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Original scientific paper

EFFECT OF AIR OXYGEN ENRICHMENT ON GASEOUS FUELS COMBUSTION AND GHG EMISSION

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Abstract

The subject of this article is an analysis of the influence of air oxygen enrichment on the gaseous fuel combustion and the GHG emision. Combustion conditions for three different chemical compositions and heating values of gaseous fuels are defined by changes in values of %O_2 (21-30). GHG emission is defined as the sum of CO_2 and NO_x. For all analyzed gaseous fuels, the correlation of %O_2, flame temperature, volume of combustion products and GHG emissions was calculated. The results were obtained using analytical method.The flame temperature increase with increasing values of %O_2 and as a results of this, emission of NO_x increases. This can be explained by statement that at higher combustion temperature, volume of thermal NO_x increase.

Keywords*: air enrichment, flame temperature, NOx*

1. INTRODUCTION

Improvements in the overall energy efficiency of an industrial plant are primarily achieved by reducing the energy input values and also the energy losses on the output side of a process step [1]. The amount of waste flue gases can be minimized and the heating rate of the unit can be increased by the oxygen enrichment of combustion air. With the same fuel input, enriched air for combustion raises the flame temperature of a given fuel, thereby improving the heat-transfer rate and increasing the production. Oxygen influences the burning process primarily by reducing nitrogen concentration in the gaseous combustion products, which results in fewer combustion products, higher flame temperature, etc.[2]. Oxygen-enriched combustion technology is accomplished by raising the oxygen content in the intake air, enabling combustion to be mainly governed by the mass ratio of oxygen to fuel instead of the conventional air–fuel ratio [3]. Yilmaz et al. have been analysed the effect of oxygen enrichment on the flame stability and emissions during biogas combustion [4]. A novel combustion technology which combines colorless distributed combustion (CDC) and oxygen enriched combustion (OEC) air is examined to achieve optimum benefits of both technologies and to foster novel technologies for cleaner environment [5]. One of the key objectives of thermal engineering calculations for fossil fuel combustion is to define the conditions and determine the quantities that influence heat exchange intensification, reduce specific fuel consumption, and minimize the harmful impact of exhaust gases on the environment.

2. EXPERIMENTAL

The central hypothesis of this paper is that an analytical correlation exists between the chemical composition of the fuel mixture, the air enrichment , and the emission of primary combustion byproducts (CO_2, NO_x), which have a dominant impact on air pollution.

For these calculation the varying composition of gaseous fuels (G1,G2,G3) are used as shown in the Table 1.

Table 1. The chemical composition of gaseous fuels (%)

Fuel	CH_4	H_2	CO	C_2H_4	C_2H_6	CO_2	O_2	H_2O	N_2
G1	84	-	-	0,5	0,7	-	-	8,2	8,6
G2	10,2	27,4	15,4	1,5	-	4	2,4	1,6	33,5
G3	24,4	4,2	3,8	12,5	4,1	1,2	1,1	0,8	47,9

The values of the oxygen content in combustion air for each analyzed fuel were selected from a range 21÷30%, (Table 2). The heating values (Qd) are calculated on the base of fuel chemical composition.

Table 2. The content of the oxygen in combustion air and Qd for analyzed fuels

	G1	G2	G3
% O_2	21÷30	21÷30	21÷30
Qd (MJ/m^3)	30,99	9,47	19,85

3. RESULTS AND DISCUSSION

As a consequence of the intensification of the combustion process, there is a change in the flame temperature and the volume of the combustion products formed. As typical, representative examples of the interdependence of the mentioned parameters, graphs related to the average value of the coefficient λ=1,12, from the analyzed range for all types of fuel, are presented (Figures 1 and 2).

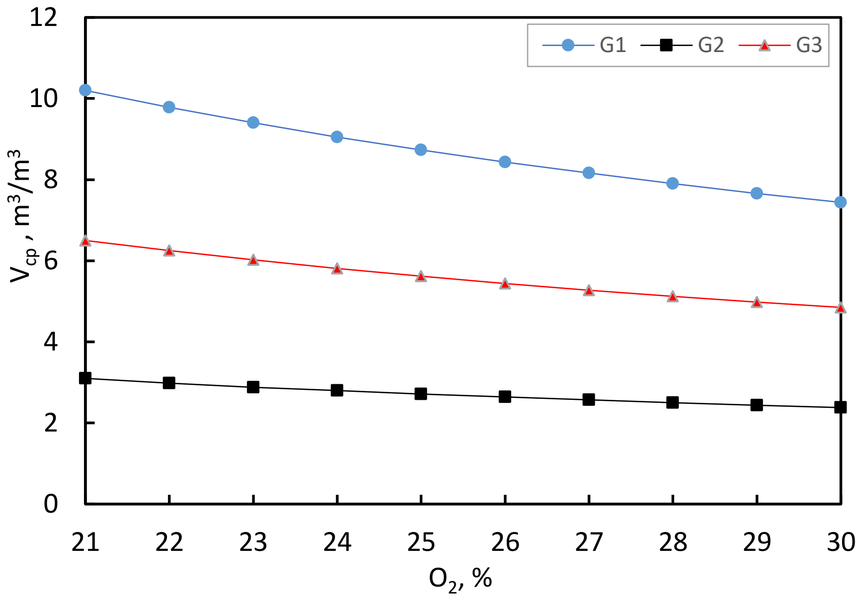

Figure 1. The influence of oxygen enrichment on the combustion products volume

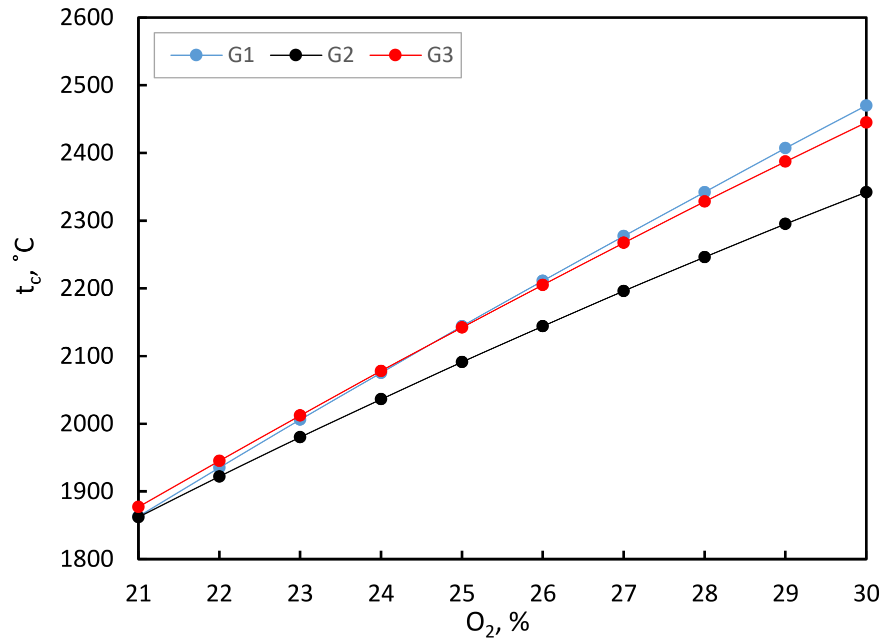

Figure 2. The influence of oxygen enrichment on the combustion temperature

Graphical presentations of the derived calculations show that, for all types of fuel, with the enrichment of air for combustion, i.e., with the increase in the percentage of oxygen in it, the volume of combustion products decreases, and the flame temperature increases.

In addition, the lines of change in combustion temperatures tG1 and tG3 intersect at 25% O_2, indicating a different intensity of their increase. This occurs as a result of significant differences in the chemical composition and lower heating value of the analyzed gaseous fuels.

The results of the calculations clearly show that CO_2 emissions depend solely on the initial carbon content and stoichiometric correlations, and not on the degree of air enrichment. The values of the calculated volumetric emissions and the CO_2 emission coefficient per unit of combusted fuel are shown in Table 3.

Table 3. The volume and K(CO_2) for analyzed fuels

*	G1	G2	G3
V(CO_2), m^3/m^3	0,86	0,33	0,63
K(CO_2), [kg/GJ]	54,8	59,3	60,8

The lower volumetric CO_2 emissions for gaseous fuels can be explained by the lower carbon content in the total mass of the fuel, which results in lower Qd values. Although a lower Qd is not favorable from a heat technology standpoint, considering K(CO_2) as an important reference parameter for environmental impact, it is observed that its values are relatively low for gaseous fuels.

The influence of the O_2 content in enriched air on the volumetric emission of NO_x and the emission coefficient K(NO_x) is shown in the Figure 3. Analytical calculations were performed for all types of fuel and all values of the excess air coefficient, but only the graphical dependencies for the average value of λ=1,12 are shown. For all analyzed fuels, it is observed that NO_x emissions increase with air enrichment, i.e., with the increase in % O_2, more or less according to an approximately exponential law.

It is characteristic that the presented correlations for gaseous fuels do not follow the principle that a higher initial N_2 content leads to a higher K(NO_x), because the highest value of the emission coefficient is for G2 and the lowest for G1. Since $K(NO_x)$ is directly proportional to the initial % N_2 and inversely proportional to the heating values of the fuel (Qd), it is evident that complete synergy of these two factors exists for G1 (low $\%N_2$ and high Qd). In the case of G2, despite the relatively high nitrogen content, the heating value of the fuel is extremely low, so the influence of Qd dominates, causing high values of $K(NO_x)$.

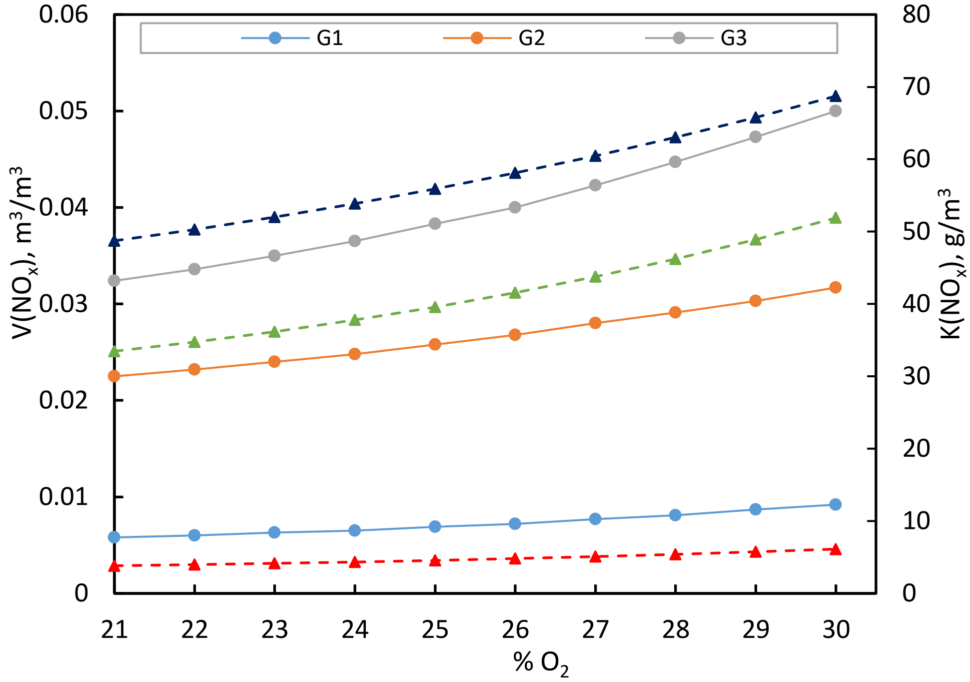

Figure 3. The influence of oxygen enrichment on the volume and the emission coefficient K(NOx)

4. CONCLUSION

For all analyzed fuels, with the increase in % O_2, the volume of combustion products decreases, and the flame temperature increases. Considering this, the most favorable heat technology indicators are achieved at an enrichment of 30% O_2, but the environmental effects must also be taken into account.

The influence of $\%O_2$ in the air is twofold. On one hand, with the increase in $\%O_2$, the $\%N_2$ in the air decreases, thereby reducing one of the available "sources" of NO_x formation. However, on the other hand, with the increase in O_2 content, the combustion temperature significantly increases, which is the basic precondition for the formation of "thermal" NO_x.

It is obvious that the second influence is dominant, so, ultimately, enriching the air with oxygen leads to an increase in NO_x emissions.

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