Method of increasing the ecological indicators of the process of combustion of organic fuel in TPP boilers

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Abstract – Power boiler installations of thermal electric power plants (TPP) are among the main pollutants of the air basin of the environment.

The object of this study is the method to improve the environmental performance of the coal combustion process in TPP, which lies in supplying air with an increased oxygen content to the combustion zone.

The purpose of the article is the theoretical study of the application of the method of increasing the ecological indicators of the process of coal combustion in TP-100 boilers of the Burshtyn TPP, which is achieved by delivering pure oxygen to the prepared dust-air mixture directly to the burners. This article shows that it is possible to reduce the volume of combustion products by 30 thousand nm^3/h and by 50% by concentration of nitrogen oxides for a power unit of 200 MW with a boiler TP-100 of the Burshtyn TPP with fuel consumption of 55-89 tons per hour.

Keywords: coal, combustion process, oxygen, burner, boiler, thermal electric power plant, nitrogen oxides.

I. Introduction

A significant part of the emissions of harmful substances into the atmospheric air is made by industrial enterprises, among which the predominant portion belongs to power boilers of TPP and industrial furnaces. The main process, in which such harmful substances are formed as sulfur compounds, nitrogen oxides, carbon monoxide and others, is the process of combustion organic fuel [1-3], which are the basis of the thermal generation of electric energy by the steam cycle. Environmental problems of thermal energy, associated with the wear of the main technological equipment, can be resolved not so much by developing and wide use of dust and gas cleaning equipment, but also by combining the steam and gas mode of generation in combined steam and gas power plants (SGPP). Such installations are characterized by a wide range of station flexibility and high mobility [4], which makes them indispensable in case of necessity to cover peak loads in the consumption of electric and thermal energy.

II. Presentation of the main material

Among the harmful substances that are released by TPP, the most dangerous are nitrogen oxides [5 – 7]; and the source of formation is also atmospheric air nitrogen, which is fed with a certain excess. Environmental problems of thermal power associated with the wear of the main technological equipment can be solved at the stage of technical re-equipment [8]. The combination of the steam and gas generation cycle at Ukrainian TPP has not been widely used due to the high cost of turbine fuel. Recently, developments relating to the adaptation of the gas part of the generating equipment, which can work on products of gasification of coal, are ongoing. In such SGPPs, it is possible to simultaneously solve two inextricably connected tasks. Along with the decrease in the amount of harmful substances released into the environment, it is also possible to improve the start-stop characteristic of the TPP, as well as slightly increase the speed of the power ascension. In the proposed SGPP, it is possible to ensure the function of the gas part by burning coal of even poor quality. The portion of coal of low quality, both domestic and imported, will increase. Therefore, its use is possible only in the case of efficient combustion, ensuring the minimal formation of nitrogen oxides.

We have proposed a method for decreasing the formation of nitrogen oxides in the process of combustion of organic fuels, the formation of which is endothermic, which leads to a decrease in the temperature in the combustion zone. This further reduces the efficiency of the whole power unit. The source of the so-called "atmospherics" is nitrogen, the content of which in the air can reach 79-80%. Additional problems arise in the case of two (three)-stage burning of low quality coal, when, at the initial stage, the excess air ratio is less than one, and further it may assume the value of 1.14-1.2.

The feature of the proposal is the supply to the combustion zone of the air with increased oxygen content, which can be achieved by delivering pure oxygen to the prepared dust-air mixture (the so-called “oxygen blast”), which is widely used in metallurgy. In order to reduce the cost of oxygen production at the place of consumption, dissolution of air in ordinary water and then its degassing can be used. In this way, oxygen content in the enriched air can be obtained in volumetric percentages of up to 33.3%. The process of water degassing, which is not difficult what concerns the implementation, will result in a 1.5-fold enrichment of the oxygen mixture fed to the combustion of the organic fuel, which, additionally, will reduce the volume of flue gases.

At the end of the last century, one of the authors proposed the use of membrane technologies for such processes, which membrane technologies at that time began to develop rapidly. Nowadays, technologies of non-cryogenic nitrogen production at the place of consumption ensure the release of industrial gases from the air, with which significant technological progress is observed in this regard.

It should be noted that by separating atmospheric air into “oxygen” and “nitrogen”, it is possible to organize the full use of atmospheric air separation products. Oxygen-enriched air can be supplied in the combustion process, and the nitrogen fraction can be used to form the working fluid for the gas part of the generation.

In order to confirm some of the above-mentioned assumptions, we present some results of the theoretical studies of the burning process of coal of grade G from the Lviv-Volyn Basin at the 200 MW power unit with the TP-100 boiler of the Burshtyn TPP. At the same time we shall assume that for the Burshtyn TPP, the coal (the quality of which will only deteriorate in the future) has such a composition per fuel working mass: ash content – A^p =29%; humidity – W^p =10%; the lower net calorific value Q_i^{∂} =4650 kcal / kg (19.47 MJ/kg).

The results of the calculations of the air consumption for combustion of coal in the TP-100 boiler, depending on the power of the power unit are summarized in Table 1.

TABLE 1

EXPENDITURE AIR FOR COALING IN COPPER TP-100

Power of the power unit, MW	200	160	120
Theoretical amount of the air flow, nm^3/h	461821	368419	285395
Air flow rate at α=1,15, nm^3/h	530094	423681	328204
Volume of combustion products at α=1,15, Vg, nm^3/h	570024	455536	352880

Also, it is worth noting that the volume of the combustion products does not take into account the suction air in the convection shaft and boiler ducts.

In order to reduce the negative influence of the TP-100 boilers upon the environment, in particular, to reduce emissions of nitrogen oxides, let us consider increasing the proportion of oxygen, and, accordingly, reducing the proportion of nitrogen in the air supplied for the fuel combustion.

We shall study how the flow of air and flue gases will change, if the ratio of oxygen and nitrogen in the air fed to the combustion of coal, is changed by 35/65 and by 40/60.

The calculation results are summarized in Table 2.

TABLE 2

CONSUMPTION RATE OF PRODUCTS DURING BURNING COAL IN THE TP-100 BOILER

Power of the power unit, MW	200	160	120
Volume of the combustion products at α=1,15, nm^3/h	570024	455536	352880
Volume of combustion products with the oxygen content in the air of 30%, nm^3/h	505698	403422	312510
Volume of combustion products with the oxygen content in the air of 40%, nm^3/h	483198	385473	298606

The theoretical amount of nitrogen in combustion products with the oxygen content of 30% is 3.38 nm3 / kg of the combusted fuel and with an oxygen content of 40%, it is 3.12 nm^3 / kg of the combusted fuel.

Thus, we see that as a result of an increase in the oxygen content in the air supplied for coal combustion, the consumption of combustion products and nitrogen content is reduced, which allows to increase the technical characteristics of the TP-100 boiler by reducing the flow of the flue gases, reducing the consumption of electricity for transporting flue gases , and environmental indicators – by reducing emissions of nitrogen oxides.

Conclusion

This work proposes a method for increasing ecological parameters of the process of combustion of organic fuel in TEPP boilers by way of feeding air with increased oxygen content into the combustion zone, which can be achieved by feeding pure oxygen to the prepared dust-air mixture directly to the burners.

Theoretical calculations show that, it is possible in case of the power unit of 200 MW with the TP-100 boiler of the Burshtyn TPP with the fuel consumption of 55-89 t/h to reduce the volume of combustion products by 30 thousand nm^3/h and the concentration of nitrogen oxides by 50%.

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