Thermal effect of hydrocarbon fuels combustion after a sudden change in the specific calorific value

E R Saifullin¹, V M Larionov¹, A V Busarov², V V Busarov²

¹Kazan Federal University, 18 Kremlyovskaya str., Kazan 420008, Russian Federation
²Limited Liability Company «Center of industrial safety expertise», 90a Julius Fucik str., Kazan 420140, Russian Federation

E-mail: mr.emilsr@gmail.com, techphys@kpfu.ru

Abstract. Using associated gas and waste oil refineries in thermal power plants, a complex problem due to the variability in fuel composition. This article explores the burning of hydrocarbon fuel in the case of an abrupt change in its specific combustion heat. Results of the analysis allowed developing a technique of stabilizing the rate of heat release, ensuring complete combustion of the fuel and its minimum flow.

1. Introduction
Currently, one of the acute and unresolved problems in the energy, oil and gas sector in the Russian Federation and in other countries is the problem of utilization of associated petroleum gas (APG below) and wastes of petrochemical plants. The most advanced and affordable method of disposal is burning it mainly in flares or in power plants, such as boiler units and gas turbine installations [1]. APG and wastes of petrochemical production include hydrocarbons and can be used as a "secondary fuels" [2], replacing traditional fuels, such as natural gas [3]. These secondary fuels have a non-permanent structure and therefore a non-constant specific heat of combustion. These deviations have a negative impact on the combustion process and on the heat removal from the hot products of combustion, reduce the efficiency of the combustion process, for example - there is a chemical incomplete combustion, reduces the efficiency of thermal power plants, causes damage to the environment. The task of optimization of the combustion of these fuels is to ensure complete combustion and thermal capacity of a given power plant in the event of changes in fuel composition. Available methods [4], [5] of optimization of combustion are not sufficiently effective, requires continuous analysis of the fuel composition, combustion products and the development of sophisticated control systems.

The aim of this work - the development of a simplified technique of optimization of hydrocarbon fuels combustion in the case of sudden change of specific heat of combustion.

2. The physical model of the optimization process
Mathematical analysis of the combustion process in the case of sudden change of specific heat of combustion of hydrocarbon fuels was carried out in [6]. It was determined the conditions when the fuel burns completely and its flow rate is minimal for the production of a predetermined thermal power:
1. After the reduction of the specific heat of combustion of fuel at a small relative value, to restore the initial thermal conditions is necessary to increase the fuel consumption by the same relative value, without changing the air flow.

2. After raising the specific heat of combustion of the fuel at a small relative value, necessary to reduce the fuel flow rate to the same relative value without changing the air flow.

These results have the following physical explanation. It is assumed that the initial specific heat of combustion of fuel is constant, burning - optimal, that is, the fuel burns completely, and the fuel flow rate is minimal for the production of a predetermined thermal energy.

Assume that in a burns fuel in a short time, there is an abrupt increase in the proportion of heavy fractions. Further, the fuel composition does not change.

This case corresponds to incomplete combustion of fuel, as available air is not enough for its complete combustion. Then the reduction of fuel consumption at a constant flow of air increases the completeness of combustion of fuel and combustion temperature [7]. At the same time, due to the decrease of fuel flow rate the amount of thermal energy contained in the combustion products is decreasing. As a result, the transmitted to the coolant heat flux through the wall of the heat exchanger is not changed, that is reflected in the constant temperature of the coolant at the outlet of the heat exchanger. Next steps is to periodically reduce fuel flow rate. Reducing of the fuel flow rate is completed when the temperature of the coolant at the outlet of the heat exchanger is reduced by an amount greater than the measurement accuracy of this parameter. This means that the amount of fuel burned decreased so that there was an excess of air, leading to a decrease in the coolant temperature at the outlet of the heat exchanger, as shown in Figure 1. In this case is necessary to increase the fuel flow rate to the previous value. The optimization process of combustion is considered complete, as reached the minimum fuel flow rate, combustion of which provides a predetermined amount of heat flow imparted to the coolant in the heat exchanger.

Consider another case where in a burned fuel in a short time, a rapid increase in the proportion of light fractions. Further, the composition of the fuel is not changed.

In this case, after reduction of the fuel flow rate at a constant air flow rate outlet coolant temperature becomes lower than a predetermined value. Differently from the first case, the fuel burns completely, because the excess air higher than theoretically necessary for complete combustion (α > 1), which can be seen from Figure 1. Therefore, necessary to reduce the air flow. If the reduction of air flow leads to the fact that the outlet temperature of the coolant becomes larger than a predetermined value by more than the measurement accuracy of this parameter is necessary to complete gradual reducing of the air flow rate. After stabilization the air flow is necessary to begin a discrete reduction.

![Figure 1](image-url)
in the fuel supply. When after a reduction of the fuel flow rate cannot increase the temperature of the coolant at the outlet of the heat exchanger to a predetermined value, is necessary to return the flows of fuel and air to the previous values. This means that there has been the case with the stoichiometric air/fuel ratio \((\alpha = 1)\), providing complete combustion of fuel. Further, for some time oversee the outlet coolant temperature. If the temperature remains constant, the optimization of combustion considered completed.

3. Conclusion
The physical model and methods of optimization of hydrocarbon fuel combustion in the case of sudden change in the specific calorific value is developed. In the case of an abrupt change in fuel composition, causes an increase in the specific heat of combustion is necessary to conduct periodic reduction of fuel flow rate. When the temperature of the coolant at the outlet of the heat exchanger is reduced by greater than the accuracy of measurement of this parameter value, it's needed to return the fuel flow rate to the previous value, and complete optimization of the combustion process. In the case of an abrupt change in fuel composition, causes a decrease in the specific heat of combustion it's needed to produce a periodic reduction of fuel and air flow rates to raise the temperature of the coolant at the outlet of the heat exchanger. When next reduction of air flow rate don't increases the temperature of the coolant at the outlet of the heat exchanger to a predetermined value, the air flow rate is returned to the previous value, and complete optimization of the combustion process.

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

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