Influence of Backplate width and port size on the performance of Aluminum based minichannel solar collectors

Sai Kiran Hota, Julio Perez, Gerardo Diaz*

School of Engineering, University of California, Merced

Motivation

The Earth's natural gas resources are finite and limited. About $1.08\text{x}10^{14}$ kW reach the Earth's surface from the sun. Total solar irradiation absorbed by Earth is 7500 times the world's total energy annual demand [2]. Natural gas plants have shown to be susceptible to leaks.

109,000 Metric tons of Natural Gas leaked

Same As:

- 9,156,00 metric tons of CO_2
- 1,030,268,900 gal. of gasoline burned
- $21,545,930 worth of natural gas waste

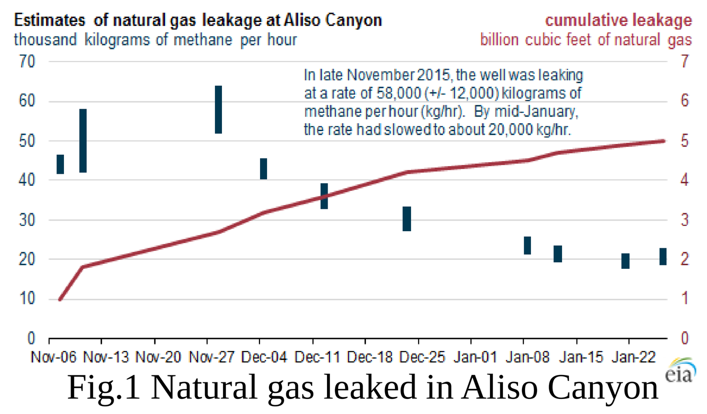

Fig.1 Natural gas leaked in Aliso Canyon

Abstract

Minichannel based solar collectors have gained popularity due to better performance over standard solar collectors. They act as absorber surfaces and directly transfer heat to the working fluid. Performance analysis on aluminum based minichannel system can be found in [1-2].

One of the ways to enhance the performance is to introduce a backplate [3] which increases the heat absorption area. Here we analyze the effects of having a backplate in a constant heat exchange surface with a width of 100mm per tube.

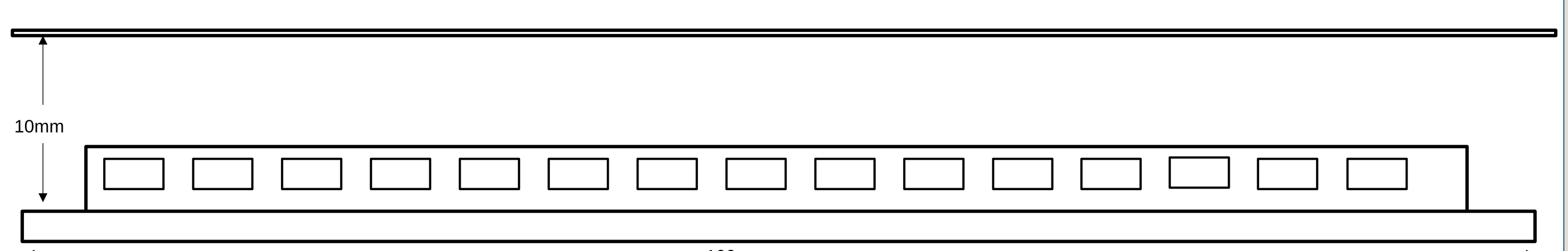

Fig.2 Representation of the minichannel system with backplate

Objective

The minichannel size varies as the backplate width changes for a total width of 100mm. We aim at keeping a constant hydraulic diameter. As a result of changing the port width, the height of the port changes, which varies the air gap between the top of the tube and the glass cover, as seen in Fig. 2. The distance between the plate and the glass cover is kept constant at 10mm. The performance will be analyzed with respect to the flow performance and fin - plate efficiency.

Methods

Engineering Equation Solver (EES) is used to determine the performance of the collector system for the described varying conditions. The test conditions adopted according to the experimental conditions are: Incoming heat flux: 800 W/m^2; ambient temperature: 30°C; Inlet temperature: 35°C; Mass flow rate: 0.109 kg/s and wind velocity 5 m/s.

Performance Parameters

The collector performance depends on the fin efficiency of the minichannel cross section (η_f), backplate efficiency (η_{plate}). The collector is characterized by performance parameters: Heat recovery factor (F_R) and collector efficiency factor (F') [3]. The efficiency (η) of the collector is a direct function of heat recovery factor (F_R). The description of these parameters can be found in [3].

Results

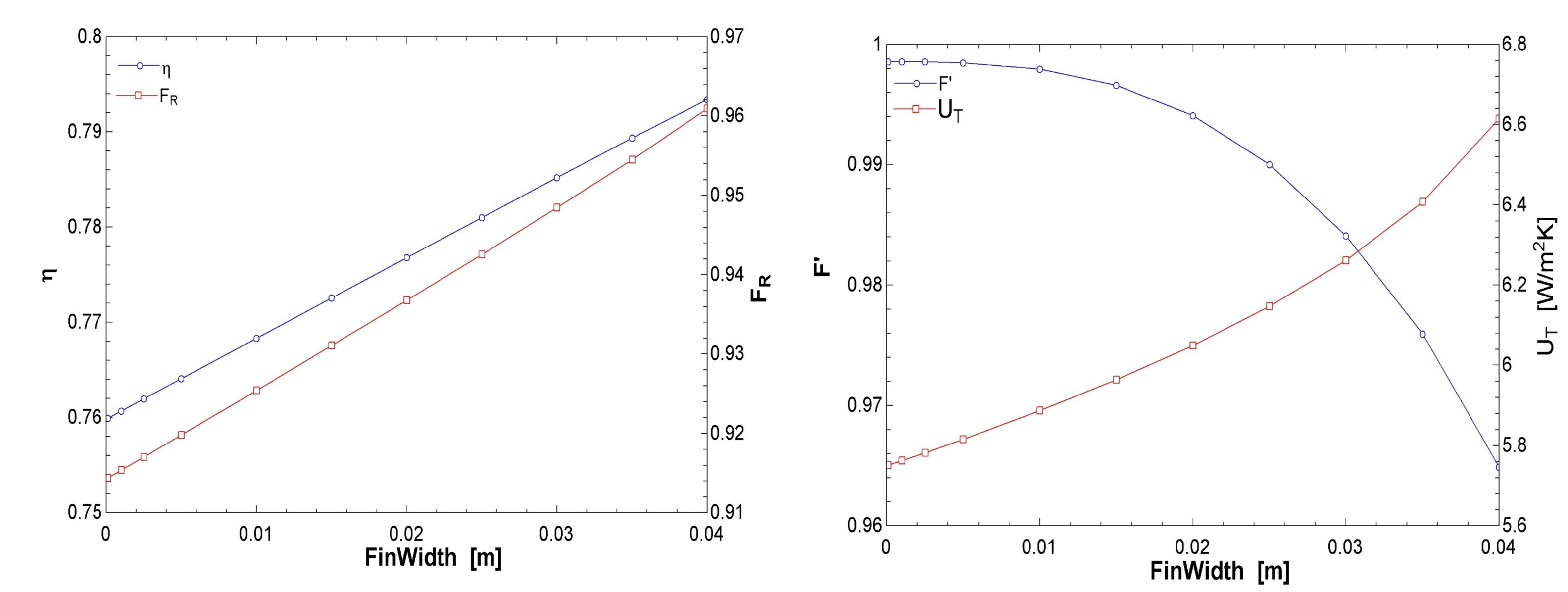

Fig.3 Performance parameters of the collector at varying Plate width

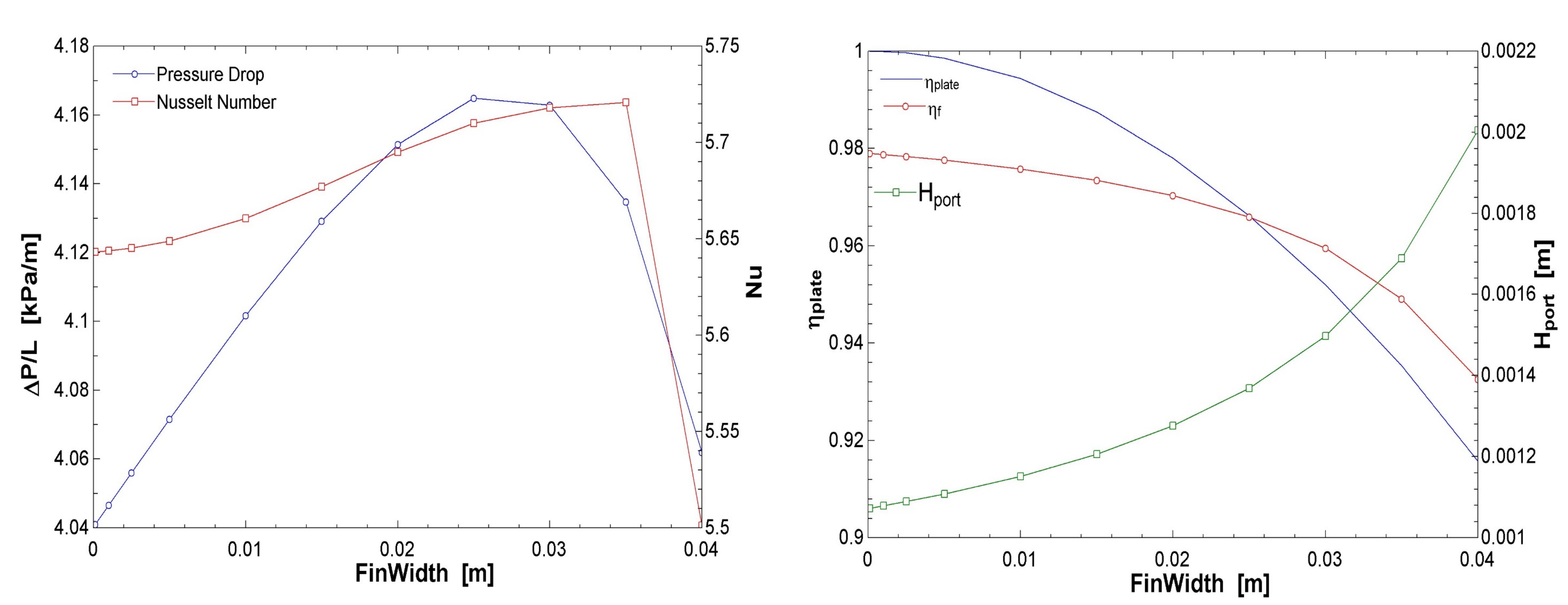

Fig.4 Flow performance and fin efficiency variations at varying Plate width

Highlights

- Analysis for the back plate efficiency has been carried out in view of the inherent gaps between minichannels welded to the header due to production limitations.
- A constant heat exchange width per tube and constant glass-minichannel surface height is maintained to keep the volume of the collector system the same.
- Addition of the back plate increases the heat transfer surface area.
- The efficiency of the collector and heat removal capacity linearly increase with plate width, as it can be seen in Fig.3,
- As seen in Fig.4, the pressure drop and Nusselt number are found to increase initially, but after a certain limit, the pressure drop reduces. Consequently, around the same fin width, the Nusselt number also reduces.
- The heat carrying efficiency is denoted as fin efficiency. From Fig.4, it can be seen that it reduces as the plate width increases. At the same time, the minichannel fin efficiency reduces since the port height increases.

Future Direction

The model developed gives an understanding on the effect of various minichannel geometries for future collector considerations. It also shows, a backplate can be welded to the minichannel surface to increase the performance.

References

[1] Duong, Van Thuc. (2015). MINICHANNEL-TUBE SOLAR THERMAL COLLECTORS FOR LOW TO MEDIUM TEMPERATURE APPLICATIONS. UC Merced: Mechanical Engineering.
[2] Julio Perez et.al, Analysis of phase change Thermal storage configurations for minichannel-based solar collectors, Conference and proceedings of ASME IMECE2018 (*to be presented)
[3] Sai Kiran Hota et.al, EFFECT OF GEOMETRIC CONFIGURATION AND BACK PLATE ADDITION IN MINICHANNEL SOLAR COLLECTORS, Conference and proceedings of ASME IMECE2018 (*to be presented)

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Contact

Sai Kiran Hota: shota@ucmerced.edu ; Julio C. Perez: jperez92@ucmerced.edu ; Gerardo Diaz: gdiaz@ucmerced.edu .