SUCCESS STORY

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K1 MET
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LOWNO$_X$

A NUMERICALLY EFFICIENT METHOD FOR THE PREDICTION OF NITROGEN OXIDE EMISSIONS IN INDUSTRIAL FURNACES

Due to constantly increasing environmental requirements, nitrogen oxide (NO_X) emissions in industrial furnaces are a permanent topic of interest. Exhaust gas treatments such as the selective catalytic reduction of NO_X increase the investment and operating costs of the furnace. To reduce the formation of NO_X at the source, a detailed understanding of the specific flame is required. The most cost-effective method for that purpose is the use of Computational Fluid Dynamics (CFD). As a rule, a complex reaction mechanism is needed to accurately model the formation of NO_X in a flame. Detailed chemistry mechanism within the combustion models such as the Eddy Dissipation Concept (EDC) or the Partially Steered Reactor (PaRS) is too time-consuming for practical industrial applications. The Laminar Flamelet Model uses tabulated chemistry in combination with probability functions allowing a fast prediction of the flame propagation but cannot resolve slower time scale reactions like the formation of NO_X.

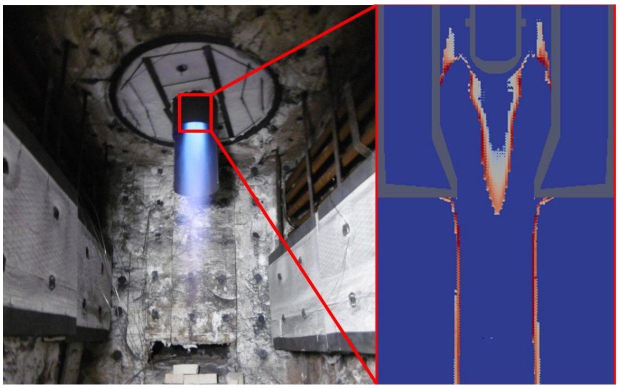
To solve this problem, a NO_X post-processor for the laminar flamelet model has been developed. The postprocessor uses the fixed flow, turbulence and temperature fields as the results of the laminar flamelet model and solves the NO_X formation reactions with a detailed mechanism in a subsequent step. To increase the computational speed, an algorithm was developed, which only solves the reactions in the region of physical relevance. This approach reduces the calculation time by 85% making the concept applicable for the large industry scale geometries. Still, for the fully optimized burner, an iterative process with multiple subsequent model simulation is required.

In order to carry out such an optimization process in a reasonable time frame, the speed of the initial post processor had to be further increased, which is achieved with implementation of three additional methods for computing time reduction. The first method reduces the number floating point operation by internal restructuring, which results in a speed increase of a 35%, with some compromise in memory usage. The second method generates starting values for several chemical species based on a simpler reaction mechanism decreasing computational time to approximately 68% of the initially needed value. The third method automatically generates a new calculation grid optimized for the nitrogen oxide post-processor, resolving only NO_X formation zones with the results of the laminar flame calculation as a basis. The last step could lead to a speed up to approximately one third, which primarily depends on the burner design.

Impact and effects

Using the NO_X postprocessor 2.0, a particular burner design has been improved in the last funding period. The developed concept led to a better understanding of the influential parameters by the formation of NO_X in a shaft furnace. Several derived influential operating parameters made it possible to reduce the NO_X emission from 46 to 30 ppm. Two burner designs with the post-processor 2.0+ are currently in the optimisation process. Implemented concept reduces emissions without increasing operating costs or compromising energy efficiency at any stage.

Preheating the combustion air to higher temperatures will increase energy efficiency and reduce carbon dioxide emissions; however, it inevitably increases the NO_X formation. The best compromise can be achieved by an optimised burner design.



Nitrogen monoxide formation zones of an industrial burner

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