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A numerical investigation of some approaches to improve mixing in laminar confined impinging streams

S.J. Wang [a,*], S. Devahastin [b], A.S. Mujumdar [a]

[a] *Department of Mechanical Engineering, National University of Singapore, 9 Engineering Drive 1, Singapore 119260, Singapore*
[b] *Department of Food Engineering, King Mongkut's University of Technology, Thonburi, Bangkok 10140, Thailand*

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Abstract

The laminar flow in an in-line mixer based on opposing jet impingement was examined as a first step toward the development of a simple efficient in-line fluid mixer. Some new design approaches to improve mixing effectiveness under laminar conditions in two-dimensional configurations were studied numerically for different operating conditions and geometric configurations. It was found that unequal inlet momenta of opposing jets obtained using both equal and unequal slot widths and the addition of baffles in the exit channel yield better mixing over shorter distances after impact. The pressure drop for the case with the addition of baffles increased as well, however. The improvement of mixing effectiveness was found to depend strongly on the operating conditions and geometric configurations.

Keywords: Opposing jets; Mixing characteristics; Baffles; In-line mixer

* Corresponding author. Tel.: +65 6874 2256.
E-mail address: g0202482@nus.edu.sg (S.J. Wang).

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Nomenclature

b	distance between inlet jet and first baffle (m)
c	distance between two baffles (m)
c_p	heat capacity ($\mathrm{J\,kg^{-1}\,K^{-1}}$)
D_H	slot hydraulic diameter (m) $D_\mathrm{H} = 2WH/(W + H)$
H	opposing jet separation spacing (m) (fixed at $H = 0.01$ m)
h	baffle height (m)
k	thermal conductivity ($\mathrm{W\,m^{-1}\,K^{-1}}$)
L	exit channel length (m)
M	ratio of inlet mass flow rate of the two jets
MI	mixing index
p	static pressure (Pa)
Δp	static pressure difference between the center points of the inlet and outlet (Pa)
R	ratio of slot width of the hot jet to the cold jet
T	temperature (K)
T_b	bulk temperature at specific cross-section (K)
u	velocity component in x-direction ($\mathrm{m\,s^{-1}}$)
v	velocity component in y-direction ($\mathrm{m\,s^{-1}}$)
u_i, u_j	velocity component ($\mathrm{m\,s^{-1}}$)
u_{in}	inlet slot jet velocity ($\mathrm{m\,s^{-1}}$)
W	slot width (m)
x, x_i, x_j, y, z	coordinate (m)

Greek symbols

μ	dynamic viscosity ($\mathrm{kg\,m^{-1}\,s^{-1}}$)
ν	kinetic viscosity ($\mathrm{m^2\,s}$)
ρ	air density ($\mathrm{kg\,m^{-3}}$)

Dimensionless group

Re	Reynolds number based on inlet jet velocity and hydraulic diameter $Re = u_\mathrm{in}\mathrm{D}_h/\nu$

1. Introduction

Opposing jet impacting head-on provide a simple in-line mixer configuration with potential industrial applications for rapid mixing of viscous fluids. Single or two-phase impingement of two opposing jets has been studied for its applications in such processes as reaction injection molding (RIM), thermal drying of solid particles with high water content, fuel combustion, gas or liquid mixing, pharmaceutical crystallization, absorption, catalytic reactions, dust collection, liquid–liquid extraction [1–8]. A comprehensive literature review on various aspects of the opposing jet techniques and their applications has been presented by Kudra and Mujumdar [9] and Tamir [10].