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Numerical Analysis of NO_x Emission in Staged Combustion for the Optimization of Once-Through-Steam-Generators

Authors : Adrien Chatel, Ehsan Askari Mahvelati, Laurent Fitschy

Abstract : Once-Through-Steam-Generators are commonly used in the oil-sand industry in the heavy fuel oil extraction process. They are composed of three main parts: the burner, the radiant and convective sections. Natural gas is burned through staged diffusive flames stabilized by the burner. The heat generated by the combustion is transferred to the water flowing through the piping system in the radiant and convective sections. The steam produced within the pipes is then directed to the ground to reduce the oil viscosity and allow its pumping. With the rapid development of the oil-sand industry, the number of OTSG in operation has increased as well as the associated emissions of environmental pollutants, especially the Nitrous Oxides (NO_x). To limit the environmental degradation, various international environmental agencies have established regulations on the pollutant discharge and pushed to reduce the NO_x release. To meet these constraints, OTSG constructors have to rely on more and more advanced tools to study and predict the NO_x emission. With the increase of the computational resources, Computational Fluid Dynamics (CFD) has emerged as a flexible tool to analyze the combustion and pollutant formation process. Moreover, to optimize the burner operating condition regarding the NOx emission, field characterization and measurements are usually accomplished. However, these kinds of experimental campaigns are particularly time-consuming and sometimes even impossible for industrial plants with strict operation schedule constraints. Therefore, the application of CFD seems to be more adequate in order to provide guidelines on the NO_x emission and reduction problem. In the present work, two different software are employed to simulate the combustion process in an OTSG, namely the commercial software ANSYS Fluent and the open source software OpenFOAM. RANS (Reynolds-Averaged Navier–Stokes) equations combined with the Eddy Dissipation Concept to model the combustion and closed by the k-epsilon model are solved. A mesh sensitivity analysis is performed to assess the independence of the solution on the mesh. In the first part, the results given by the two software are compared and confronted with experimental data as a mean to assess the numerical modelling. Flame temperatures and chemical composition are used as reference fields to perform this validation. Results show a fair agreement between experimental and numerical data. In the last part, OpenFOAM is employed to simulate several operating conditions, and an Emission Characteristic Map of the combustion system is generated. The sources of high NO_x production inside the OTSG are pointed and correlated to the physics of the flow. CFD is, therefore, a useful tool for providing an insight into the NO_x emission phenomena in OTSG. Sources of high NO_x production can be identified, and operating conditions can be adjusted accordingly. With the help of RANS simulations, an Emission Characteristics Map can be produced and then be used as a guide for a field tune-up.

Keywords : combustion, computational fluid dynamics, nitrous oxides emission, once-through-steam-generators
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