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Effect of increasing load on the MILD combustion of COG and its blend in a 30 kW furnace using low air preheating temperature

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Abstract

MILD combustion is a high efficiency technique, applied on industrial furnaces to have low polluting emissions and significant energy saving by high air preheating. The main purpose of this work was the investigation of the behavior of two fuels rich in H2 burning in MILD regime at different furnace temperature levels (1200 K ÷ 1300 K), using air preheating temperature which can be guaranteed by low performance heat exchanger too. Both fuels had very good performance but the one with higher H2 content, which reduces the ignition delays, showed higher capability to keep a well-positioned reaction zone at higher heat transfer to the load and consequently wider flue gases temperature range.

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Keywords: MILD combustion; air preheating; furnace temperature; H2-rich fuels; alternative fuels; low LHV fuels; low effectiveness; low polluting emissions

1. Introduction

MILD combustion is an efficient combustion technology, which has been successfully applied to industrial furnaces to have significant energy saving by high air preheating and very low polluting emissions. The main feature of this technique is the use of a proper configuration of the injection system able to guarantee a strong recirculation inside the chamber. The hot flue gases are entrained by the fuel and air jets and they dilute the reactants with consequent temperature increase above the auto-ignition threshold. Therefore, combustion takes place in a wide volume and in diluted way. Thermal gradients and peaks of temperature are reduced, thereby the formation of

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hot-spots, NOx and carbon monoxide emissions are prevented [1]. Moreover, the narrow temperature range allows design, optimization, and adjustment in the process by fine tuning the external parameters [2]. Nowadays, there is an increasing request from industry for new combustion techniques which can be safely used to burn gasified waste or by-product gases as alternative fuels in manufacturing processes. These non-conventional fuels are blends of CH4, CO, H2, N2, and CO2 in variable proportions. The generation of a stable flame can be difficult because of their highly variable calorific value (*LHV*). MILD combustion can be an interesting solution, since there is no need to stabilize a flame front. Achieving maximal heat recuperation efficiency is one of the main reasons of interest in MILD combustion. These results however are only possible in combination with regenerative exchanger or auto-regenerative burners. More frequently, industrial communities are interested in using MILD combustion with limited air temperature, especially if the use of regenerative systems is not possible as retrofit process of existing plants [3].

Nomenclature

ρ	Density (kg/Nm^3)	E	Excess Air
$\dot{q}$	Volumetric flow rate (Nm^3/h)	v	Speed (m/s)
$\dot{m}$	Mass flow rate (kg/s)	$\dot{G}$	Momentum rate (N)
P	Power (W)	T	Temperature (K)
η	Thermal efficiency	S_h	Sensible heat (W)
Imm	Immersion of the water-cooled tubes	ε	Effectiveness
NTU	Number of transfer unit	C	Capacity (W/K)
LHV	Low heating value (kJ/Nm^3 @ 298.15K)	Δ	Difference
K_v	Recirculation ratio	δ	Relative difference

2. Specific Objectives

The UMONS combustion research has been focused on the creation of an experimental database for a furnace working in MILD combustion using different fuels with very variable calorific value, produced by gasification of biomass or wood, or obtained as waste or by-products of industrial processes [4][5][6][7][8]. This work investigates the effect of the decreasing furnace temperature on the combustion characteristics in the MILD regime, using low air preheating temperature easily guaranteed by classical heat exchanger and two different alternative fuels: coke oven gas (COG), and a blend (B50) consisting of 50% coke oven gas and 50% blast furnace gas (BFG) by volume. Table 1 shows their composition and properties with respect to classical natural gas (NG).

Table 1: Composition of the used fuels by volume and their properties compared to natural gas.

	N2	CO2	CH4	H2	CO	Other CxHy	*LHV*	ρ
NG	2.5%	1.21%	89.46%	-	-	6.83%	37105	0.805
COG	2%	1.5%	28.5%	62%	6%	-	17652	0.389
B50	28%	12%	14.25%	32.5%	13.25%	-	10282	0.882

The chamber was designed to work with NG and was deeply tested with this fuel [4][5]. The design of the injection system ensures at the meeting point of the air and fuel jets the minimum recirculation rate K_v, defined as the ratio between the flue gases mass flow rate entrained into the jets and total mass flow rate in inlet:

$$K_v = \frac{\dot{m}_{flue\_entrained}}{\dot{m}_{fuel} + \dot{m}_{air}} \quad (1)$$

If the temperature level and the K_v are sufficiently high to determine the autoignition of the mixture, the conditions of stable MILD combustion are reached. However, it was already observed in other works [8][9] that for classical