IOP Conf. Series: Journal of Physics: Conf. Series **789** (2017) 012045 doi:10.1088/1742-6596/789/1/012045

The heat effect of combustion process depending on fuel composition fluctuations

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Abstract. This article describes effects of changes in the fuel composition on the combustion process. Assessment of effect made on example of the steam boiler analysis.

1. Introduction

The problem of natural resources rational use, energy efficiency and energy saving is relevant at the moment. In this connection, the task of rational and efficient use of natural resources in their combustion is relevant, in particular in thermal power plants. One way of solving this problem is the use of alternative fuels, such as mine gas, landfill gas, biogas, gas of waste water and that is especially true - associated petroleum gas and waste oil refineries.

The problem of using such fuels is in the uncontrollable changes of their composition in time (Table 1) [1].

Table 1. The fluctuation ranges of fuel composition.

	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12} and higher	CO_2	H_2	N_2
Natural gas	80-98	0-1	0-0.5	0-0.5	0-0.5	0-1	2-10	0
Associated petroleum gas	15-90	0-25	0-20	0-10	0-15	0-10	0-5	0-30
Waste of oil refineries	0-35	0-19	0-32	0-40	0-47	0	0-25	0

These changes negatively effect on the combustion process, reduce combustion process efficiency, causing damage to the environment [2-4].

The aim of this work was to assessment of the changes effect of fuel composition on the thermal effect of the combustion process.

2. Calculation results

The optimality of combustion process (stoichiometric ratio of "fuel-air") can quantify the excess air factor α. When α = 1 the combustion optimal, combustion temperature maximum (Figure 1) [5].

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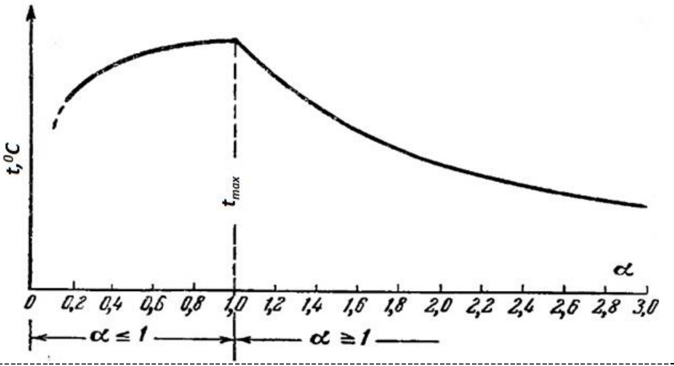

Figure 1. The nature of the theoretical fuel combustion temperature curve in case of lack and excess of air. The y-ordinate is fuel combustion temperature t, ºC; x-axis – excess air factor α

The fuel composition affects the carbon number of fuel n, and hence the theoretically required amount of air V_0, which affects the factor α.

$$n = \frac{1CH_4 + 2C_2H_6 + 3C_3H_8 + ...}{(100 - B)},$$

where CH_4, C_2H_6, C_3H_8, etc. – the sum of the hydrocarbons components, %; B - the sum of the ballast components CO_2 and N_2, %.

$$V_0 = 7.13n + 2.28.$$

$$\alpha = V / V_0,$$

where V is the real amount of air.

Increasing the proportion of fuel heavy fractions with a large carbon number reduces α, reduction of carbon number - to increase α. In both cases, the combustion temperature is reduced, optimality of combustion process is impaired.

Assessment of the fuel composition impact on the thermal effect of the combustion process carried out by the example of analysis a steam boiler operating mode. The steam capacity D = 6097 kg/h; enthalpy of water at the inlet H_w = 0.508 MJ/kg; the required enthalpy of steam H_s = 2.77 MJ/kg; boiler efficiency $\eta = 91.85$ %. The optimal mode: the fuel composition CH_4=60 %, C_2H_6=4.5 %, C_3H_8=13 %, C_4H_{10}=7.5 %, C_5H_{12}=4.9 %, CO_2=0.1 %, N_2=10 %; fuel consumption G_f= 286.98 m^3/h.

The fuel composition affects specific heat of combustion (SHC) Q_m, that affects the enthalpy of coolant [6].

$$Q_m = 0.01(Q_{H_2S}H_2S + Q_{CO}CO + Q_{H_2}H_2 + \sum Q_{C_mH_n} C_mH_n),$$

where Q_{H_2S}, Q_{CO} etc. – combustion heat of gas components.

$$H_s = \frac{G_f Q_m \eta}{100 \cdot D} + H_w.$$

The graph (Figure 2) shows the change in enthalpy of the coolant in case of SHC deviation from the optimum values.

As can be seen from the graphs, in the case of reducing the fuel SHC enthalpy of the coolant begins to decline sharply. This is due to a decreasing in heat release of fuel combustion and the increasing of air excess. In the case of SHC increasing enthalpy of the coolant rises slightly or remains constant. This is because the increase of combustion heat was compensated by combustion incompleteness.

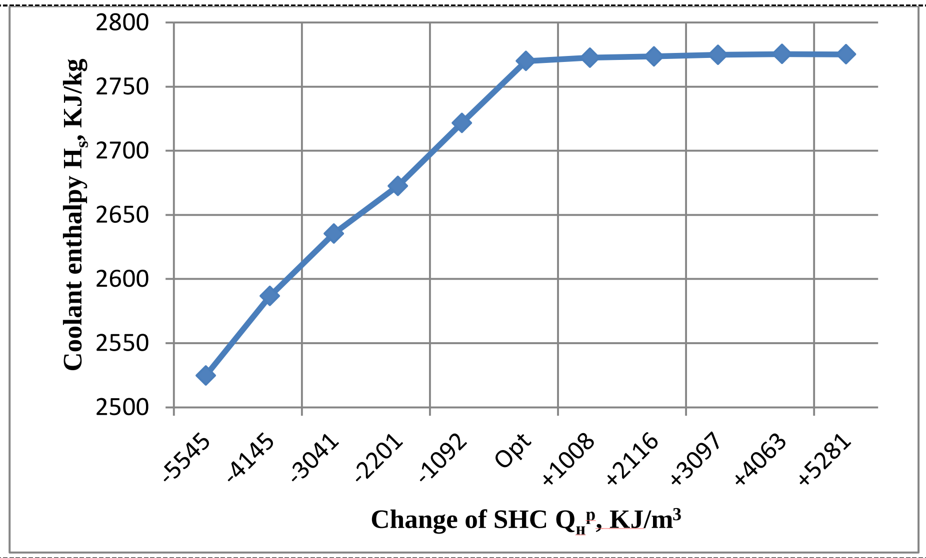

Figure 2. The effect of SHC change on the coolant enthalpy

3. Conclusion

Uncontrolled changes in fuel composition lead to instability of the thermal effect of the combustion process, which adversely affects the thermal performance of power plants.

Reducing the SHC leads to a sharp decrease in the enthalpy of the coolant at the outlet because of the excess air coefficient increasing. With increasing fuel SHC the coolant enthalpy is not substantially changed due to the growing underburning value.

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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