Influence of Axial Conduction in the Design of a Compact Recuperator for Catalytic Combustor Based Portable Power Generation

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Abstract

Catalytic micro-combustor represents an exciting area of research for portable power generation. Extensive research is being currently conducted on the design of the reactor and catalyst selection [1]. However another critical element of the design will be a recuperator to minimize losses and provide energy at a more uniform temperature. The mini-recuperator must be both compact and highly effective. The design investigated in this paper is a mini-channel based counter flow heat exchanger. A model was developed using standard methods for analyzing heat exchangers. The heat transfer coefficients were determined using correlations for thermally developing laminar flow in rectangular channels [2]. The basic geometry for the channel cross-section is shown in figure 1. The side walls of the channel are treated as extended surfaces. Due to the compact nature of the heat exchanger and limitations in the minimum wall thickness from both strength and manufacturing, back conduction is an important parameter in the design. Back conduction was accounted for in the model using a modified effectiveness equation derived by Kroeger [3]. COMSOL Multiphysics® software was used to predict the performance of the heat exchanger both with and without back conduction to compare to the heat exchanger model. Figure 2 shows the results for 5 mm x 1 mm channels accounting for back conduction. The effectiveness is determined from the COMOSL model, and compared to the heat exchanger model. The COMSOL model accounts for temperature dependent properties and does not assume the velocity profile is fully developed. It is shown that the heat exchanger model is appropriate and slightly conservative since the thermal entry length heat transfer coefficients are lower than combined entry length coefficient.

Reference

[1] Tolmachoff, E.D., Allmon, W. and Waits, C.M. "Analysis of a high throughput n-dodecane fueled heterogeneous/homogeneous parallel plate microreactor for portable power conversion" Applied Energy, DOI: 10.1016/j.apenergy.2014.04.057, 2014.

[2] Smith, A.N. and Nochetto, H. "Laminar thermally developing flow in rectangular channels and parallel plates: uniform heat flux" Heat Mass Transfer, DOI 10.1007/s00231-014-1363-8, 2014.

[3] Kroeger, P. G. "Performance deterioration in high effectiveness heat exchangers due to axial heat conduction effects." Advances in cryogenic engineering. Springer US, 1967. 363-372.

Figures used in the abstract

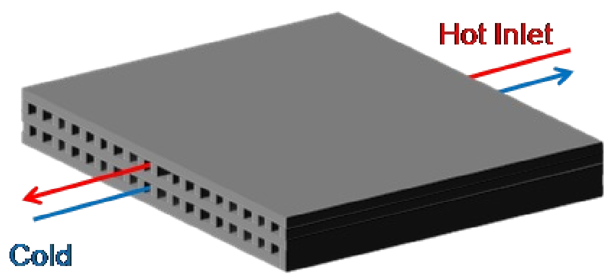

Figure 1: Schematic of counter flow mini-channel recuperator.

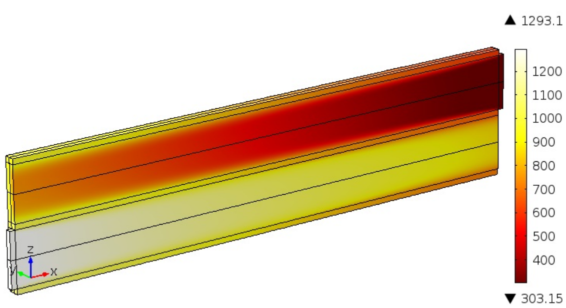

Figure 2: Temperature profile for a single section of a cross-flow heat exchanger with axial conduction, channel dimensions of 5 mm x 1 mm and a wall thickness of 0.5 mm.