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EFFECTS OF BIOMASS SHARE ON SO_2 AND NO_X EMISSIONS IN A CIRCULATING FLUIDIZED BED COMBUSTOR

Afsin Gungor*, Ugur Yildirim
Akdeniz University, Faculty of Engineering
Department of Mechanical Engineering, 07058 Antalya
Turkey

ABSTRACT
In this study, effect of biomass share on co-combustion of coal and biomass in a circulating fluidized bed is investigated by previously developed model. SO_2 and NO_x emission predictions of the model are compared with test results obtained from the laboratory-scale 30 kW (thermal) atmospheric test unit of 0.86 m i.d. and 7 m tall riser data published in the literature. Simulation results show that emission of NO_x decreases dramatically from 125 to 79 ppm when mass ratio of rice husk to coal increases from 0 to 30 wt%. Emission of SO_2 is found to show a slight increase with the increase of rice husk mass share.
Keywords: co-firing, co-combustion, fluidized bed, modeling, simulation

1. INTRODUCTION
Circulating fluidized bed (CFB) combustion is receiving wide research attention in view its potential as an economic and environmentally acceptable technology for burning low-grade coals, biomass and organic wastes, and thereby mixtures of them. Recent studies show that the emissions of SO_2 and NO_x are reduced in the most co-combustion tests (depending on the biomass fuel used) [1].

Although large numbers of modeling studies have addressed emission characteristics for co-combustion coal and biomass, co-firing is a developing technology still in the testing phase [2, 3]. More detailed investigations covering different fuel types, fuel mixtures, combustors types and combustion conditions are needed [3]. This study improves the current data on the effect of biomass share on NO_x and SO_2 emissions are extensively investigated for co-firing biomass and coal in CFBs. A previously developed model is used to reveal simulation results concerning benefits of co-firing biomass and coal in CFBs [4, 5]. The model addressed in this paper considers two dimensional motion of single particles through fluids. Simulation model calculates the axial and radial distribution of voidage, velocity, particle size distribution, pressure drop, gas emissions and temperature at each time interval for gas and solid phase both for bottom and upper zones. The results are compared with an industrial-scale CFB data which is published in the literature.

2. MODELING
The designing of the CFB is very important because it enables burning mixtures of fuels with high efficiency and within acceptable levels of gaseous emissions. To simulate and optimize the behavior of a CFB, firstly the mathematical modeling of the hydrodynamic and kinetic characteristics is needed. In the present study, a previously developed 2D CFB model is used for the simulation [4, 5]. The model addressed in this paper uses particle based approach which considers two-dimensional motion

*Corresponding author. Tel.: +90 532 397 30 88; fax: +90 242 310 63 06.
E-mail address: afsingungor@hotmail.com (A. Gungor)

of single particles through fluids. The Gauss-Seidel iteration which contains successful relaxation method and combined Relaxation Newton-Raphson methods are used for solution procedure. Flow chart of the numerical solution of the model is shown in Fig.1. Simulation model calculates the axial and radial distribution of voidage, velocity, particle size distribution, pressure drop, gas emissions and temperature at each time interval for gas and solid phase both for bottom and upper zones. The structure and details of numerical solution have been given in previous studies [4, 5].

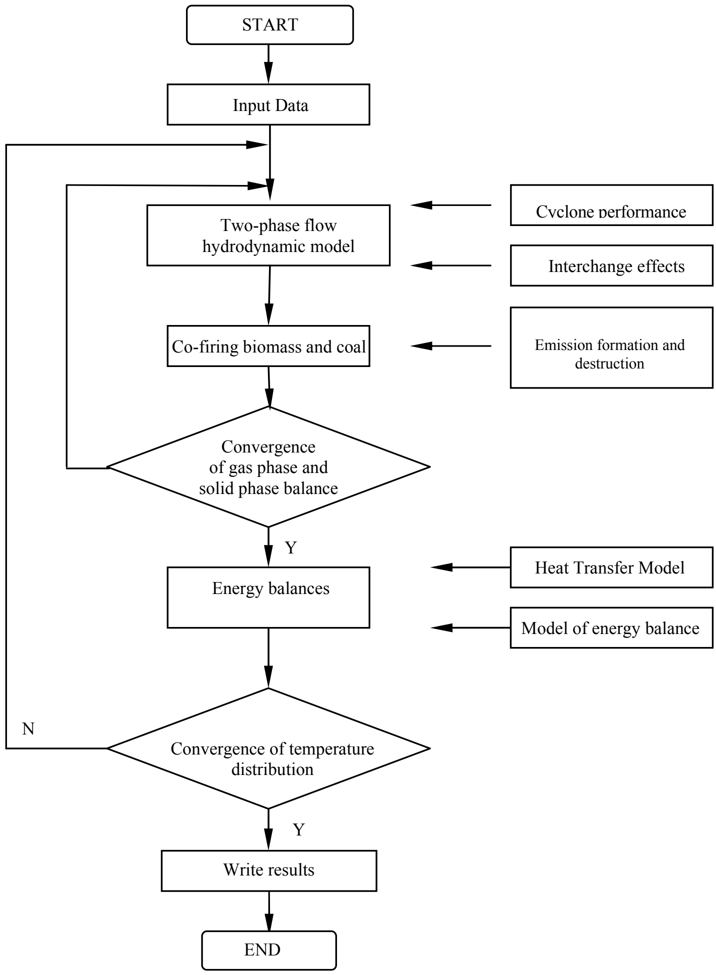

Figure 1. Flow chart of the numerical solution of the CFB model.

3. RESULTS AND DISCUSSION

The objective of this work is to investigate the effect of biomass share on SO_2 and NO_x emission to reveal the benefits of co-firing biomass and coal in CFBs. SO_2 and NO_x emission predictions of the model are compared with test results obtained from the laboratory-scale 30 kW (thermal) atmospheric CFB test unit of 0.86 m i.d. and 7 m tall riser. In these comparisons, the same input variables are used in the tests as the simulation program input. Rice husk is used as biomass fuel in the experiments. Further details are given in the literature [6]. The analytical data for the fuels are listed in Table 1. The considered parameters and computation conditions are given in Table 2.

Table 1. The proximate and ultimate analyses of fuels.

	Coal	Rice husk
Proximate analysis (wt%, dry)		
Ash	11.41	15.93
Volatile Matter	27.92	68.74
Fixed Carbon	60.67	15.34
Ultimate analysis (wt%, dry)		
C	72.98	44.44
H	3.69	5.68
N	1.16	0.55
S	0.62	0.06

Table 2. Operating parameters of the experimental data referred to in this study.

Operating Parameters					
Biomass share (%)	0	13	22	27	30
Coal (kg/h)	2.68	2.68	2.68	2.68	2.68
Rice husk (kg/h)	0	0.4	0.75	0.97	1.15
Primary air flow-rate (Nm^3/h)	20.8				
Secondary air flow-rate (Nm^3/h)	5.1				
O_2 in flue gas (%)	1.07-4.52				
Bed temperature (◦C)	800				

The model predictions about the influence of the biomass share on SO_2 and NO_x emission are shown in Fig.2 which also plots the experimental results of Xie et al. [6].

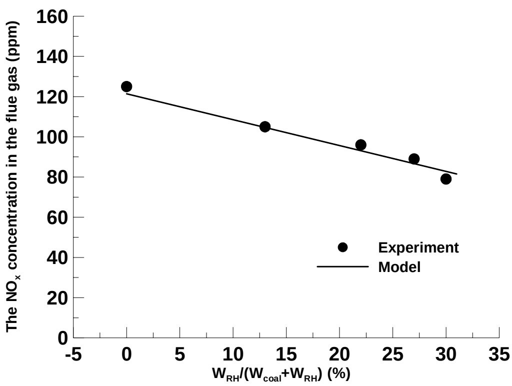

Figure 2a. Comparison of model predictions with Xie et al. [6]'s experimental data with regard to NO_x emission.

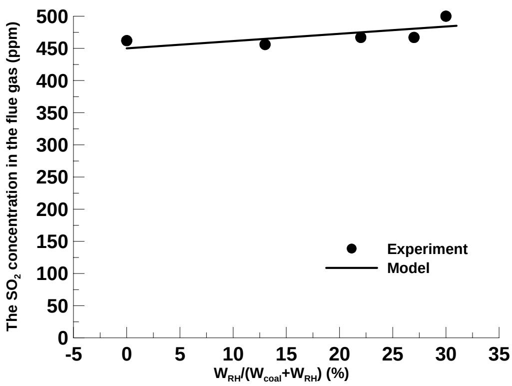

Figure 2b. Comparison of model predictions with Xie et al. [6]'s experimental data with regard to SO_2 emission.

NO_x emissions decrease compared with the ''coal only'' case as it is clearly seen in Fig.2a. When mass ratio of rice husk to coal increases from 0 to 30 wt%, emission of NO_x decreases dramatically from 125 to 79 ppm. Because the nitrogen content in biomass is less than that in coal, the less emission of NO_x and SO_2 during co-firing can be easily explained as the dilution on N and S content in the mixed fuel [6]. Xie et al. [6]'s experiments are performed with rice husk mass share as 0, 13 wt%, 22 wt%, 27 wt% and 30wt%, whereas coal feeding rate kept at 2.68 kg/h. Hence, the energy load in the experiments is increasing. So, oxygen concentration in the CFB decreases with the increase of amount of fuel, therefore, rapid conversion of carbon in fuels to CO reduces oxygen reaction competition ability with N to form NO and N_2O. The formation of NO from fuel nitrogen takes place via combustion of nitrogen species as volatiles and oxidation of nitrogen in char. due to the density difference between coal and rice husk particles, rice husk particles will be devolatilized and combusted at higher region than coal in the riser, the released volatile gases can reduce generated NO from oxidation of coal char at higher region of the riser to form N_2 [6].

Emission of SO_2 is found to show a slight increase with the increase of rice husk mass share. The slight increase of SO_2 emission during co-firing can be considered as a result of fuel S increase with increasing rice husk mass share as shown in Fig.2b. It is clearly seen from Fig.3 that both experimental data and model predictions show the close agreement on SO_2 and NO_x emissions for small scale CFB.

4. CONCLUSION

In this study, the effect of biomass share on SO_2 and NO_x emission is investigated. The present study proves that CFB co-combustion allows clean and efficient way of the transform of coal and biomass into energy which is demonstrated by the fact that both experimental data and model simulation results have low and acceptable level of emission pollutants.

5. ACKNOWLEDGMENT

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