Investigation of the Combustion Process in the TGME-464 Boiler with Tertiary Injection

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Presented at International Conference on Trends & Innovations in Management, Engineering, Sciences and Humanities, Dubai, 19-22 December 2023 (ICTIMESH-23).

https://doi.org/10.37082/IJIRMPS.ICTIMESH-23.16

Published in IJIRMPS (E-ISSN: 2349-7300), ICTIMESH-23

Abstract

The article analyzes the combustion process in the TGME-464 boiler with tertiary injection as an effective way to reduce the emission of toxic and polluting substances - nitrogen oxides NO_X. To implement this study, modeling of the TGME-464 boiler unit was carried out in the STAR-CCM+ environment. An analysis was carried out and results were obtained that made it possible to optimize fuel combustion in the TGME-464 boiler and reduce NO_X emissions.

Introduction

When analyzing global greenhouse gas emissions since the signing of the Kyoto Protocol, which was ratified by 192 countries, one can observe particular inertia in reducing emissions in the energy sector. In the global energy sector, the maximum effect from reducing emissions of harmful substances is achieved by: increasing the efficiency of thermal power plants, increasing the share of electricity production without burning fossil fuels at nuclear power plants and hydroelectric power plants, replacing burned coal with gas and fuel oil. Thermal power plants are the main sources of NO_X emissions into the atmosphere.

The technology for optimizing the fuel combustion process is especially relevant for thermal power plants operating on solid and liquid fuels. The production of thermal and electrical energy at thermal power plants in the context of rising prices for hydrocarbon fuels and tightening environmental requirements requires the development of new technical and technological solutions for the most efficient and environmentally friendly combustion of fuel in power plants at thermal power plants. A key indicator of the efficiency of thermal and electrical energy production is the consumption of equivalent fuel. For power plants, the specific consumption of equivalent fuel for electricity generation should tend to a value of less than 250 g/kWh. To do this, it is necessary to ensure the most complete combustion of fuel. The combustion process is influenced by the aerodynamics of the combustion chamber, since it determines the intensity of mixing of fuel with combustion products [1]. Chemical combustion reactions in the combustion process proceed at high speed, and the determining condition is to ensure optimal conditions for mixing fuel with air, ignition and burnout of the fuel. The main pollutant when burning natural gas in power plants is thermal nitrogen oxides, the main indicator of the intensity of their formation is the temperature in the active combustion zone. To reduce NO_X emissions from flue gases, a number of measures are used, including sectioning the furnace, recirculating flue gases, lowering the air temperature, injection of moisture into the combustion zone, staged combustion, etc. Documents are issued separately.

One of the tools for reducing emissions of harmful substances into the atmosphere and increasing boiler efficiency modeled in this work is tertiary injection. In two-stage combustion, the fuel is divided into streams and gas and air are supplied to the first combustion zone through the burner device, and combustion products, gas and air, are supplied to the second zone, the excess air ratio of which is greater or less than that supplied in the first zone. In steam boilers, tertiary injection refers to the process of supplying air to the boiler after the main combustion of fuel and secondary injection. This process allows for afterburning of the fuel [2].

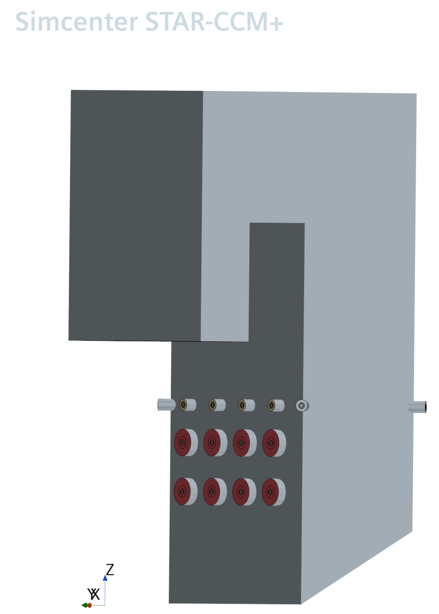
By using tertiary injection, the amount of nitrogen oxides contained in emissions can be significantly reduced, making this process very important for compliance with environmental regulations.

Computational fluid dynamics approaches in numerical modeling environments make it possible to simulate various operating modes of boilers and combustion processes of fuel consisting of swirling flows of several types of gas without the risk of critical situations associated with equipment damage and at the same time opening up the opportunity to obtain a large amount of data on the state and various modes equipment operation [3]. In the context of tightening environmental requirements, determining optimal fuel combustion conditions is an urgent task.

Digital Model

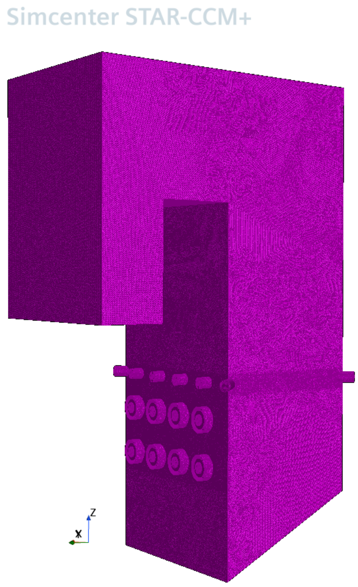
The simulation was performed in the STAR-CCM+ environment. The object of study was the energy boiler TGME-464 (E-500-13.8-560GMN). The solid-state model of the boiler is shown in Figure 1.

Figure 1: 3-D Model of the TGME-464



To carry out the calculations, a computational mesh consisting of 8 million cells was created. A more detailed description of the combustion process, with validation of the combustion model and verification of the adequacy and estimation of the error of the obtained data, is presented in our other works [4, 5]. The tertiary air injection is organized above the upper tier of the burners. Two cases were simulated: injection from the front screen (towards the torch) and from the rear screen. In both cases, NO_X emissions simulations were performed at a steam load of 400 t/h.

Figure 2: Calculation Grid



Results

Figures 3 and 4 present the simulation results. As we can see from Figure 3, the injection of additional air helps to reduce the temperature of the flame core. As the proportion of supplied air increases, the NO_X concentration decreases. When tertiary air is blown in from the rear screen, a reduction in NO_X concentration of 2.8% is achieved at the same parameters and load.

Figure 3: Temperature Distribution

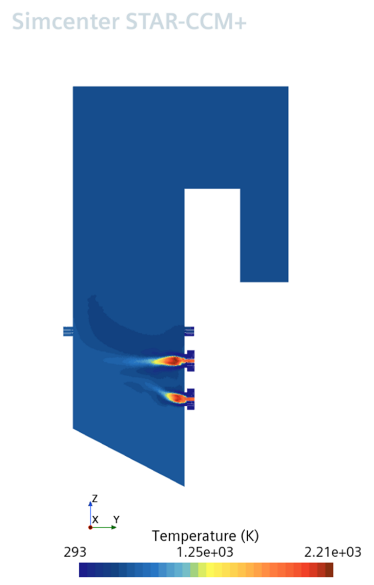
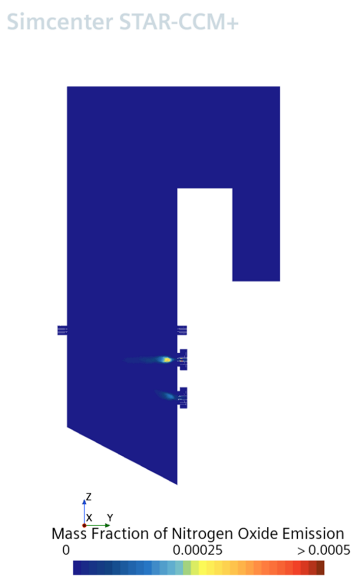


Figure 4: Distribution of NOX Concentration



Acknowledgement
This research was funded by a Megagrant from the Government of the Russian Federation under project No. 075-15-2021-584 and a grant from the President of the Russian Federation under project NSh-28.2022.4

References
[1] Migay V.K. (1987). Modeling of heat exchange power equipment.
[2] Shtym, K.A., Lesnykh, A.V., Golovaty, S.V. (2014). Analysis of the influence of tertiary injection on the formation of nitrogen oxides in the furnace of the BKZ-210-140 boiler. Mining Information and Analytical Bulletin, S4-3, 75-80.
[3] Aiki, Hidetoshi, et al. (2018). Boiler digital twin applying machine learning. Mitsubishi Heavy Industries Technical Review 55.4, 1.
[4] Fedorov, R.V., Generalov, D.A., Sherkunov, V.V., Sapunov, V.V., Busygin, S.V. (2023). Improving the Efficiency of Fuel Combustion with the Use of Various Designs of Embrasures. Energies, 16, 4452. https://doi.org/10.3390/en16114452 441
[5] Kovalnogov, V., Fedorov, R., Klyachkin, V., Generalov, D., Kuvayskova, Y., Busygin, S. (2022). Applying the Random Forest Method to Improve Burner Efficiency. Mathematics, 10, 2143. https://doi.org/10.3390/math10122143