ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

A preliminary analysis for development of a high-temperature gas-phase solar receiver

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In this study a compound calculation method which combines a mathematical heat transfer model [1] used for calculation of required convection coefficient and empirical correlations for calculation of Heat Transfer Enhancement (HTE) techniques convective flux, is proposed and employed here for a preliminary design of a pressurised, high-temperature, indirect-irradiated HTF cavity receiver to absorb the heat from another side of the cavity absorber and to keep the temperature of the cavity below the material limitation. Active and passive HTE techniques, which are utilised in this study to absorb the heat from another side of the cavity, include jet impingement [2],[3], roughened surface [4] and extended surfaces including porous medium [5] and pinned plate[6], [7]. For further enhancements in efficiency and HTF outlet temperature, compound HTE techniques including impinging jet on porous medium and pinned plate are also proposed to be used [4]-[6]

The results showed that the compound techniques of impinging jet on a aluminium foam (Figure 1 (d)) and a plate-fin ((Figure 1 (c)) provide the highest convective heat transfer coefficients, respectively while a plate-fin heat sink exposed to a turbulent forced convection flow (Figure 1 (a)) has the lowest amount. Overal, the impinging jet can be more efficient solution for increasing the efficiency and outlet temperature in a non-windowed cavity gas-phase receiver compared with using a heat sink under a convective forced flow on another side of the absorber. Moreover, the heat transfer coefficient provided by impinging jet either on clean surface or heat sink-covered surface almost can meet our design point, at which the cavity temperature needs to be less than 1200C, whereas the heat transfer coefficient provided by the plate-fin heat sink under a forced convective flow is lower than the convective heat transfer required to keep the temperature less than this amount (1200C).

In addition, the paper also includes a parametric study on different diameters and numbers of nozzle located around the cavity absorber. In a same mass flow rate, the convective heat transfer provided by an impinging jet on different target plates are higher for more nozzles with a lower nozzle diameter. The metal foam results in the highest convection coefficient, up to around 1793W/mK at diameter of 5 mm and 18 nozzles. At the same diameter and number, an impinging jet on the pinned plate heat sink provides around 1215 W/mK coefficient, whereas the values for a rough surface and clean plates are almost similar around 600 W/mK. The diameters of nozzle for a clean plate model need to be 8 mm and lower with usage of at least 11 nozzles. The selections for an impinging jet on a pinned plate and porous medium are so wider. The former needs to have 15mm-diameter nozzle or lower with a minimum of 6 nozzles, while for the latter a 25 mm diameter with at least 3 nozzles. In other words, this comparison demonstrates that for an aluminium foam heat sink it is possible to use numerous nozzle arrangements from 15mm to 5 mm diameters with 3 to 18 nozzles, whereas for a clean plate it decreases from 8 to 5mm diameters with 11 to 18 nozzles.

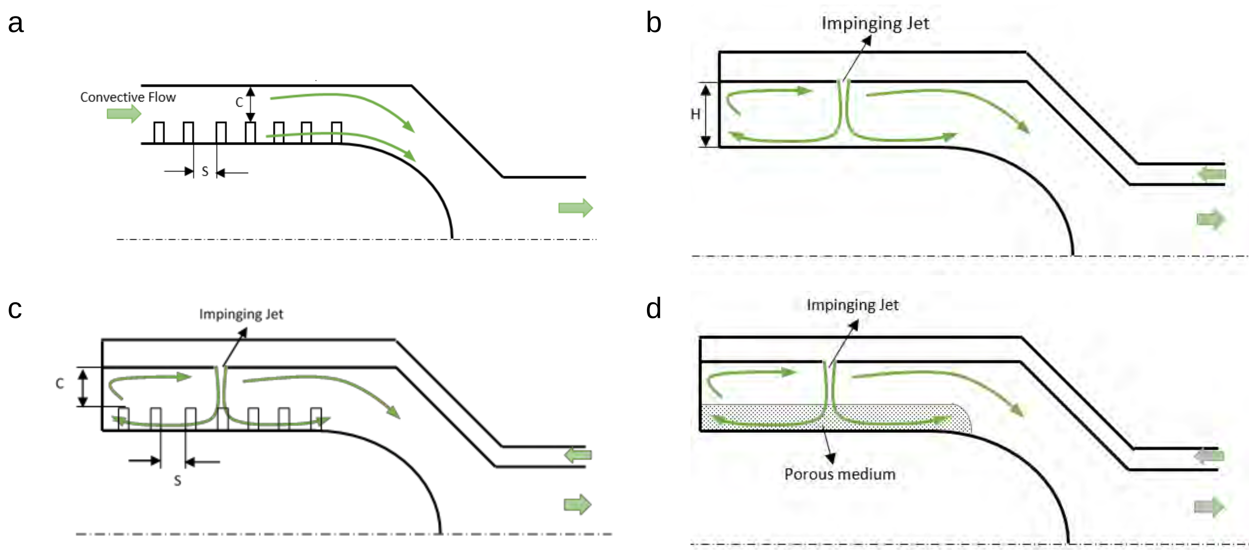

Figure 1 Schematic of the models analysed in this paper: (a) plate-fin under convective flow; (b) clean cavity (or roughened cavity) exposed to impinging jets; (c) cavity with plate-fin exposed to impinging jets; (d) cavity with porous medium exposed to impinging jet.

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