

Heat Enhancement In Backward Facing Step Channel Equipped With Inclined Solid And Permeable Baffles

Bader H. Albusairi¹, Fajer B. Shabakouh²

¹Chemical Engineering Department, Kuwait University, Kuwait

²Kuwait Integrated Petroleum Industries Company (KIPIC), Kuwait

Abstract

Enhancing heat transfer in a backward facing step air channel equipped with a aluminum solid baffle followed by permeable one was investigated by using COMSOL® Multiphysics program. The air channel was composed of three sections, the entrance, test, and exit ones to ensure minimal entrance and exit effect on the simulation results (See Figure 1). The walls of the entrance and exit sections were assumed to be insulated as well as the top wall of the test section. The bottom wall of the test section was assumed to be at constant temperature of 330 K. The air enters the entrance section at 293 K. The tested parameters were Reynolds number, baffle inclination angel, and permeability of the second baffle. Tested Reynolds number were 3000, 5000, and 10000 to ensure turbulence mode operation. Baffle inclination angels were 0o, 30o, 45o, and 60o. The second baffle permeability ranged from 8.5×10^{-11} to 1.0×10^{-8} m². In the simulation, Free and Porous media Flow module and heat Transfer in Porous Media module were used. The velocity and temperature profiles were obtained for all cases as well as the streamlines. The comparison between different cases was based on the heat transfer enhancement parameter, HEF, that relates the heat gain increase and pressure drop increase in the studied case to the reference case without baffles, where the higher value for this parameter the better the case. Figure 3 shows the streamlines obtained at different 2nd baffle permeability. These streamlines shows different eddies generated due to the flow amount inside the baffle that will enhance the heat transfer by the turbulence in the bulk as well as the flow inside the baffle. Moreover, the results show that as the inclination angel increases, the pressure drop decreases, and the temperature rise decreases as well for certain permeability range. On the other hand, increasing permeability would decrease temperature gain and decrease pressure drop at constant inclination angel. These observations are similar for all Reynolds' numbers. Accordingly, the major achievement of using heat transfer enhancement parameter is shown in Figure 3 that shows operating with the second baffle permeability of 2.0×10^{-9} and inclination of 45o would result in the optimum heat enhancement that provides the most heat gain in the lowest pressure drop.

Reference

- D. E. Abbott and S. J. Kline, "Experimental Investigation of Subsonic Turbulent Flow Over Single and Double Backward Facing Steps," *Journal of Basic Engineering*, vol. 84, no. 3, pp. 317-325, (1962).
- A. R. Abu Talib and A. K. Hilo, "Fluid flow and heat transfer over corrugated backward facing step channel," *Case Studies in Thermal Engineering*, vol. 24, p. 100862, (2021).
- A. N. M. Alhusseny et al., "High-Porosity Metal Foams: Potentials, Applications, and Formulations," in *Porosity - Process, Technologies and Applications*, T. H. Ghrib, Ed. Rijeka: IntechOpen, 2017.
- B. K. P. Ary et al., "The effect of the inclined perforated baffle on heat transfer and flow patterns in the channel," *International Communications in Heat and Mass Transfer*, vol. 39, no. 10, pp. 1578-1583, (2012).
- S. Bhattacharyya et al., "Computational investigation of heat transfer enhancement by alternating inclined ribs in tubular heat exchanger," *Progress in Computational Fluid Dynamics, an International Journal*, vol. 17, no. 6, pp. 390-396, (2017).
- N. R. Caetano et al., "Bibliographic Review: The Influence of Obstacles Inside the Ducts on the Flow Proprieties," *Mathematical Modelling of Engineering Problems*, vol. 9, no. 3, (2022).
- P. Dutta and S. Dutta, "Effect of baffle size, perforation, and orientation on internal heat transfer enhancement," *International Journal of Heat and Mass Transfer*, vol. 41, no. 19, pp. 3005-3013, (1998).
- A. Ejlali et al., "Application of high porosity metal foams as air-cooled heat exchangers to high heat load removal systems," *International Communications in Heat and Mass Transfer*, vol. 36, no. 7, pp. 674-679, (2009).
- B. Ghobadi et al., "Optimization of heat transfer and pressure drop of the channel flow with baffle," *High Temperature Materials and Processes*, vol. 40, no. 1, pp. 286-299, (2021).
- K. H. Hilal, "Experimental Investigation of Heat Transfer and Pressure Drop in Square Metal Packed Duct with Different Boundary Heating," *Engineering and Technology Journal*, vol. 30, no. 6, pp. 1082-1107, (2012).

- J.-J. Hwang et al., "Measurement of Interstitial Convective Heat Transfer and Frictional Drag for Flow Across Metal Foams," *Journal of Heat Transfer*, vol. 124, no. 1, pp. 120-129, (2001).
- A. Kennedy, "Porous Metals and Metal Foams Made from Powders," in *Powder Metallurgy*, K. Kondoh, Ed. Rijeka: IntechOpen, 2012.
- J. A. Khan et al., "Enhancement of Heat Transfer with Inclined Baffles and Ribs Combined," *Enhanced Heat Transfer*, vol. 9, no. 3-4, pp. 137-151, (2002).
- K.-H. Ko and N. K. Anand, "Use of porous baffles to enhance heat transfer in a rectangular channel," *International Journal of Heat and Mass Transfer*, vol. 46, no. 22, pp. 4191-4199, (2003).
- C. Li et al., "Enhanced heat transfer and flow analysis in a backward-facing step using a porous baffle," *Journal of Thermal Analysis and Calorimetry*, vol. 141, no. 5, pp. 1919-1932, (2020).
- Y. Menni et al., "Baffle orientation and geometry effects on turbulent heat transfer of a constant property incompressible fluid flow inside a rectangular channel," *International Journal of Numerical Methods for Heat & Fluid Flow*, vol. 30, no. 6, pp. 3027-3052, (2020).
- J.-E. Salhi et al., "Turbulence and thermo-flow behavior of air in a rectangular channel with partially inclined baffles," *Energy Science & Engineering*, vol. 10, no. 9, pp. 3540-3558, (2022).
- H. T. Steven Darmawan, "CFD Investigation of Flow Over a Backward-facing Step using an RNG k- ϵ Turbulence Model," *International Journal of Technology*, vol. 10, no. 2, pp. 291-319, (2019).
- R. L. Webb, "Performance evaluation criteria for use of enhanced heat transfer surfaces in heat exchanger design," *International Journal of Heat and Mass Transfer*, vol. 24, no. 4, pp. 715-726, (1981).

Figures used in the abstract

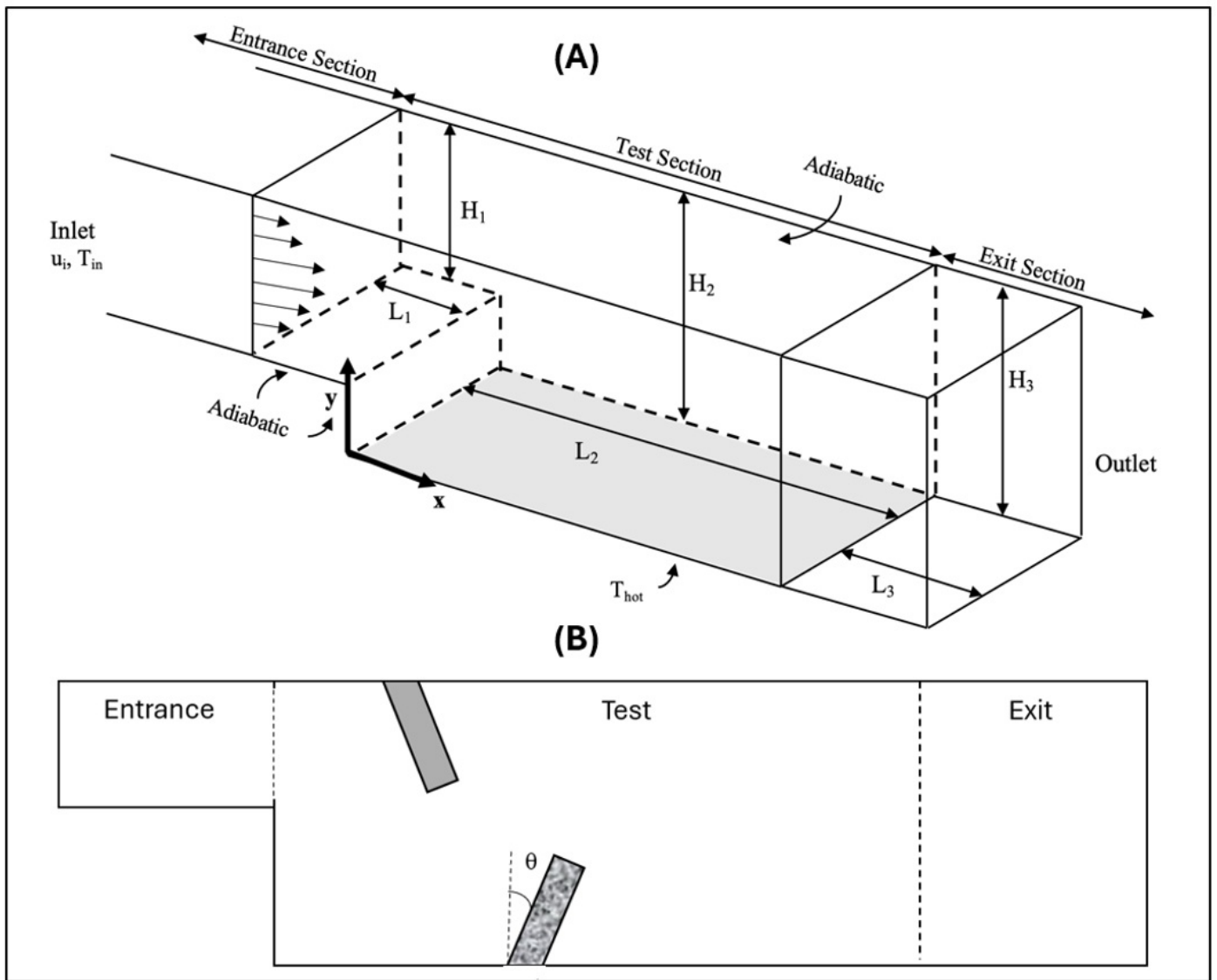


Figure 1 : Figure 1: A) Schematic 3D-diagram for the horizontal backward-facing step channel without baffles. B) 2D-diagram for the simulated channel with baffles.

Permeability (m^2)	Streamlines
8.50E-11	
8.50E-10	
8.50E-09	

Figure 2 : Figure 2: Streamlines in the test section for different permeability values at 0° inclination and $Re=10000$.

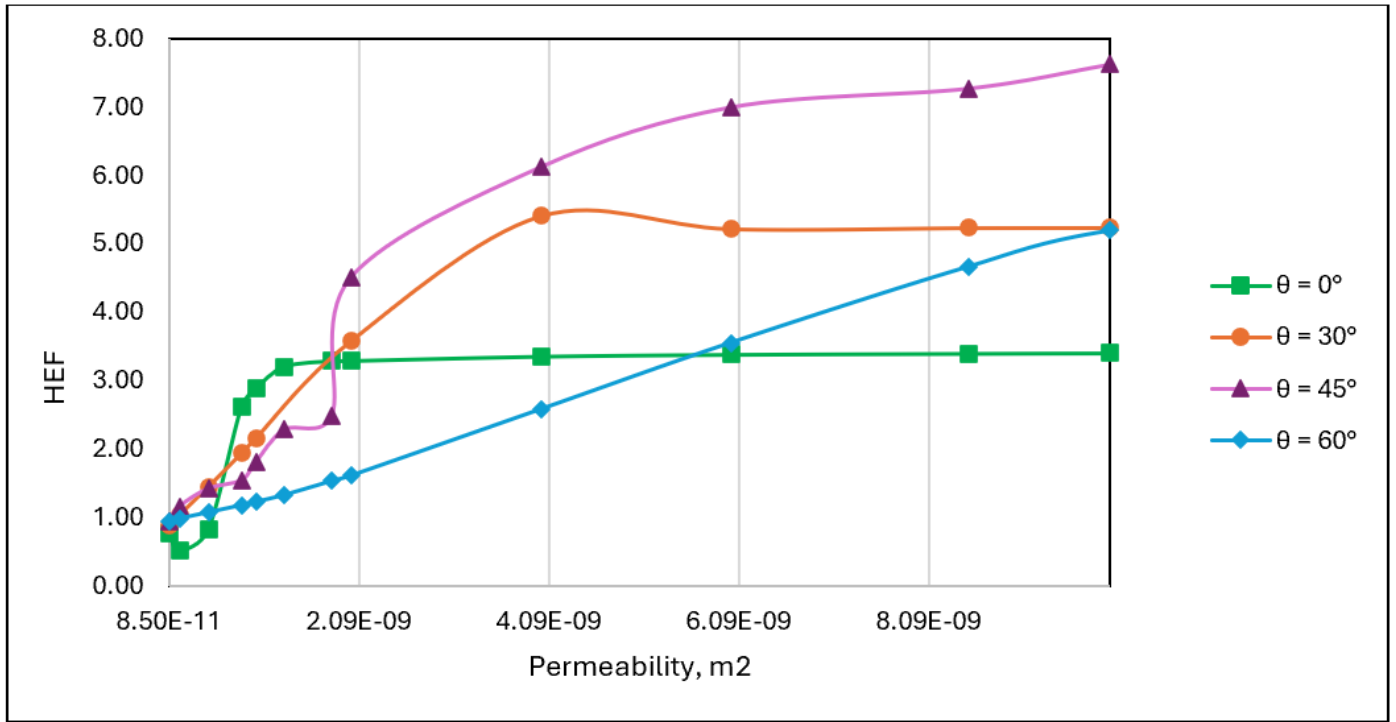


Figure 3 : Figure 3: Heat transfer enhancement factor, HEF, as function of inclination angel and second baffle permeability at Re = 10000.