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Effect on O_2 enrichment and CO_2 dilution on rapeseed oil combustion in a stationary burner

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ABSTRACT

Application of oxygen-enhanced and CO_2 diluted combustion to existing fossil fuel/biofuel energy systems to facilitate CO_2 capture presents several challenges. This paper investigates the combustion characteristics of rapeseed oil and its blends with diesel oil in swirling spray flames. It focuses on the stability of flames, NOx, CO and particle emissions. We observed that the oxygen enrichment produced an increase of NOx emission due to the higher furnace temperature, while CO emissions slightly increased. Moreover, it did not modify the modes of the particle size distribution functions, but it tended to reduce the total amount of particle emissions by one order of magnitude. On another hand, CO_2 dilution decreased the NOx emission (up to 20 times) due to the lower furnace temperature at fixed oxygen concentration. Although the dilution of combustion does not produce significant effect on the shape of the size distribution functions, this modifies significantly the absolute concentrations of the emitted particles. Finally, the produced oxygen-enhanced/diluted flames were stable and more luminous than the air/fuel flames. The increase of O_2 concentration caused that the flames were longer by about 20% compared with base line flame.

1. Introduction

There is a growing concern that the use of fossil fuels and the associated carbon dioxide emissions are contributing to global warming. The Energy Information Administration estimates that world carbon dioxide emissions from energy production will increase by 51% by 2030, from 28.1 billion metric tons in 2005 to 42.3 billion metric tons in 2030 [1]. As energy use grows, concerns over global warming may lead to imposing limits on greenhouse gas emissions from fossil fuel plants. This has stimulated extensive research on the subject of carbon capture and sequestration. The International Energy Agency estimates that carbon capture and sequestration could play an important role in decreasing carbon dioxide emissions [2]. To achieve a deep reduction in carbon dioxide emissions through carbon capture and sequestration within power generation systems, several technologies are being investigated, one of which is oxy-fuel combustion. In oxy-fuel combustion, fuels are burned in a nitrogen-lean and carbon dioxide-rich environment, which is achieved by feeding the combustor with an oxygen-rich stream and recycled flue gases. The recycled gases are used to control the flame temperature and replace the nitrogen separated prior to combustion [3]. Oxy-fuel combustion yields flue gases consisting of predominantly carbon dioxide and condensable water, whereas conventional air-fired combustion flue gases are nitrogen-rich with only about 15% (by volume) of carbon dioxide [4,5]. The high carbon dioxide concentration and the significantly lower nitrogen concentration in the oxy-fuel raw flue gases is a unique feature that lowers the energy and capital costs of oxy-fuel carbon dioxide capture when compared to alternatives [6]. The interest to oxy-fuel combustion in the last decade is mainly oriented to low rank fuels for energy production. A more recent interest is devoted to oxygen enriched and CO_2 dilution combustion of methane [7], but a few studies for first generation liquid biofuels are present in the literature. Some papers dealing with second generation are available [8]. The use of the first generation biofuels was widely studied as fuels for energy production [9,10] and they could be useful to further lower CO_2 emission, while enhancing sequestration. The present study presents experimental results on oxygen-enriched flames and CO_2 dilution combustion of pure rapeseed oil and its blends with diesel oil. A particular interest is focused on the size distribution functions of the emitted solid particles.

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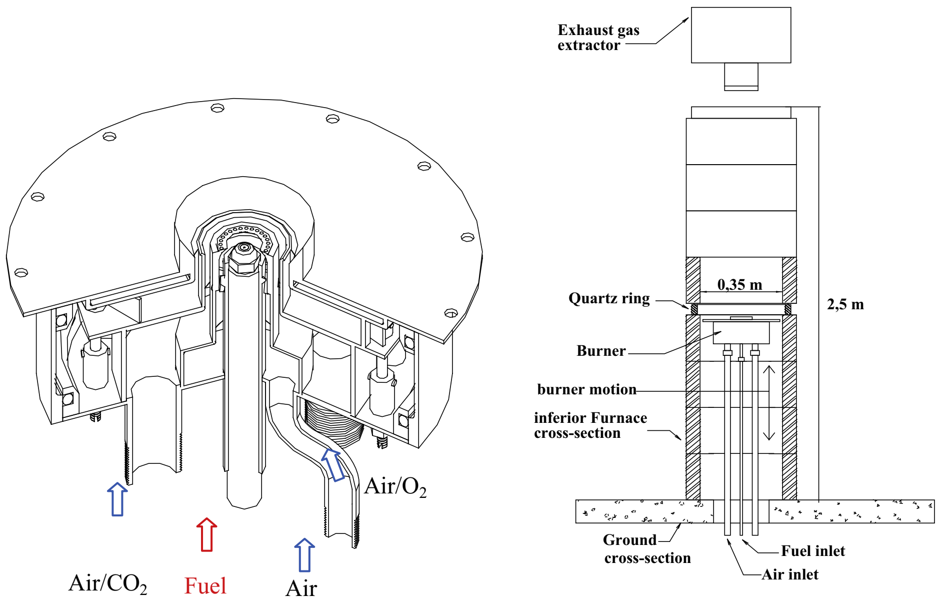

Fig. 1. Sketch of the combustion apparatus (left: burner, right: furnace).

Table 1
Fuel properties.

		Rapeseed oil	Diesel oil
Density, 15 °C	kg/m^3	920	870
Viscosity @50 °C	mm^2/s	28	6 (@20 °C)
Flash point	°C	>290	58
Gross calorific value	MJ/kg	40.5	39.5
C	%	76.9	83
H	%	11.8	13
O	%	11.3	–
S	%	–	0.2

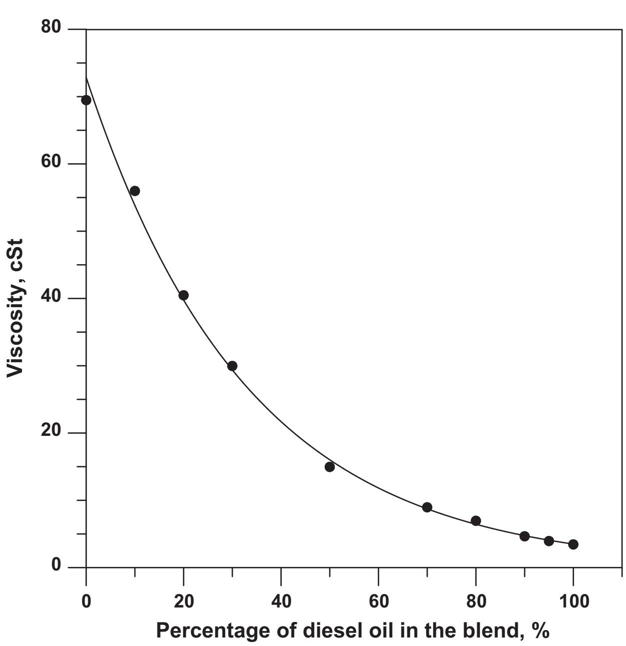

Fig. 2. Viscosity of rapeseed oil/diesel oil blends@20 °C.

Table 2
Test measurement species and ranges.

	Species	Meas. range	Accuracy
Testo 350 S	O_2	0–25 vol.%	±0.8% fs
	CO	0–500 ppm	±2 ppm
	NOx	0–300 ppm	±2 ppm
	CO_2	0–50 vol.%	±0.3 vol.% + 1% mv

Table 3
Emissions at the exhaust under baseline condition, @3%O_2.

	[CO] ppm	[NOx] ppm
Diesel oil	3	40
Rapeseed oil	0	38
Blend B20	1	42
Blend B50	3	45

2. Experimental set-up

2.1. Combustion apparatus

Measurements were carried out on spray flames obtained by atomising the fuels in a 100 kW three-flux low-NOx burner inserted in a cylindrical vertical furnace of ceramic fibre (0.36 m ID and 2.5 m height) equipped with optical accesses (Fig. 1). The air temperature was 20 °C. The differential pressure in combustion chamber was ΔP = +5 mm H_2O to avoid oxygen entrance in the furnace. The oxygen enrichment was performed in the secondary air duct, while the carbon dioxide dilution was obtained in the tertiary duct (Fig. 1) to simulate exhaust gas recirculation. Both oxygen and carbon dioxide were fuelled at 20 °C. The fuels used in this work were rapeseed oil and diesel oil, whose main physical and chemical characteristics are reported in Table 1. The commercial name of the rapeseed oil is "DNS" (Degummed Neutral Dried). The diesel oil is commercial heating fuel.