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Experimental and sensitivity analysis of a rotary air preheater for the flue gas heat recovery

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Abstract

Energy saving is one of the key issues, not only from the viewpoint of fuel consumption but also for the protection of global environment. A rotary regenerator (also called an air preheater or a heat wheel) is a sizeable porous disk, fabricated from some materials having a fairly high heat capacity, which rotates between two side-by-side ducts; one for the cold gas; the other for the hot stream. Its application is in a wide range of temperature waste heat recovery systems. In this work, a rotary regenerator is simulated by solving a developed mathematical model and optimized with the experimental design method. In this method, the effect of dimensionless parameters on the effectiveness of rotary heat exchangers was investigated. Numerical results were obtained by solving continuity, momentum and energy equations, and a two-step, predictor–corrector procedure is used. Experimental results are obtained by using a lab-scale rotary type regenerator and factorial design of experiments was performed for the analysis of the data. The simulation results have been compared with the experimental data and good agreement has been obtained.

Keywords: Rotary regenerator; Air preheater; Simulation; Experimental analysis

1. Introduction

Rotary regenerators are exclusively used in gas-to-gas heat transfer and mainly in waste heat recovery applications. They consist of a rotor usually made of corrugated materials which rotates at very low speeds with a constant fraction of the core facing partially for the hot and cold fluids. The heat transfer surface area or flow passages are generally made of metals with cellular

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Nomenclature

C	flow stream heat capacity rate (W/C)
C^*	heat capacity rate ratio (C_{min}/C_{max})
C_{min}	minimum of C_h and C_c (W/C)
C_{max}	maximum of C_h and C_c (W/C)
Cr	total heat capacity rate of a matrix (W/C)
D_i, D_o	rotor diameters (m)
Cr^*	total matrix heat capacity rate ratio (Cr/C_{min})
$Ntu_{,0}$	modified number of transfer units (–)
$(hA)^*$	symmetry factor related to thermal resistance ((hA) on the C_{min} side/(hA) on the C_{max} side)
h	convective heat transfer coefficient (W/m^2 K)
A	overall heat transfer area (m^2)
φ_r	correction factor for rotational speed (–)
φ_c	correction factor for cleaning region (–)
J	Colburn j-factor for heat transfer ($St\,Pr^{2/3}$)
St	Stanton number ($h/\rho u C_p$)
Pr	Prandtl number ($\mu C_p/k$)
Re	Reynolds number (GD_h/μ)
G	mass flowrate (kg/m^2 s)
T	temperature (K)
P	pressure (kPa)
u	velocity (m/s)
ρ	fluid density (kg/m^3)
ρ_w	matrix density (kg/m^3)
C_v	specific heat at constant volume (J/kg K)
C_p	specific heat at constant pressure (J/kg K)
C_w	specific heat of matrix (J/kg K)
r_h	hydraulic radius (m)
σ	porosity ($A_{ff}/\frac{1}{4}\pi(D_o^2 - D_i^2)$)
A_{ff}	free flow cross-sectional area (m^2)
f	friction factor ($\tau_w/(\frac{1}{2}\rho u^2)$)
x	distance (m)

Subscripts

c	cold
h	hot
o	outlet
i	inlet
max	maximum
min	minimum
g	gas
w	wall