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Optimal design of compact recuperators for microturbine application

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Abstract

This paper presents a new approach for the optimization of microturbine recuperators from the technical and economic standpoints. The procedure proposed has been implemented in the software called CHEOPE (compact heat exchanger optimization and performance evaluation), which considers two types of recuperator concept, which have proved to be the most promising for microturbine applications: the furnace-brazed plate-fin type and the welded primary surface type. The general design rules for performance evaluation of gas–gas heat exchangers are summarized and specifically applied to these two types of recuperator. Moreover, the cost equation, employed to estimate the capital cost of these types of heat exchanger, is discussed.

With regard to the sizing procedure, a special optimization procedure of the recuperator matrix has been developed, which takes into account several targets in a single multi-objective function: the compactness, the pressure drops and the expected cost of the device.

The tests performed for the validation are presented, and three case studies are illustrated for three different microturbine sizes, for a 50 kW, 100 kW and 500 kW machine, respectively.

Keywords: Compact heat exchanger; Microturbine; Recuperator; Cost equation

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Nomenclature

A	heat transfer total surface [m^2]
b	distance between the plates [m]
c_p	specific heat at constant pressure [J/kg K]
C	thermal flow capacity, $\dot{m} \cdot c_p$, [W/K]
D_h	hydraulic passage diameter [m]
f	fanning friction factor
G	specific flow rate [kg/m^2 s]
h	convective heat transfer coefficient [W/m^2 K]
j	Colburn number
l	length [m]
$\dot{m}$	mass flow rate [kg/s]
N	shaft rotational speed [rpm]
Nu	Nusselt number
OF	objective function
p	pressure [Pa]
Δp	pressure loss or pressure difference [Pa]
p_f	fin pitch [m]
Pr	Prandtl number
Re	Reynolds number
s	thickness [m]
TIT	turbine inlet temperature [K]
TOT	turbine outlet temperature [K]
V	volume of material [m^3]
W	section resistance modulus [m^3]
β	compactness [m^2/m^3]
ε	heat exchanger effectiveness
δ	fin thickness [m]
ρ	density of material [kg/m^3]
σ_d	design mechanical stress [Pa]
ψ	reference cost [$]

Subscripts

c	cold side
des	on-design
h	hot side
i	inlet
min	minimum
o	outlet
sides	sides
tot	total
0	reference