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Comparative analysis of simulated kinetic schemes when calculating the nitrogen oxide formation in solid fuel flaring

Elena Zueva[1], *Natalia*Vizgavlyust[1*], *Lyudmila* Vorobjeva[1], and *Alexander* Starchenko[2]

[1] National Research Tomsk Polytechnic University, 634050 Tomsk, Russia
[2] National Research Tomsk State University, 634050 Tomsk, Russia

Abstract. This paper presents a comparative analysis of the kinetic schemes with the numerical analysis of the generation of nitrogen oxides during the combustion of the pulverized fuel. The distributions of the concentration of nitrogen oxides of two studied kinetic schemes with height of the combustion chamber are obtained. The conclusions about the accuracy of numerical researches and the choice of optimal kinetic scheme are made.

1 Introduction

Protection of atmosphere from pollutant emissions is one of crucial current problems. Rapid growth of energy consumption is known to be accompanied by the increase of emissions polluting atmosphere.

Thermal stations consuming big quantities of organic fuel emit combustion products containing solid particles, sulfur, nitrogen and carbon oxides into atmosphere.

Every year requirements to environment protection become stricter. Due to the above one of the problem of designers is to adhere to the requirements on ultimate permissible concentrations set up by sanitary bodies (first of all - nitrogen oxide) both for new thermal plants and for the ones already operating.

In order to define the most efficient way to control NO_x for each specific boiler it is necessary to perform some field experiments. However it is not always possible to run such field experiments.

In order to optimize designing and to reduce the experiment costs the numerical simulation will be used. It would allow analyzing the nitrogen oxide emissions during designing of new plants and working out several options for upgrade of the existing boilers choosing the best option for solution of this problem.

For introduction of effective techniques for suppression of nitrogen oxide formation it is necessary to develop numerical simulations of combustion of nitrogen containing fluids in the furnaces and combustion chambers. When creating the numerical model describing the formation of nitrogen oxide it is important to consider all specific processes going on in the furnace: complicated spacial mechanics, combustion of coal duster etc.

* Corresponding author: vizgavljust@tpu.ru

2 Description of the model and the object of research

At present the mechanism for thermal wastes of nitrogen oxide is well studied and described by the diagram of Ya.B. Zeldovich [1]. Simulation of formation of fuel and rapid nitrogen oxides is more complicated. As a rule the offered kinetic models require accounting the significant number of chemical reactions accompanying this condition. It significantly limits their use when performing numerical investigations for field facilities.

This article presents the numerical simulation of nitrogen oxide formation in combustion of powdered nitrogen containing fuel in the furnaces of industrial boilers basing on the kinetic model for NO formation developed by Mitchell and Tarbell [2], and with use of the model developed by Gusev, Zaychik nd Kudryavtsev [3].

Mitchel-Tarbell model is fairly convenient for using; its kinetic scheme includes only 13 reactions. Kinetic scheme of this model is described by the system consisting of seven equations simulating chemical reactions of combustion of hydrocarbons, coke, emission and combustion of volatile substances, formation of thermal nitrogen oxides, heterogeneous reaction of nitrogen oxide conversion in the result of their interaction with coke carbon [2, 4, 5].

Gusev-Zaychik-Kudryavtsev model supposes that all fuel nitrogen oxides are formed from nitrogen fuels transferring into gas form along with volatile substances and the impact of nitrogen remaining in the coke is neglected. Formation of fuel nitrogen oxide is calculated supposing that during emission and combustion of volatile substances the nitrogen containing components of fuel are decomposed into active atomic nitrogen N or hydrogen cyanide HCN. Further the process is supposed to go into two directions: oxidation of nitrogen to nitrogen oxide and formation of molecular nitrogen due to recombination of atomic nitrogen or as a result of nitrogen oxide reduction. The estimated scheme for fuel oxides generation is described by the system consisting of three equations [2, 4].

The above numerical models for NO_x generation were applied to the operating boiler of BKZ-220-100ZHSH, which configuration is presented on Fig.1. Fig. 2 shows distribution and concentration of nitrogen oxide in the furnace of BKZ-220-100ZHSH boiler with abundant air α=1.2.

BKZ-220-100ZHSH boiler has prismatic furnace. The boiler is 24.9 m high; the furnace is 8.64 m wide and 7.74 m deep. The furnace is completely shielded by pipes of 60 mm in diameter. Slightly sloping symmetric hearth (α=15º) formed by pipes of the front and back shields complies with the system of fluid slag removal and the lower part of the furnace is refractory-faced and covered with chrome plastic up to 5.750 m high. Lighting-up burners are installed to the walls at 9.6 m high and built in into special burners with secondary air supply [6].

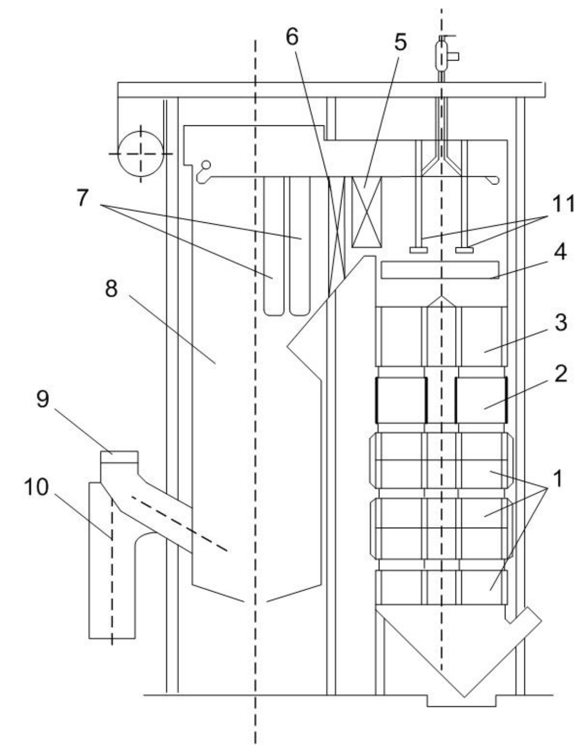

Fig. 1. BKZ-220-100ZHSH boiler: 1, 3–air heater stages; 2, 4–economizer stages; 5–convention stage; 6, 7–outlet and furnace shields; 8–furnace; 9– secondary air nozzle; 10–miller separator; 11–shot cleaning system.

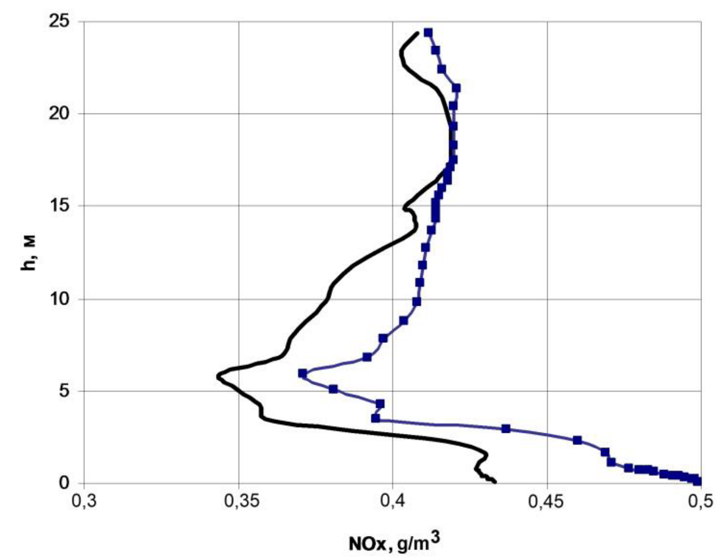

Fig. 2. Formation of nitrogen oxides respective the furnace height of BKZ-220-100ZHSH boiler: ———— – model [2], –■–■–■–■– – – model [3].

3 Results and discussion

Fig. 2 shows that the selected numerical models for investigation of nitrogen oxide formation provide fairly similar results. The accuracy of the forecast NO_x formation greatly depends on the part of nitrogen fuel emitted together with volatile substances or during the combustion of coke residue. Model [2] describes more accurately and fully the process of nitrogen oxide formation since it includes the combustion of coke residue, turbulent diffusion and transfer of furnace medium components by averaged movement. Fig.3 shows the typical of all models [2, 3] character for NO_x concentration distribution in the vertical section of the furnace between direct-injection burners and 3D model.

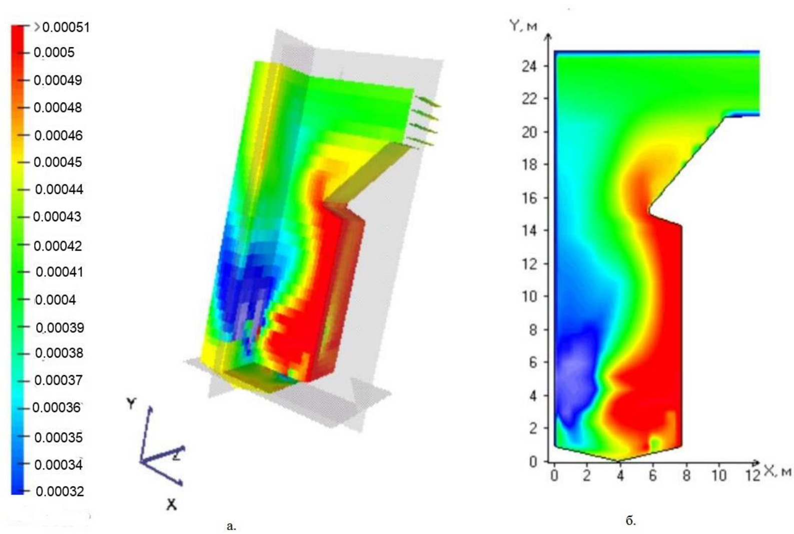

Fig. 3. Distribution of NO_x weight concentration in the furnace of BKZ-220-100ZHSH boiler: a – 3D model, b – vertical section.

Fig. 3 shows that the maximum quantity of NO_x nitrogen oxide is formed in the upper and lower parts of active burning area which is characterized by the increased values of flow temperature. NO_x concentration changes to very insignificant extend in the part of the furnace from 10 to 25 mm high where combustion is already over. The area of maximum temperature values (up to 1900 K) is located in the part of the furnace opposite to burners. The furnace outlet temperature is 1250 K.

4 Conclusions

Model [2] is an effective tool for forecasting nitrogen oxide generation in coal-dust furnaces compared to model [3], which is confirmed by the results of calculation experiments and tests showing fair convergence with the data of field measurements. Model [2] considers the data on outlet process and combustion of fuel volatile components, after-burning of coke residue, non-isothermality, turbulent diffusion and transfer of furnace medium components by the averaged movement, and using model [2] for NO formation during coal combustion will allow optimizing combustion process for powdered fuel in boilers of the thermal plants in order to increase the efficiency of fuel burning out and reduction of NO_x emissions.

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