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Influence of oxy-coal on fly ash transformations and corrosion behavior of heat-exchangers

Gosia Stein-Brzozowska*, Selahattin Babat, Jörg Maier*, Prof. Günter Scheffknecht[a]

[a]*IFK, Institute of Combustion and Power Plant Technology, Univ. of Stuttgart, Pfaffenwaldring 23,70569 Stuttgart, Germany*

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Introduction

Although the road-map of the oxy-fuel process seems to be very advanced, there are still plenty of open questions. One of the significant ones covers the interactions between the flue gas and fly ash deposits and their subsequent impact on the heat exchanger surfaces. The Institute of Combustion and Power Plant Technology, University of Stuttgart, performs research on the fireside corrosion under oxy-fuel and conventional combustion conditions for the current and supercritical power plants considering the influence of combustion modus, gas atmosphere and fly ash deposits on the waterwall and superheater surfaces. Since the oxy-fuel-combustion atmosphere is composed of recirculated flue gases and pure oxygen, significantly higher concentrations of CO_2, SO_2, SO_3 and H_2O are present compared to the conventional combustion of coal with air as an oxidizer. In this study the influence of an oxy-fuel combustion of three different mineral systems was studied and the interactions between the combustion atmosphere, fly ash deposits and selected heat exchanger materials are examined carefully.

The aim of this study is to acquire information concerning the interactions of the flue gas and fly ash and its deposits on the chosen heat exchanger materials that are planned to be applied in an ultra-super-critical oxy-fuel power plant. The studies are run concerning three different mineral systems:

- lignite of a basic character (coal A)
- lignite of an alumino-silicatic character and increased sulphur content (coal B)
- hard coal of an alumino-silicatic character (coal C).

1. Experimental Procedure

The research is performed in two steps. With the use of a 0,5 MWth pulverized fuel test rig (KSVA) at IFK[3] the combustion tests are performed, combustion atmosphere is characterized and fly ashes are collected in different

* Corresponding author. Tel.: +49 711 685 67762; fax: +49 711 685 63491.
E-mail address: stein-brzozowska@ifk.uni-stuttgart.de
* Corresponding author. Tel.: +49 711 685 63396; fax: +49 711 685 63491.
E-mail address: maier@ifk.uni-stuttgart.de

[3] IFK – Institute of Combustion and Power Plant Technology, University of Stuttgart, renamed in October 2009 from IVD – Institute of Process Engineering and Power Plant Technology

sections of the combustion chamber and flue gas path (see Fig. 1). Here it was differentiated between the fly ash and deposition collection methods in order to obtain a full characteristic of primary and secondary deposition layer and fly ashes. As primary layer one understands the first fly ashes settling down directly on the heat exchangers surfaces of the boiler and thus the particles facing the thermo-diffusion effect. Whereas the secondary deposition layer encompasses the fly ashes building a deposition over the primary layer thus the secondary layer is further out from the cooling medium and hence the cooling effect can be neglected. All the three coals are combusted in both conventional air and oxy-fuel modes set-up at 300 kWth.

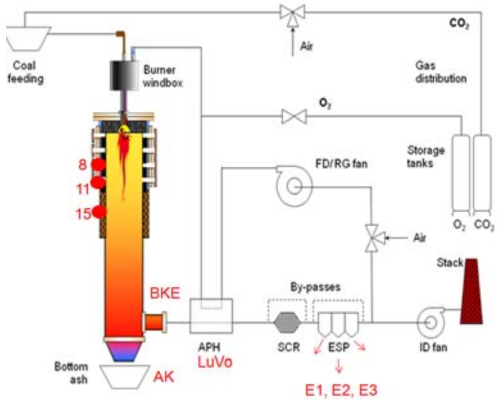
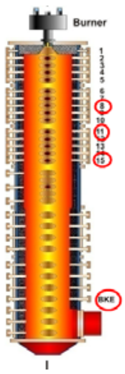


Fig. 1.: Deposition and fly ash collection points (red marking) at 500 kWth test rig KSVA at IFK.

Subsequently with the information on the flue gas atmosphere and collected fly ashes and depositions the long-term tests are performed in the laboratory furnaces where the selected alloys are exposed to the fly ashes and flue gas atmosphere. Beside the laboratory tests with real fly ash depositions, additionally some minerals expected to have the highest corrosive impact are additionally applied to selected alloys under the same gas composition and temperature.

2. Results

Below some of the results are presented concerning air and oxy-fuel combustion of coals A and C with the focus on sulphur enrichment of the deposition and fly ash particles in the combustion chamber and the flue gas path, respectively. The combustion atmosphere during the combustion tests of coal C is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**. at the positions were the depositions were collected.



Level 8	CO [%]	CO_2 [%]	SO_2 [ppm]	Temperature [°C]
Air	0,12	14,4	497	1163
Oxy-fuel	0,12	81,8	1377	1172

Level 11	CO [%]	CO_2 [%]	SO_2 [ppm]	Temperature [°C]
Air	0,1	14,8	512	1072
Oxy-fuel	0,1	81,7	1273	1057

Level 15	CO [%]	CO_2 [%]	SO_2 [ppm]	Temperature [°C]
Air	0,07	14,9	545	938
Oxy-fuel	0,10	81,7	1320	973

BKE	CO [ppm]	CO_2 [%]	SO_2 [ppm]	Temperature [°C]
Air	243	15,8	580	756
Oxy-fuel	188	87	1380	739

Fig. 2.: The gas composition during the combustion tests with coal C at KSVA. Red marked are the measuring ports where the fly ashes were collected and the gas atmosphere was analysed.

Looking at Fig. 3 representing sulphur content in deposition and fly ashes of coal C in different combustion chamber and flue gas path zones it is seen that during the oxy-fuel combustion more sulphur is found to be bound by the fly ash particles than in the conventional air-combustion case respectively.

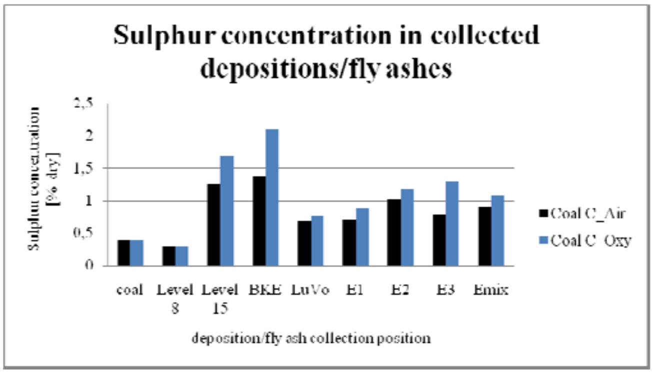


Fig. 3.: Sulphur content [% dry] of the depositions and fly ashes during air and oxy-fuel combustion of coal C. Level 8, 15 and BKE were collected with uncooled probes.

Moreover the depositions accumulate more sulphur than the fly ashes, which can be explained by the residence time of 2 - 4 h in the high temperature range (> 700°C). The same tendency is noticed for the combustion of coal A. Fly ashes resulting from the combustion of coal B are being still analyzed. For the tests with coal A and B additionally the fly ashes were sucked and primary deposition layers were collected and analysed. Concerning oxy-fuel combustion of coal A significantly more sulphur was noticed in the primary deposition layers than in their corresponding secondary layers. For the fly ash collected downstream from the incinerator during the oxy-combustion of coal A much more sulphur is noticed at the end of the electrostatic precipitator. The same tendency is observed for the fly ash from the air-combustion even though certainly less sulphur is present here compared to the corresponding fly ash from the oxy-fuel case. It is believed to have a reason in the temperatures and thus in the dew point of the sulphuric acid, condensing here on the fly ash particles. The concentrations of the SO_2 and SO_3 measured upstream from the electrostatic precipitator vary significantly between air and oxy-combustion. For the coal B SO_3 reached even 200 mg/m^3.

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