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Computational model for a condensing boiler with finned tubes heat exchanger

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Abstract

European regulations state a minimum boiler efficiency for the main steady-state functioning conditions and for the overall heating season conditions. In order to comply the demands of the new regulations, more and more boiler manufacturers are switching the gas boilers production to condensing functioning. In the paper we present the numerical and computational modeling of a boiler made out of packages of finned tubes and packages of smooth pipes. Validation of the computational results is made by comparison with experimental results obtained in a certified laboratory for the modelled equipment (boiler). The modelling was set on an aluminium finned tubes heat exchanger existent in the testing laboratory (part of a condensing boiler). The geometry modeling considered the discretization of the heat exchanger in several zones, characterized by homogenous flue gas flow speed, flow geometry and heat transfer characteristics (mainly feature-length). A good correlation between measured and calculated values was obtained, the error ranging +/- 1% for the total and sensible heat and for thermal efficiency.

Keywords: Heat and mass transfer, condensing boiler, computational model.

1. General context

The constant concern of the European countries for the energy efficiency lead to important legislation initiatives also in the field of boiler efficiency [1]. So, European regulations state a minimum boiler efficiency for the main steady-state functioning conditions and for the overall heating season conditions.

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In order to comply the demands of the new regulations, more and more boiler manufacturers are switching the gas boilers production to condensing functioning.

Condensing boilers can generally come either from an initial design as condensing boilers, either from “normal” boilers fitted with modifications allowing the condensing functioning.

Nomenclature

α_{rd} and α_{cv}	radiative and convective surface heat transfer coefficients , [$W/(m^2 \cdot K)$]
T_{pw}	wall temperature (metallic pipe or insulation) , [K]
T_{gm}	mean temperature of the flue gases , [K] ; $T_{mg} = (T_{gi} \bullet T_{ge})^{0,5}$
$C_o \bullet 10^{-8}$	Stefan – Boltzmann constant for radiation
FL	feature-length of the flow , [m]
T_t ; t_t	theoretical (adiabatic) burning temperature [K] ; [^oC]
T_f ; t_f	furnace exit section flue gases temperature [K] ; [^oC]
Θ	furnace temperature invariant; $\Theta = Tf / Tt$
Bo	Boltzmann invariant for furnaces
M	“filling factor” for the furnace (dimensionless)
a_f	general absorption coefficient for the furnace
ξ	dirt coefficient
S_R	active radiative heat transfer surface of the furnace [m^2]
B	fuel flow rate [m^3_N / s]
Vg	technical (real) specific flue gases volume [m^3_N / m^3_N]
S_{CNV}	convective heat transfer surface [m^2]
t_i ; t_e	inlet and outlet temperature of the flue gases [^oC]
a_p	radiation absorption coefficient for the heat transfer surface
a_g	radiation absorption coefficient for the flue gases
c_{pg}	specific heat capacity of the flue gases [$J/(m^3_N \cdot K)$] at a certain temperature [$c_{pg} = f(temp)$]
φ	burning process efficiency (≈ 1)
Sh	Sherwood invariant for mass transfer
DIF	diffusivity coefficient
p_{H2O}	partial pressure of the water vapors (in the flue gases or at the wall temperature at saturation point)

In the first case, the design focuses from the beginning on special heat and mass transfer geometries characterized by high flow speed for flue gases, small feature-length and combined gravitational and flue gas flow condensation discharge. The burner is with premix of air and gas, with radiative plane surface for stabilization and burning and it is placed over the boiler’s body. The radiation component of the solid surface of the burner is received by the finned pipes of the first row and is considered as a solid-solid radiation between two plane surfaces, one made of ceramics and one made of steel (for the finned pipes, due to the diaphragm effect).

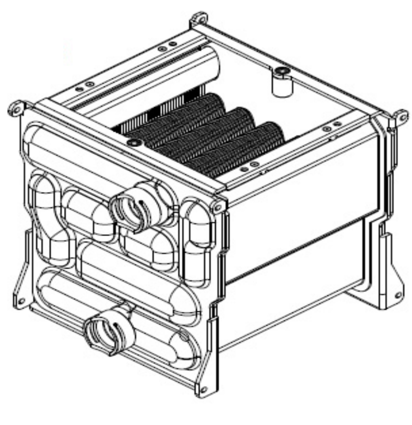

Figure 1 : boiler’s general design

In the second case, the design targets mainly to use some existing constructive parts from non-condensing boilers and fit them in a condensing boiler. From that, it generally results the need for a verification calculus for the chosen heat transfer surface when functioning in condensing boiler conditions.

Usually, the manufacturers tend to operate modifications that concerns mainly the general geometric characteristics of the heat exchangers (pipes length, number of pipes per row, number of rows) in order to obtain desires performance parameters without modifying the