STUDY OF SO_2 EMISSIONS RESULTED FROM COMBUSTION OF JIU VALLEY COAL

Liana Simona Sbirna – *Ph.D., University of Craiova*
Clementina Sabina Moldovan – *Ph.D., University of Petrosani*

ABSTRACT:
This paper reports the results obtained for the emissions of SO_2 from a large coal under staged combustion without any additive.
The experiments were carried out at fluidizing velocities of 1 and 2 m/s, bed temperatures of 1000-1100 K, 20% and 40% excess air, at a primary air staging of 70:30 and a secondary air staging of 60:40, by using bed particle sizes of 0.2 and 0.7 mm.
The effect of each of these work parameters on SO_2 emissions was investigated, in order to draw the conclusions of the study..
KEYWORDS: *Jiu Valley coal, sulfur dioxide emissions, FBC technology*

INTRODUCTION

Coal, which is primarily used for the generation of electricity, is one of the largest domestic contributors to sulfur dioxide emissions. The public has become more concerned about global warming which has led to new legislation.

The coal industry has responded by running advertising touting clean coal in an effort to counter negative perceptions.

Fluidized bed combustion (FBC) is a combustion technology that is based on suspended solid fuels in upward-blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids [5].

The mixing action of the fluidized bed brings the flue gases into contact with a sulfur-absorbing chemical, such as limestone or dolomite.

More than 95% of the sulfur pollutants in the fuel can be captured inside the boiler by the sorbent. The sorbent also captures some heavy metals, though not as effectively as do the much cooler wet scrubbers on conventional units.

The literature reports that FBC technology involves either two beds in series with two distributors or a simple air staging technique.

In the staged operation mode, the combustion air is separated into a primary air stream.

This constitutes the fluidizing air supply to the bed and a secondary air stream that is injected higher up in the bed or freeboard [3].

Combustion is then completed following the introduction of secondary air. However, overall excess air conditions are maintained in a similar way as in conventional operation.

Air-staging is a proven technique to reduce NO_x emissions, but is known to increase in SO_2 emissions.

This increment is due to the presence of secondary air in the freeboard that allows further combustion (it seems that at high staging this increment is caused by the carryover of unburned fuel sulfur into the freeboard).

The objective of this study is to determine the effects of different work parameters on SO_2 emissions.

One can compare the efficiency of SO_2 reduction with the one obtained if a sorbent is added to the bed (as previously mentioned, a sorbent denotes here a sulfur-absorbing chemical, such as limestone or dolomite).

Bed temperature exhibits a significant effect on SO_2 emissions which indicates that the rate of formation of SO_2 in the freeboard is affected by staging and changes in the temperature profile of the freeboard [1].

In this study, the simple air staging technique was adopted where most part of the total air is injected through the distributor and the remainder is injected in the freeboard of the fluidized combustor.

EXPERIMENTAL

A stainless steel combustor, 0.3x0.3 m in cross section and 2 m high was used.

Fluidizing air was supplied through a multi-hole distributor. An adjustable secondary air injector was used along the vertical axis of the combustor to introduce secondary air in the freeboard.

Investigations were carried out at 20% and 40% of total air injected in the freeboard above the bed, at a primary air staging of 70:30 and a secondary air staging (primary/secondary air) of 60:40, whereas the fluidizing velocities were of 1 and 2 m/s, bed temperatures of 1000 and 1100 K. The bed particle sizes were of 0.2 and 0.4 mm [2].

The fluidized bed was preheated by a propane burner, fixed above the bed, and the fluidizing air flow rate was set at the lowest level to minimize the heating time.

The secondary air was injected through a secondary air injector consisting of a stainless steel pipe with a 15 mm inside diameter, containing twelve holes of 3 mm diameter. This injector was located on the vertical axis of the combustor and its position above the bed or in the freeboard was adjustable. The bed temperature was maintained by using an adjustable cooling coil [4].

Coal sampled from Jiu Valley was used in the experiments.

RESULTS AND DISCUSSION

Coal feeding started when the bed temperature reached 1000 K.

The proximate and ultimate analyses of coal is given in Tables 1 and 2.

Table 1. Proximate analysis of coal used

Proximate analysis (dry basis)	Weight (%)
Ash	6.23
Volatile matter	33
Fixed carbon	60

Table 2. Proximate analysis of coal used

Ultimate analysis (dry basis)	Weight %
Carbon	70
Hydrogen	5
Oxygen	8
Nitrogen	1
Sulfur	11
Moisture	5

Values of SO_2 emissions were continuously recorded.

More specifically, the SO_2 in the flue and the axial concentration profiles of SO_2 through the combustor were measured for a fluidizing velocity of 1 and 2 m/s; the bed material was sand, of about 0.2 and 0.7 mm size respectively, staging 70:30 and 60:40, excess air 20 and 40%, at bed temperatures between 1000 and 1100 K (the Ca:S molar ratio was found to be approximately 3:1).

The results (*i.e.*, the values of SO_2 emissions – measured in ppm) are summarized in Tables 3 and 4 for the two particle types that were used. As is obviously that the particle size does not practically affect the results, one may reduce the study to the one involving the particles of 0.7 mm.

Table 3. The values of SO_2 emissions (ppm) for the case of 0.2 diameter sand particles in fluidized bed

	70:30	60:40	70:30	60:40	
1 m/s	627	670	653	700	40%
1 m/s	689	719	703	823	20%
2 m/s	731	781	833	904	40%
2 m/s	818	885	1020	1204	20%
	1000 K	1000 K	1100 K	1100 K	

Table 4. The values of SO_2 emissions (ppm) for the case of 0.7 diameter sand particles in fluidized bed

	70:30	60:40	70:30	60:40	
1 m/s	628	670	653	700	40%
1 m/s	690	720	703	823	20%
2 m/s	732	780	834	905	40%
2 m/s	818	885	1020	1205	20%
	1000 K	1000 K	1100 K	1100 K	

6.22
33.00
60.78

EFFECT OF DIFFERENT WORK PARAMETERS ON SO_2 EMISSIONS

It shows that the SO_2 emissions decreased when the amount of the secondary air was increased and the fluidizing velocity decreased. One may notice that the SO_2 emissions are sensitive to bed temperature, increasing as it increases.

The SO_2 emissions at different secondary air ratios appear to be affected by combustion efficiency.

77.51
4.8
8.5
1.43
15
5.0

They exhibit higher values at higher secondary air (which equals to lower air staging) are due to increased combustion of sulfur in the bed and freeboard.

Figures 1-4 illustrate the two charts representing SO_2 emissions as functions of bed temperature at a particular air staging (either 70:30 or 60:40) for a fixed fluidizing velocity (either 1 or 2 m/s) and also for a fixed excess air (either 20% or 40%).

The results demonstrate that the extent of SO_2

emission during staged combustion is influenced by the amount of secondary air and by the bed temperature. More specifically, it increases as bed temperature increases and the primary/secondary air increases (*i.e.*, at higher secondary air).

One can observe that the trends obtained are alike for these charts.

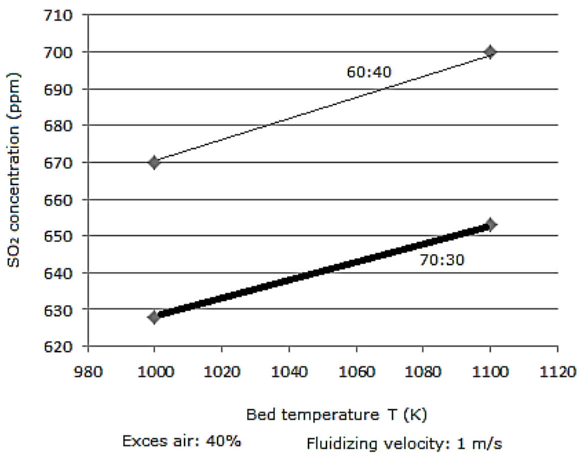

Figure 1. SO_2 emissions as functions of bed temperature at two particular air staging levels (the fluidizing velocity is fixed at 1 m/s, whereas the excess air is fixed at 40%)

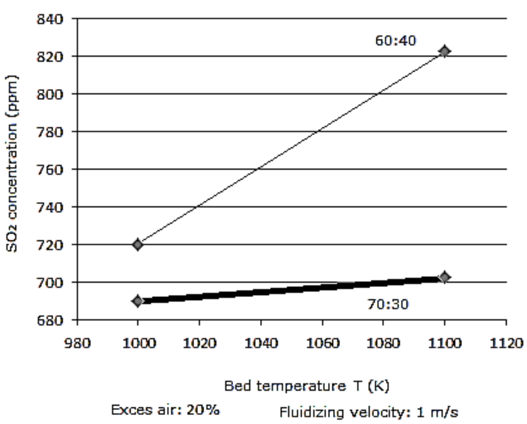

Figure 2. SO_2 emissions as functions of bed temperature at two particular air staging levels (the fluidizing velocity is fixed at 1 m/s, and the excess air is fixed at 20%).

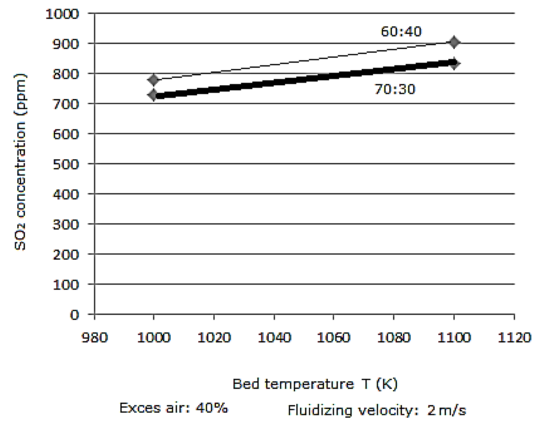

Figure 3. SO_2 emissions as functions of bed temperature at two particular air staging levels (the fluidizing velocity is fixed at 2 m/s, whereas the excess air is fixed at 40%)

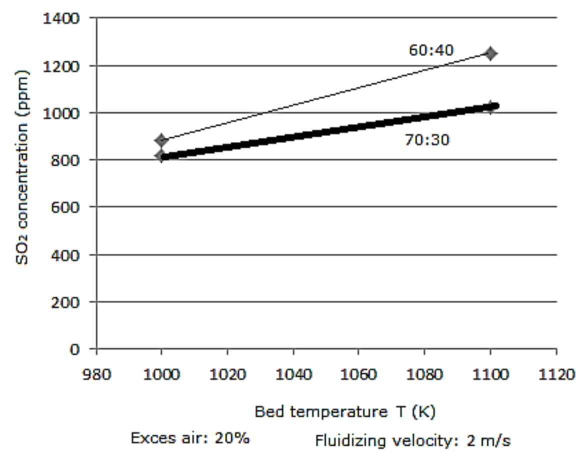

Figure 4. SO_2 emissions as functions of bed temperature at two particular air staging levels (the fluidizing velocity is fixed at 2 m/s, whereas the excess air is fixed at 20%)

The primary air to coal ratio (air/fuel ratio) is defined as the ratio of primary air supplied to the stoichiometric air required, calculated from the coal composition (at 40% staging, an excess air level of 40% resulted in a primary air to coal ratio of 0.8, and 20% excess air resulted in a primary air to coal ratio of 7:10, *etc*.).

At a low primary air to coal ratio, an increase in carryover of unburned fuel sulfur species into the freeboard where it subsequently oxidizes also increase SO_2 emissions.

This indicates that oxidation of some of the sulfur bearing compounds to SO_2 cannot be ignored in the second stage (above the bed).

The air:fuel ratio has significant influence on the rate of sulfur release from the coal and on the ratio of H_2S formed during fuel-rich combustion.

CONCLUSION

The results indicate that SO_2 emissions increase with a rise in bed temperature. The extent of SO_2 emission during staged combustion is strongly influenced by the amount of secondary air and bed temperature.

For a given bed temperature and excess air level, increasing the level of air staging or lowering the primary air to coal ratio causes an increase in SO_2 emissions.

An increase in SO_2 emissions as excess air is reduced was observed at both fluidizing velocities and at all secondary air ratios.

REFERENCES

1. Modrak, T. M., Tang, J. T., Auliso, C. J., *Fuel*, 2007
2. Tatebayashi, J., Okada, Y., Yano, K., Ikeda, S., *Fuel*, 2007
3. Tomita, M., Hiramo, T. Adachi, T., Yamaguchi, H., Horio, M., *International Conference on Fluidized Bed Combustion*, Atlanta, Georgia, USA, ASME, 2000
4. Valk, M., Bramer, E. A., Toissant, H. H. J., *Conference on Fluidized Bed Combustion*, Montreal, Canada, ASME, 2002
5. www.netl.doe.gov