Minimization of air ingress during the retrofitting of bubbling fluidized combustion to oxyfuel combustion

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1. Introduction

Oxyfuel combustion is a developing technology capable of generating near zero CO\textsubscript{2} emissions when using fossil fuels or negative emissions when using biomass. If we compare to air combustion, some important process parameters changes must be considered when retrofitting. Fundamental questions which involve gases recycling, ignition, flame stability, heat transfer, combustion characteristics, emissions kinetics, among others, have been studied and investigated [1]. Among these questions, the air ingress when retrofitting and the gas recycling are some parameters that are directly connected for a proper establishment of the oxyfuel combustion atmosphere and a high CO\textsubscript{2} concentration achievement in the flue gases. In this context, several authors have already presented problems from false air entrance and recirculation gases for the establishment of a proper oxyfuel combustion atmosphere [2, 3, 4].

In the oxyfuel combustion, the air ingress typically occurs between the furnace exit, the recirculation pipes and the recirculation fan. Conventional plants and new ones suffer air ingress between 2 and 4\% and values between 8 and 16\% have already been observed in older plants [2]. If we consider that the fan design is connected to the air ingress minimization and the recirculation system necessities, by using a bubbling fluidized furnace, it gets a higher importance due to the needs of fluidization condition maintenance. From this, we should also consider that the gas volume that enters into the furnace is lower in the oxyfuel technology.

By taking into consideration some important questions about the parameters that strongly influence the air combustion retrofitting to oxyfuel combustion, this work studies the influence of the fan system design and gases...
recycling in the oxyfuel combustion. In this sense, an analysis of the air combustion retrofitting to oxyfuel combustion on a 0.25 MWth bubbling fluidized pilot plant is done. The fan system design and the gases recirculation were optimized in order to provide proper oxyfuel combustion conditions from air ingress minimization.

2. Methodology

The retrofitting for the generation of necessary conditions for the oxyfuel combustion was done from the establishment of coal air combustion on stable conditions concerning heat generation on a bubbling fluidized furnace. As the gases recycling provided negative pressure points in the recirculation pipeline, air leakage increased through the system.

Thus, the main parameters – fan design and gases recycling – that influence the air entrance in the system were analyzed and optimized. From air combustion stabilization, the transition step parameters that influence on air leakage were analyzed. Fig. 1 shows the steps for the air combustion retrofit to oxyfuel combustion. On a first step, the optimization of the fan design for a head value increase and pressure analysis was done. Secondly, the gases recycling valve was adjusted in order to provide an atmosphere prone to oxyfuel combustion. Such atmosphere must show a decrease on oxygen (from atmosphere) concentration in the gases, what evidences the establishment of higher pressure points through the recycling equipment and pipelines.

![Fig. 1: Retrofitting steps for oxyfuel combustion atmosphere establishment.](image)

3. Results

3.1 Retrofitting for oxyfuel combustion from air combustion

For a first adaptation for oxyfuel combustion, the plant was designed with a fan system composed of a forced and an induced draught fan. From air combustion stabilization, the recirculation steps were applied and atmospheric air entrance was withdrawn with the attempt of decreasing the oxygen concentration in the recirculation gases – from atmospheric air – for pure oxygen introduction into the system.

However, the observed behavior of the process was the increase of O₂ concentration from air ingress and a decrease on CO₂ concentration prior to the oxygen introduction. System pressure analysis showed negative pressure points where considerable air ingress was occurring, when the recirculation system was applied.

The energy increase for the recirculation gases imposed by the forced fan was not sufficient to provide the necessary head increase for the gases to flow to the furnace and throw the recirculation pipes, thus maintaining such negative pressure points. So, a new fan design, composed only of one forced fan with a higher power was applied in the system and some fluid dynamics characteristics were analyzed.

3.2 Process parameters analysis

By introducing a frequency converter in the forced fan, the fan power influence in the head loss and consequent air ingress was determined. An equilibrium between the fan suction zone and its power to provide the air ingress minimization showed the need for being provided achieved. Due to decrease on gases volume when oxyfuel conditions are applied, the mass gases flow appeared as an important parameter for the maintenance of fluidized bed
conditions. For three frequency converter values (70%, 80% and 90%), the 70% and 80% did not present considerable different values on the head measurement in different points of the system. The 90% frequency converter value presented higher values of the gases head in specific points of the system which are prone to higher air ingress. Such head values were connected primarily with static pressure values. As a consequence, points with higher head values presented lower air ingress.

The recirculation valve influence on pressure points of the system was also analyzed. For each frequency converter value (70%, 80% and 90%), the recirculation valve opening of 100%, 50%, 25% and 10% was observed by its influence on static pressure points. Lower values of recirculation valve opening provided lower air ingress on the pressure measured points.

It should be pointed that these parameters have a strong influence on the gases flow recirculation in order to maintain the fluidized bed condition and higher static pressure points in the system. Lower values of recirculation value opening must be followed by higher values of fan power (frequency converter on 80% and 90%) in order to provide energy to the gases to be able to show higher head values in the air ingress points.

3.3 Oxyfuel combustion

The adjustment of the analyzed parameters could develop a better understanding of the retrofitting process and an optimized action order in the steps for the transition from air combustion to oxyfuel combustion. Such steps were adjusted as follows:

1. Partial close of the chimney;
2. Progressive close of the recirculation valve;
3. Progressive close of the air ingress entrance together with progressive introduction of oxygen for the maintenance of fluidization conditions.

From a process optimization, the air ingress could be decreased to 14.9% when using 80% fan frequency converter value with 89.4 wt.% of gases recirculation and 11.9% when using a 90% fan frequency converter value with 90.4 wt.% of gases recirculation.

As a consequence, a CO₂ concentration of 52.7% with a 80% fan frequency converter was achieved and a CO₂ concentration of 69.8% with a 80% fan frequency converter could achieved in the flue gases together with a 1.7% O₂ concentration.

4. Conclusions

The optimum fan system design of a recirculation plant for oxyfuel combustion is crucial for the achievement of better conditions connected to static pressure and head values for a lower air ingress. Some parameters showed to be essential for the retrofitting: recirculation valve opening, fan power and gases flow.

From the fan power analysis, the 90% frequency converter value presented the better influence on air ingress minimization together with 10% opening of the recirculation valve.

References