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Optimum Recycled Flue Gas Ratio in an Oxy-Coal Burner to Achieve Similar Combustion Characteristics to an Air-Fired Operation

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1. Introduction

Typically coal combustion with air results in only about 15% CO_2 in the flue gas. Due to relatively low concentration of CO_2 and also the presence of other gaseous species like sulfur oxides (that interfere with CO_2 separation), the capture of CO_2 from the flue gas is difficult. As an alternative way, nitrogen can be separated from the air stream prior to combustion. However, combustion with pure oxygen results in very high flame temperatures that the current materials of construction cannot withstand [1]. A novel method of using enriched oxygen for coal combustion with flue gas recycle to control the adiabatic flame temperature is being investigated so that the new technology can be applied as a retrofit to existing boilers. Oxy-firing of Pulverised Fuel (PF) in boilers involves the combustion of pulverised coal in a mixture of oxygen and recycled flue gas (RFG). In the ideal case this method results in more than 90% CO_2 in the flue gases to ease CO_2 capture and sequestration.

A new research project, funded by E.ON and the Engineering and Physical Sciences Research Council (EPSRC), is evaluating existing methods of coal-based power production and developing cleaner processes using Carbon Capture Sequestration (CCS). Oxy-coal combustion as one of several CO_2 capture technologies is proven, but basic research is needed to improve the cost and performance of this method. A 150kWth test combustor in Cranfield University is currently being converted to oxyfuel in order to determine process environments and impacts on ash behaviour as conditions change. This study presents the results of investigations into the gaseous emissions characteristics from combustion of El-cerrejon pulverised coal in air-firing and oxy-firing (with various flue gas ratios) conditions in order to compare the combustion characteristics and the ash deposits formed on the probe samples. Major species emissions from combustion (CO_2, O_2, H_2O) and also minor emission species (SO_2, CO, NO, NO_2, N_2O, HCl, HF), were obtained and analysed for each case. Ash deposit samples were collected from the flue gas using three ash deposit capture probes. The deposits formed were analysed using SEM/EDX and XRD techniques to assess their corrosion potential. Furthermore since emissions levels also depend on the combustion temperature the gas and rig temperatures were measured throughout the hot gas path and deposition probs. The obtained results on the major species emissions, temperature field and ash deposit analyses of the coal oxy-firing (at different RFG ratios) have been compared with the corresponding air-firing results.

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2. Experimental Setup

A 150kWh air-firing test combustor is currently being converted to oxy-firing at the Centre for Energy and Resource Technology (CERT) in Cranfield University. The experiments were carried out in this modified oxyfuel combustion rig facility. The chamber, which has an internal 30*30 cm-square cross section and internal height of 370 cm, is shown schematically in Figure 1. The rig consisted of a main combustion chamber with fuels fed from the top. Air was pre-heated by a gas burner and then passed into the main combustion chamber burner. The flue gases leaving the combustor pass through water cooled heat exchanger assembly before entering a cyclone and then going through the extraction fans, one for reticulating different ratios of the flue gases towards the chamber and another one for exiting the rest of gases through the stack. Oxygen is introduced into the RFG duct with the flow rate of between 120-200 l/min (about 20% of RFG flow rate). Combustion gas emission and rig temperature were measured throughout the hot gas path by on-line high resolution multi-component Fourier Transform Infra-Red (FTIR) gas analyser and thermocouples respectively [2].

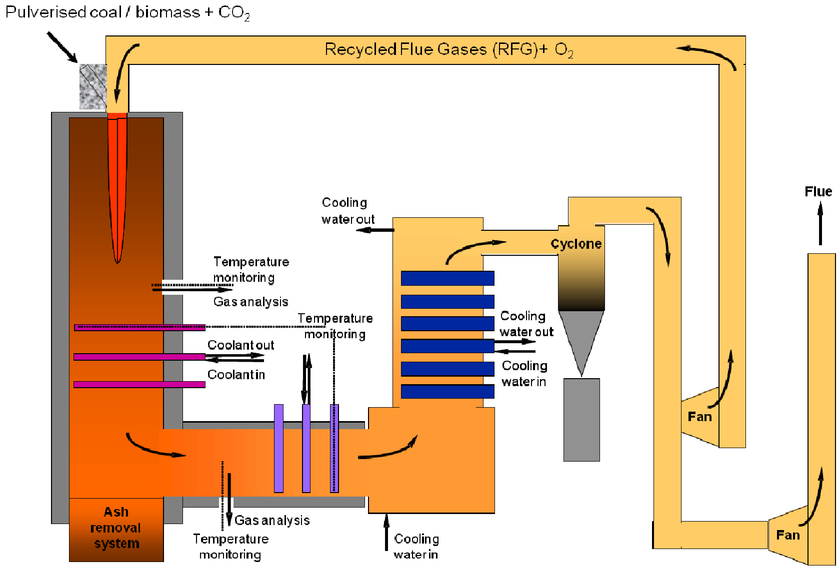

Fig. 1: Schematic diagram of the Oxyfuel combustion facility

Pulverised coal with ~ 12- 15 kg/hr feed rate is burned separately in air and in a mixture of CO_2-rich recycled flue gas and oxygen. The compositions of the El-cerrejon coal used in this study are provided by E. ON Engineering plc in terms of the major elements (C, H, O, N, S, Cl). Ash deposit samples were collected from the flue gas using three air-cooled probes that simulate heat exchanger tubes. The deposits formed were analysed using SEM/EDX and XRD techniques to assess their corrosion potential. The deposit consists of an air cooled unit with removable centre section in order to change the deposit area as required. The deposit capture section is an alumina material – trade name 'Alsint 99.7'. Two 'K type' thermocouples are secured with 'Nichrome 5' wire onto the cylindrical metal surfaces, either side of the deposit area. A fully assembled deposit capture probe including the Ceramic capture tube and the 'K' type thermocouples connection plugs is shown in Figure 2.

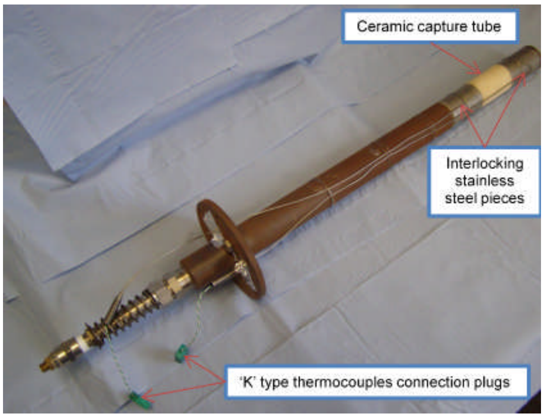

Fig. 2: A fully assembled deposit capture probe

3. Results and Discussion

Constant fuel feed rates of about 12 kg/hr were applied for El-cerrejon coal through the PF delivery system which contains of a vibrating bed with a cylindrical container and a venturi which vacuums the fuel from the CO_2 flow running through it. This allows the fuel to be drawn into the pipe leading from the assembly and then blown into the combustion environment. The targeted operating parameters were similar flue gas temperatures around the probe coupled with 4~5% O_2 in the combusted flue gases as in air firing experiments. The recycled flue gases (RFG) ratios for oxy-firing are selected to be 1/3, 1/2, and 2/3 of total flue gas rate, in order to find the RFG ratio which provides the more similar combustion and deposition characteristics of the PF air-firing results. The elemental compositions of the deposits formed on the tops and sides of all three probes for oxy-firing of El-cerrejon coal with 2/3 RFG ratio, analysed by EDX are shown in Figure 3. This figure reveals varying concentrations of silicon, calcium, sulphur, potassium, iron and aluminium in the deposits of all probes. Silicon and aluminium combined are coal derived with high melting point compounds that can tie up alkalis. High concentrations of potassium and sulphur suggest formation of potassium sulphates in the deposits.

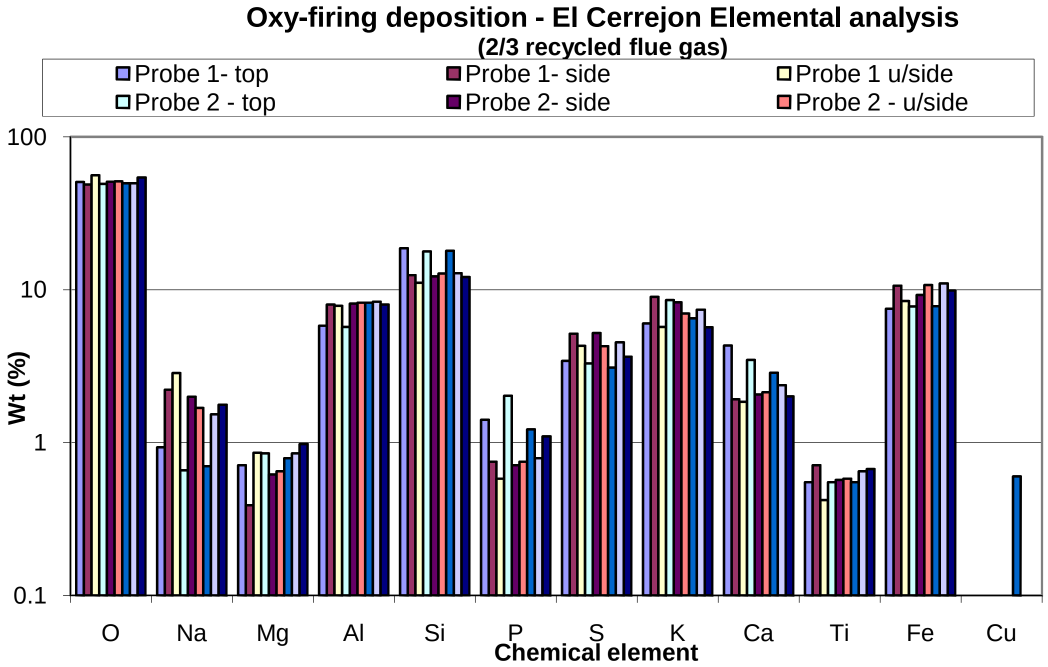

Fig. 3: Elemental concentrations of the three probe deposits from oxy-firing of El-cerrejon coal with 2/3 RFG ratio.

The obtained data from the combustion of El-cerrejon pulverised coal with air in terms of the major emission species concentration, the gas temperature around the deposit probes and ash deposit analyses are processed. The experimental data of El-cerrejon coal combustion with oxygen at ~2/3 RFG rate is obtained, which is under process. We are aiming to add two more experimental results for El-cerrejon oxy-firing with ~1/3 and 1/2 RFG ratios. This research will provide us with an inclusive data base for the optimum recycled flue gas ratio within the Cranfield's oxy-coal combustor. The optimum condition in an oxy-firing burner is defined the condition to achieve the similar combustion and ash deposition characteristics as in air-fired operation of the burner.

In the oxy-firing experiments the maximum recorded temperature in the exhaust flue gases were measured to be between 800 to 900 ºC; this is generally 100 to 200 ºC less than the air-firing results. To achieve the similar combustion characteristics to an air-firing operation a secondary line of oxygen insertion is going to be introduced to the main burner rig chamber. Also a purging box with CO_2 is designed for installation on the recirculation fan system, in order to resolve the air ingress into the oxy-fuel chamber. The full set of the comparison results will be presented in the full manuscript after performing completing the data processing and analyses.

4. Sample References

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