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Flameless Oxidation of liquid fuel oil in a reverse-flow cooled combustion chamber

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Abstract

This paper presents the experimental results on flameless oxidation of light fuel oil in a reverse-flow cooled combustion chamber. NO_X and CO emissions as well as temperatures in the combustion chamber are used to determine combustion performance of the cold air flameless oxidation (FLOX®) burner. Five different twin fluid atomizers with varying spray angles between 0° and 80° and different bore diameters have been used and the influence of atomizing air pressure between 4 and 6 bar on the combustion performance was investigated. In the tests air stoichiometry ratios ranged from 1.1 to 1.9 and thermal inputs were varied between 50 and 150 kW.

Results show that good combustion performance in flameless mode was achieved. Low NO_X emissions combined with low CO emissions which meet strictest CO (according to DIN EN 267 class 3 burners, 60 mg/kWh_{th}) and NO_X regulations (according to 1. BImSchV, 110 mg/kWh_{th}) were obtained at an air ratio of 1.1.

Keywords: NO_X Reduction; FLOX® Combustion; Liquid Fuels

1. Introduction

Over 90% of the world's energy demand is covered using combustion of solid, liquid and gaseous fuels [1]. The environmental pollutant NO_X (generic term for the mono-nitrogen oxides NO and NO_2) is formed during the combustion process from nitrogen in the combustion air and from nitrogen contained in the fuel. Nitrogen oxides form along three paths which are thermal NO_X, fuel-NO_X and prompt NO_X formation [1-5].

In the recent years, efforts have been made to reduce the emissions of NO_X which resulted in the development of various low-NO_X combustion techniques: FLOX®, MILD, HiTAC, CDC, HiCOT to name few of them [1, 5-8]. The

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generic term for these techniques is flameless combustion which originates from the fact that combustion takes place without any visible flame [6]. Though the mentioned combustion techniques are not identical, they are similar and have a basic principle in common: Fuel and combustion air are intensely mixed with recirculated flue-gas to form a hot diluted mixture avoiding temperature peaks and providing fuel lean combustion conditions. This hot mixture reacts slower and in an extended reaction zone compared to conventional combustion processes which is accompanied by a reduction of peak combustion temperatures as a result of the dilution which in turn reduces NO_X formation [6, 9-10]

Research on liquid fuels for flameless oxidation is scarce, but has gotten more popular lately. Liquid fuels need to be evaporated before they can be combusted so it is understandable that so far most studies focused on the combustion of liquid fuels with preheated air [8, 11-17]. In this work, it is investigated whether and how flameless combustion of light fuel oil can be adopted in a reverse-flow cooled combustion chamber fired by a FLOX® burner supplied with cold air. The aim of this study is to identify suitable nozzles for fuel atomization and favorable process conditions for low emission operation meeting strictest German and European limit concentrations for CO [18] and NO_X [19]. These limits are 60 mg/kWh$_{th}$ @ 0 vol% dry O_2 for CO and 110 mg/kWh$_{th}$ @ 0 vol% dry O_2 for NO_X.

2. Experimental setup

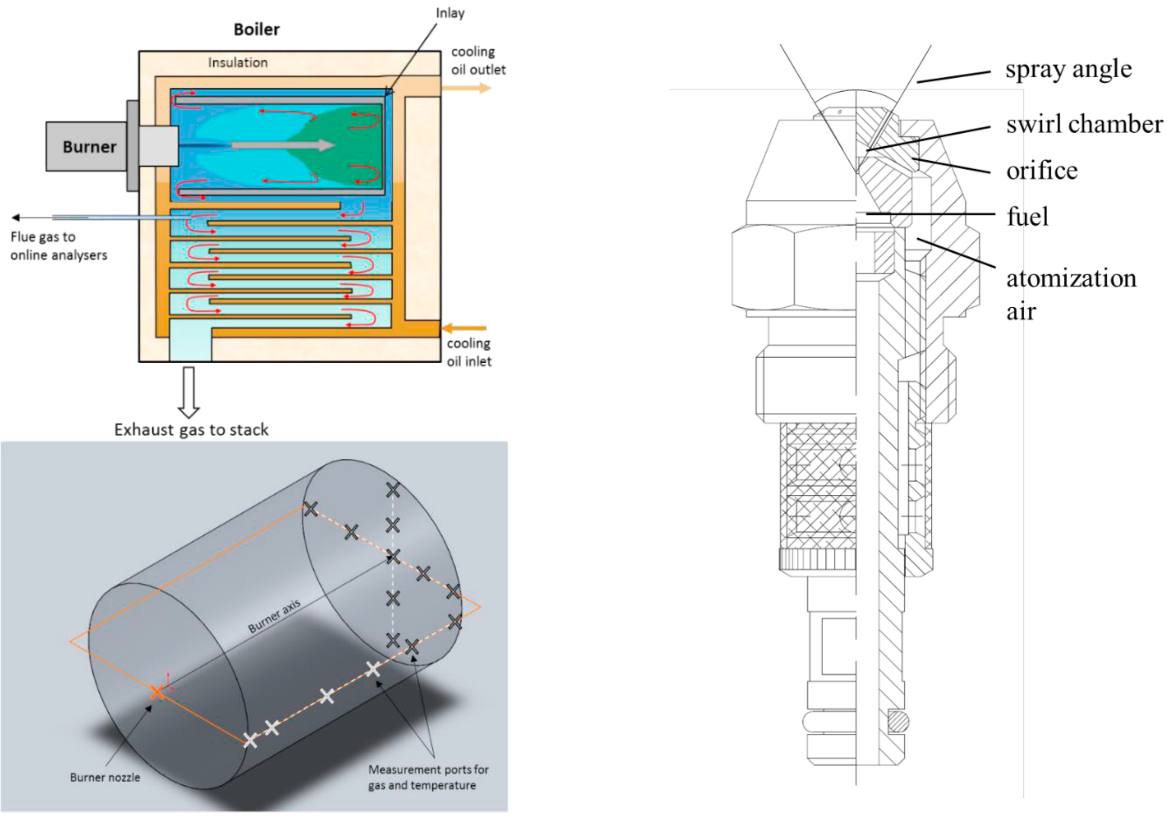

Figure 1: Schematic (top left) of the 150 kW$_{th}$ FLOX® combustion chamber at the Institute of Combustion and Power Plant Technology at the University of Stuttgart. The location of the measurement ports in the cylindrical combustion chamber is shown on the bottom left. On the right the type of twin fluid atomizer used in this study is depicted.

Figure 1 shows a scheme of the experimental set up of the reverse-flow combustion chamber and the ports that allow accessing the furnace for gas and temperature measurements. The cylindrical combustion chamber is 400mm in diameter and 1000 mm long and the burner nozzle is located 30 mm inside the furnace. The inlay placed in the