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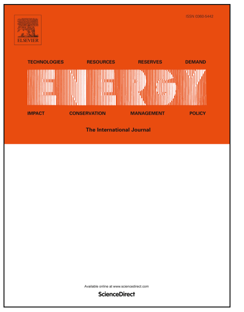

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Optimizing the Heat Transfer Performance of the Recovery Boiler Superheaters Using Simulated Annealing, Surrogate Modeling, and Computational Fluid Dynamics

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Abstract

The energy efficiency of recovery boiler power plants is largely influenced by the heat transfer to the superheaters. In the design process of such very large-scale applications, one of the key challenges is the a priori geometry optimization by robust numerical approaches. The main objectives of this work are to demonstrate a numerical optimization framework and to optimize the geometry of the superheater region to enhance the heat transfer. The framework is implemented as a surrogate-based optimization method, which combines simulated annealing, local polynomial regression, and computational fluid dynamics. The novelty of this work consists of the following: 1) The optimization framework is designed and introduced. 2) The connection between the geometry and heat transfer is quantified by formulating the optimal design curve. 3) The optimal design for a typical, existing recovery boiler is identified. The results indicate that the uniformity of the flow field is improved, and the heat transfer rate is increased by 5%. 4) The results indicate the importance of minimizing the separation vortices through the geometrical design with a strong linkage to the overall heat transfer rate. 5) The potential of optimization methods in this very large-scale energy production application is demonstrated for the first time.

Keywords: heat transfer, energy efficiency, optimization, recovery boiler, computational fluid dynamics, surrogate modeling

Nomenclature

CFD model	
$D_{n,\mathrm{eff}}$	effective diffusivity of species *n* [m^2/s]
e_{mean}	mean absolute error of the heat transfer rates to the SHs [%]
e_{total}	error in the total heat transfer rate to the SHs [%]
$\boldsymbol{f}$	body force vector [N]
$\boldsymbol{g}$	gravitational acceleration vector [m/s^2]
$\mathrm{GCI}_{\mathrm{total}}$	discretization error estimate for the total heat transfer rate to the SHs [%]
h	sensible enthalpy [J/kg]
h_{desh}	enthalpy of the desuperheating water [J/kg]
h_n	sensible enthalpy of species *n* [J/kg]
h^i_{bef}	enthalpy of the steam before SH *i* before desuperheating [J/kg]
h^i_{in}	enthalpy of the steam at the inlet of SH *i* after desuperheating [J/kg]
h^i_{out}	enthalpy of the steam at the outlet of SH *i* [J/kg]