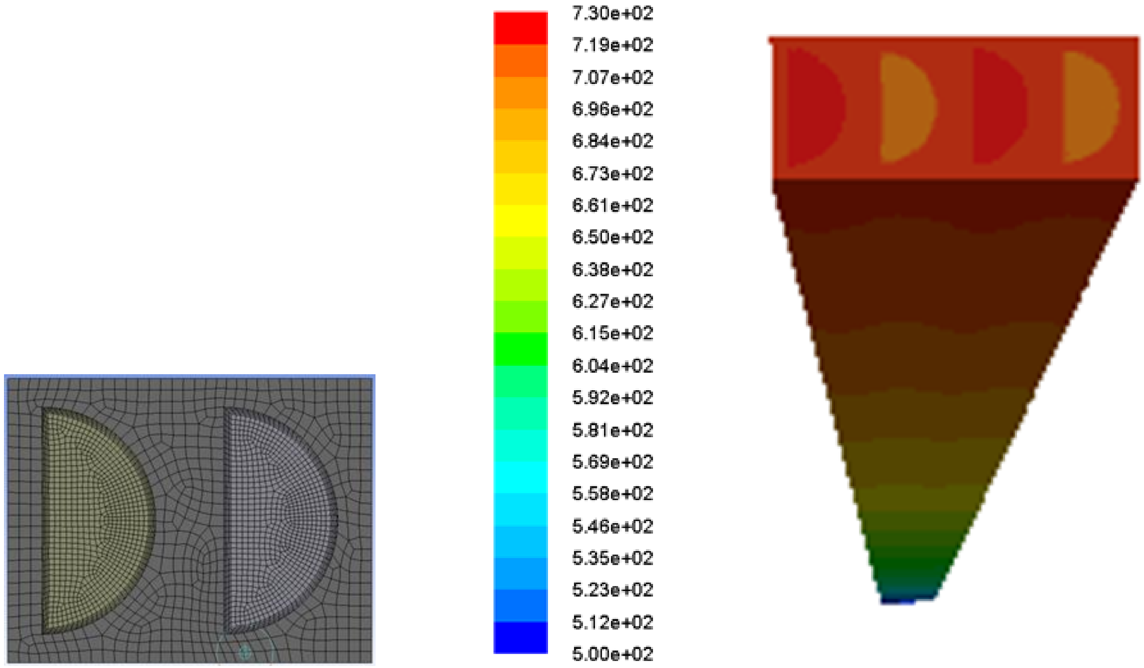
Using ANSYS Fluent, three-dimensional modelling was carried out for a module of a straight channel with semicircular profile comprising of the hot and cold fluid cells plus the solid interface between them. Hence, a module with three domains was considered for which boundary conditions are; periodic at top, down, and sides of the module, meaning that the module is selected from the middle of the system. Velocity inlet and pressure outlet are the other boundary conditions for the primary and secondary fluids. As both primary and secondary flows are in the turbulent region, the Reynolds-averaged Navier-Stocks (RANS) model is used.

Temperature dependent thermophysical properties have been adopted for sodium and sCO_2. For Inconel 617, density, specific capacity and thermal conductivity are 8360 kg/m^3, 417 kJ/kg, and 21 W/m K, respectively.

The results from modelling the straight channel with semi-circular profile has been verified with the results from Meshram et al. [1]. The verified model is used for the investigation of an airfoil-fin channel.

Preliminary Results

In a counter flow configuration, sCO2 was the primary and secondary fluid with temperature inlet of 700 K and 500 K, respectively. Figure 1a shows the section of the grid, while Figure 1b shows a preliminary temperature profile at the steady-state condition. More details of the model verification, and the results for the airfoil-fin channel will be included in the full paper.



(a) (b)

Figure1- (a) Schematic drawing of the grid, (b) Temperature profile at the steady-state condition for the sCO2-sCO2

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