Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 157 (2016) 66 – 71
Procedia Engineering
www.elsevier.com/locate/procedia

IX International Conference on Computational Heat and Mass Transfer, ICCHMT2016

The Non-Iterative Estimation of Bed-to-Wall Heat Transfer Coefficient in a CFBC by Fuzzy Logic Methods

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Abstract

The Fuzzy Logic (FL) approach is proposed in this paper to determine the overall heat transfer coefficient in the combustion chamber of a large-scale 670 t/h circulating fluidized bed (CFB) boiler. The FL model for the prediction of bed-to-wall heat transfer coefficient was successfully validated against data from the boiler. The model can be easily applied by scientists and engineers for simulations and optimizations of CFB units.

Peer-review under responsibility of the organizing committee of ICCHMT2016

Keywords: Bed-to-wall heat transfer; fuzzy logic; circulating fluidized bed (CFB); membrane-walls; modeling

1. Introduction

Heat transfer in the furnace of a circulating fluidized bed (CFB) boiler is affected by complex factors [1-5]. There are many different methods to describe the heat transfer processes, e.g. detailed measurements in the furnace, multiple equations, correlations and models, shown in the literature [5-8].

Another estimation method in engineering analysis and predictions is using the fuzy logic (FL) techniques as an alternative for the above described methods of data handling [9]. Apart from artificial neural networks and evolutionary computations, fuzzy-logic (FL) constitute one of the main representatives of the artificial intelligence

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Peer-review under responsibility of the organizing committee of ICCHMT2016
doi:10.1016/j.proeng.2016.08.339

methods [9-14]. This technique uses linguistic variables as well as fuzzy sets. The FL approach enables qualitative judgment applied to parameters quantitative in nature and also allows to deal with imprecise, vague and uncertain information [15, 16 - 18].

The presented work deals with the FL method to predict the local overall heat transfer coefficient for membrane-walls in a large-scale 670 t/h CFB boiler.

Nomenclature

e	voidage
h	heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$
T	temperature, °C
U	flue gas velocity, $m\ s^{-1}$
z	the distance from the gas distributor, m
Subscipts	
d	desired
p	predicted
Acronyms	
CFB	Circulating Fluidized Bed
CFBC	Circulating Fluidized Bed Combustor
MCR	Maximum Continous Rating

2. Calculating conditions

In order to obtain the heat transfer coefficient, some experiments have been carried out on the 670 t/h steam capacity CFB boiler, operating in PGE GiEK SA Turow Power Power Station in Poland. The schematic diagram of the combustor is shown in Fig 1.

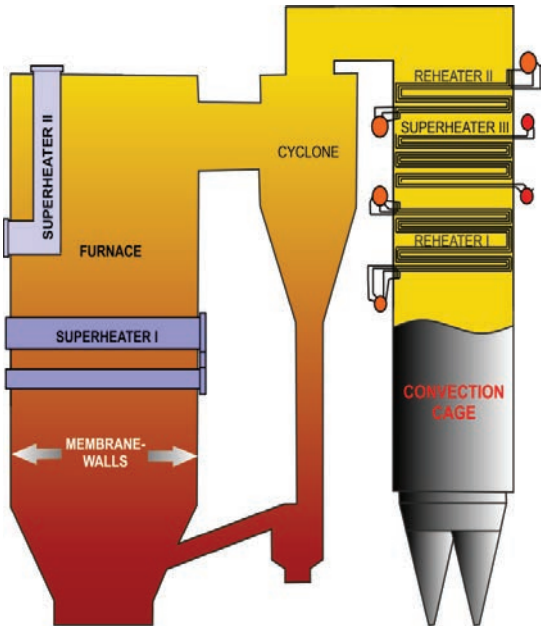

Fig 1. Schematic diagram of the large scale CFBC

The boiler is made of furnace of 48 m in height, formed by the membrane-walls and two cyclones of 10 m i.d. The membrane-walls constitute a tight structure with the total surface of 2477 m^2, made of tubes, welded together. The fuzzy logic approach was used to study the local, overall heat transfer coefficient for membrane-walls of the large-scale CFB combustor (CFBC).

The previously obtained results of heat transfer coefficient [5, 19-21] was used for validation of the performed FL model. The qtfuzzylite software, i.e. a fuzzy logic control application was applied in the paper [22]. The distance from the gas distributor z, the temperature T and voidage e of the bed, flue gas velocity U and the MCR of the boiler constitute the of input parameters as they influence the overall heat transfer coefficient [3, 9, 25-29]. The overall heat transfer coefficient for membrane-walls makes the output parameter.

The input parameters were described by five overlapping sigmoid linguistic terms very low, low, average, high, very high.

Five constant linguistic terms, i.e.: very low, low, average, high and very high describe the output parameter i.e. the overall heat transfer coefficient.

The Takagi-Sugeno inference engine is used to determine the fuzzy output variable [23, 24].

3. Results and discussion

The model allows to estimate the overall heat transfer coefficient for membrane-walls in the CFB combustor. The comparison between desired and predicted by the model results for different operational conditions is shown in Fig. 2.

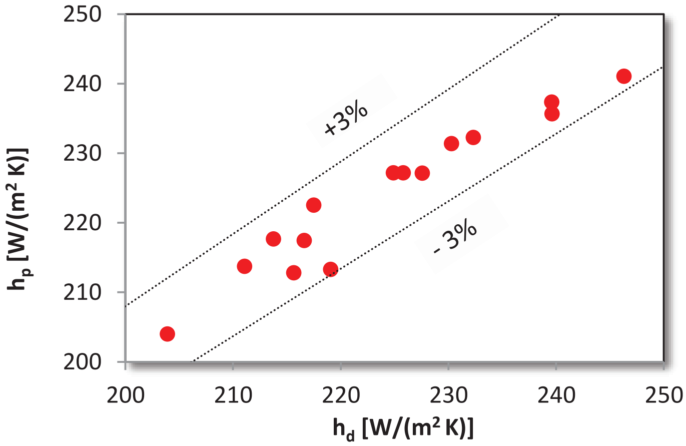

Fig. 2. Comparison of the local overall heat transfer coefficient values desired and predicted for membrane-walls by the fuzzy logic model

The maximum relative error is lower than 3 %. The local heat transfer coefficients evaluated using the developed model are in a good agreement with the desired data.

Such performed model can be further applied to study the behaviour in the local, overall heat transfer coefficient fotr membrane-walls in the large-scale CFB combustor.

The influence of bed voidage on the bed-to-wall heat transfer coefficient in the large-scale 670 t/h CFB boiler is given in Fig. 3.

The heat transfer coefficient for membrane-walls decreases with the increase in bed voidage. Similar results were discussed in [1]. Such behaviour is the result of the thicker thermal boundary layer which exists for higher bed voidage.

As it can be seen the local overall heat transfer coefficient also decreases with the decrease in MCR. It corresponds to the deterioration in mixing processes, which occur for lower MCR levels.

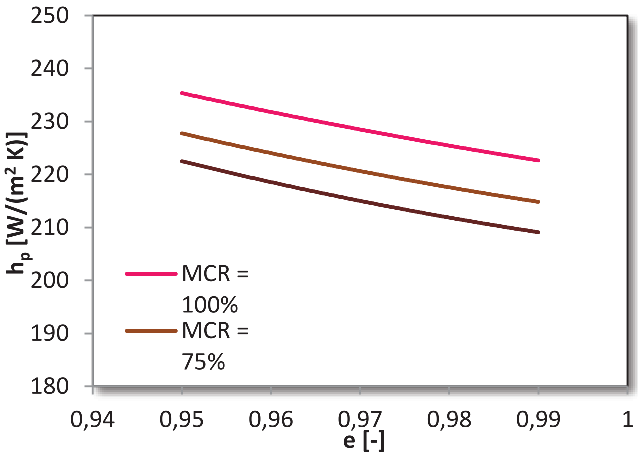

Fig. 3. The effect of bed voidage on the heat transfer coefficient; z = 30 m, U = 6 m s[1], T = 850 °C.

The results of simulations, for U = 6 m s^{-1}, T = 850 °C, z = 30 m and different MCR and e are given in Table 1.

Table 1. Calculations results.

MCR [%]	e [-]	h_p [W m^{-2} K^{-1}]
100	0.95000	235.66
	0.96000	231.51
	0.97000	227.53
	0.98000	227.00
	0.99000	222.03
75	0.95000	228.03
	0.96000	223.76
	0.97000	219.76
	0.98000	219.00
	0.99000	214.26
50	0.95000	222.76
	0.96000	218.28
	0.97000	214.18
	0.98000	213.24
	0.99000	208.55

4. Conclusions

The FL model for the predictionof of bed-to-wall heat transfer coefficient was proposed in the paper. The data obtained using the model are close to that from numerical calculations and experimental results. Maximum relative error are less than 3%, but some of them are smaller than 1%.

The performed model is capable to describe the local, overall heat transfer coefficient for membrane-walls in the large-scale 670 t/h circulating fluidized bed boiler.

Acknowledgements

Scientific work was financed within the confines of subsidies granted by the Faculty of Mathematics and Natural Sciences Jan Dlugosz University in Czestochowa. The support is gratefully acknowledged.

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