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Radiative models for the furnace side of a bottom-fired reformer

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Abstract

Two different groups of radiative models are used to simulate a Midrex reformer. The modeling includes the furnace-side as well as the reactor-side equations. The simultaneous solution of governing equations provides the flue gas and tube wall temperature profiles. These are compared with literature and plant data. It was observed that the Flux model, applied in this work on the furnace of a bottom-fired reformer, shows a good agreement with observed plant data. The well-stirred model is still satisfactory but the long-furnace model is far away to merit an attention.

Keywords: Radiation; Heat transfer; Modeling; Zone method; Flux method; Simulation

1. Introduction

In a Midrex direct reduction plant, natural gas is used to manufacture reducing gas via a reforming process. The Midrex reformer is a bottom-fired box-type furnace with the structure of a straight-flow, co-current type heat exchanger (Fig. 1). Up-fired burners are interposed between rows of vertical reactor tubes. The reactor tubes are filled with catalysts made of dispersed nickel on an alumina or magnesium spinel carrier in the shape of Raschig or ribbed rings.

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Nomenclature

A	surface area, m^2
A_r	half of refractory surface area per unit free volume, m^2/m^3
A_{ref}	surface of refractory in each zone, m^2
A_t	half tube surface area per unit free volume, m^2/m^3
$A_{t,o}$	total external surface of all tubes in each zone, m^2
C	specific heat at constant pressure, J/kg K
E	black body emission power, W/m^2
f	heat released fraction, 1/m
H	energy flux, W/m^2
I	radiation intensity, W/m^2
I_b	blackbody radiation intensity, $\sigma T_g^4/\pi$, W/m^2
K	absorption coefficient, 1/m
L	length, m
L_b	mean beam length, m
m	mass flow, kg/m^2 s
q	heat flux, W/m^2
q_{los}	heat loss, W/m^2
q_{rad}	net radiative flux between flue gas and tube surface, W/m^2
q_{rel}	heat released along the flame length, W/m^2
q^+	radiant flux density in increasing z-direction, W/m^2
q^-	radiant flux density in decreasing z-direction, W/m^2
T	temperature, K
U	overall heat transfer coefficient, W/m^2 K
z	axial distance, m

Greek symbols

σ	Stefan–Boltzmann constant (5.667×10^{-8} W/m^2 K^4)
ε	emissivity
Ω	unit vector in spatial coordinate
ψ	band radiation fraction
τ	window radiation fraction

Subscripts

B	band radiation
W	window radiation
f	flame
fg	flue gas
pg	process gas
r	refractory
t	tube
t,o	tube-out