1. Introduction

To reduce CO₂ emissions in power generation, Oxy-fuel combustion has become a promising technology due to its ability to produce concentrated CO₂ in flue gas allowing its easier capture for subsequent transportation and storage [1-3]. The Oxy-fuel technology when combined with the well established fluidized bed combustion offers additional advantages like fuel flexibility, uniform temperature distribution, low NOₓ emissions and in-bed SO₂ capture using sorbent addition [4, 5]. A combination of these two technologies – Oxy-fuel based fluidized bed (Oxy-FB) combustion - is an emerging technology for power generation using different grades of coals.

However, combustion performances (such as combustion efficiency, agglomeration and emissions characteristics during combustion) of coals are influenced by several factors, for example temperature, oxygen concentrations in combustion atmosphere and coal properties. In addition, steam, introduced into the reactor through flue gas recirculation, is another important factor in Oxy-fuel combustion, and so it could affect the flue gas composition with potential effects on CO₂ capture. Therefore, it is necessary to know the effects of these parameters during Oxy-fuel based fluidized bed combustion for a variety of coals.

Though a number of experimental studies have been performed mainly with bituminous coal to investigate the influences of different operating conditions during Oxy-fuel combustion, few studies have addressed the Oxy-fuel fluidized bed combustion with brown coal [6]. Victoria, Australia has an attractive resource of brown coal with an estimated reserve of 430 billion tonnes, which is expected to last for over 500 years at current consumption rate [7]. This study investigates the issues related to the application of Oxy-FB using this coal. This paper presents the experimental results obtained from a bench-scale fluidized bed reactor under Oxy-fuel combustion condition to investigate the behavior of Victorian brown coal at different operating conditions. The effects of oxygen, carbon dioxide and steam in feed gas, and combustion temperature on combustion efficiency, flue gas composition and agglomeration characteristics are considered in this study. The experimental results from Oxy-fuel combustion were also compared to that from air combustion.
2. Experimental Section

Experiments were performed in a \( \sim 10 \text{ kWe} \) fluidized bed combustor. The combustor consisted of a stainless steel reactor of 0.1 m in diameter and 1.5 m in length, and a freeboard of 0.15 m in diameter and 2 m in length. Figure 1 shows the schematic diagram of the installation. To simulate the typical gas composition entering into the reactor under Oxy-fuel combustion conditions, all gases - \( \text{O}_2 \), \( \text{CO}_2 \) and steam, were mixed before entering into the reactor. \( \text{O}_2 \) and \( \text{CO}_2 \) were supplied from bottle cylinders, whereas steam was supplied using a steam generator. Prior to entering the reactor, all reacting gases were pre-heated in a gas heater.

![Figure 1 - Schematic diagram of the experimental setup of Oxy-fuel fluidized bed combustion.](image)

Initially hot air was introduced through the gas pre-heating system to heat the bed. When the bed temperature reached around 200 °C, the air was replaced by desired \( \text{O}_2 + \text{CO}_2 \) mixture, and coal feeding was commenced. For ignition, additional air was introduced. This air flow was reduced gradually as bed temperature increased. When the bed temperature reached the desired steady-state value, the additional air flow was completely turned off, and steam was introduced (in cases of wet Oxy-fuel experiments). After that the combustor stayed in desired Oxy-fuel mode at constant total gas flow and the required bed temperature was maintained only by adjusting the coal feed rate. During experiment, the steady state temperature was in the range of 800 °C – 900 °C, and the gas velocity was in the range of 0.75 – 0.85 m/s. The total start-up period was around 3 hrs. Experiments were run for steady-state period of up to 6 hrs.

Three air-dried Victorian brown coals (Loy Yang, Morwell and Yallourn) were used in these experiments. The particle size of coal samples were in the range of 1 - 3 mm. As a bed material, silica sand of 351 – 401 µm was also added into the reactor. In addition, char was used for the ignition start-up during combustion. Typically all char was used up during heat-up. During experiment the generated gases were continuously analyzed by an on-line gas
analyzer (with inbuilt vacuum pump). General process data, such as total gas flow, gas composition, temperature and pressure, were continuously recorded on a computer during experiment.

3. Summary of Results

The key findings from experiments are given below:
- Combustion efficiency using Victorian brown coal under Oxy-FB condition is up to 99%.
- Oxy-fuel combustion atmosphere results in higher CO₂ concentrations in flue gas. Moreover, with the addition of steam (even with lower oxygen concentration in oxidant) in the combustion environment also results in higher CO₂ concentration (above 90%) in the flue gas.
- The particle size distribution of collected samples from bed material, primary cyclone and secondary cyclone under Oxy-fuel combustion condition is almost similar to that under air combustion.
- A very little quantity (max. 2% of total bed material) of bed coatings/ash minerals is observed in the bed. The particle size of these is in between 0.5 mm and 3 mm. The mere presence of these does not induce bed agglomeration.

4. Conclusions

In this study, experiments in a bench-scale fluidized bed reactor under Oxy-fuel combustion condition are described which were performed to investigate the behavior of Victorian brown coal at different operating conditions. From these experiments, this study finds no bed agglomeration under Oxy-fuel combustion condition (even with the addition of steam) at low temperatures (800 - 900°C). Hence, agglomeration is unlikely to be a major problem for Victorian brown coal in Oxy-fuel combustion, if the operating temperature is kept below 900°C.

5. Acknowledgement

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6. References