K1-MET

Competence Center for Excellent Technologies in Advanced Metallurgical and Environmental Process Development

Main Location	Linz, Upper Austria
Other Locations	Leoben, Styria
Key topic	K1-MET has its focus on the modeling and simulation of metallurgical processes, including metallurgical raw materials and refractories with the goal of an optimal process control with respect to product quality, zero waste and the minimization of energy and raw materials.

Title

Combustion Reaction Modelling of Burners for Industrial Kilns

Success Story short version

Modeling of combustion processes is of crucial importance to optimize furnaces and burners. CFD is a powerful tool to visualize high temperature processes, where e.g. measurements are difficult to perform. To simulate combustion the turbulent velocity field, temperature, heat transfer, radiation and concentrations with respect to chemical reactions and chemical kinetic has to be considered.

An improvement of accuracy to predict the temperature distribution and major species for the Sandia Flame D could be achieved. It is shown that the models are fast and accurate for industrial scale combustion prediction as well. The improved models are then applied to predict the temperature, concentration and velocity field in a tunnel kiln burning zone. There, the effect of less through heating at the bottom region near the tunnel kiln car, which causes deficient products in this region, could be shown. The predicted temperature of the heated and burnt products is in good agreement with kiln tracker measurements for this kind of furnace.

Success Story long version

Objectives

The modeling of combustion processes including turbulent flow fields, temperature, radiation and concentrations is of crucial importance for the optimization of furnace and burners. The simulation results are the basis for the design and optimal operation of burners and industrial furnaces. The demanding task is to combine and optimize existing models in order to simulate accurately industrial scale combustion.

Approach

To simulate non-premixed combustion at industrial scale an adequate model combination concerning turbulent flow, combustion reaction mechanism, combustion and radiation is evaluated and in terms of accuracy adapted. Therefore, an evaluation of different models, model combinations and model adaption is performed at laboratory scale by comparison with experimental data from literature of the "Sandia Flame D" published by the international TNF workshops on turbulent flames. To apply the evaluated and adapted models to industrial scale combustion processes, strategies in reducing the computational effort without losing accuracy are investigated. The improved model is then applied to predict the temperature, concentration and velocity field in a tunnel kiln burning zone. Comparison by plant measurements will result in

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further model development.

Results and Economic Impact

An improvement of accuracy to predict temperature and major species for the Sandia Flame D could be achieved in the first period of the project by combining and improving the laminar flamelet combustion model with detailed chemistry included with the GRI-Mech 3.0 methane mechanism in combination with the realizable k-ε turbulence model with the turbulence constant $C_{2\varepsilon}$ = 1.8 and the Discrete Ordinate radiation model which is less sensitive to the amount of rays. In Fig. 1 the comparison of the predicted axial flame temperature with experimental data from literature is shown.

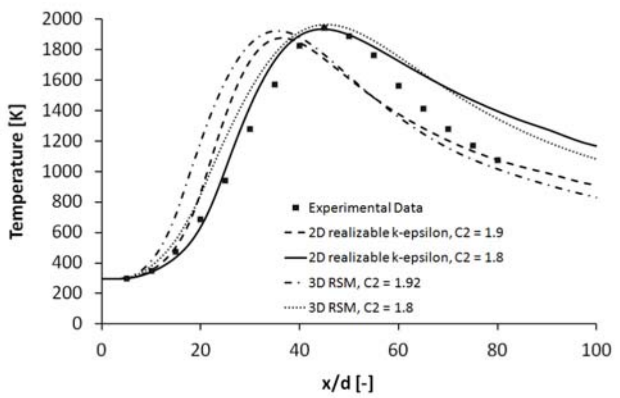

Fig. 1. Results of axial flame temperatures for a laboratory scale non-premixed flame (Sandia Flame D). Simulation results are compared with experimental data, where x/d is the normed distance from the burner nozzle.

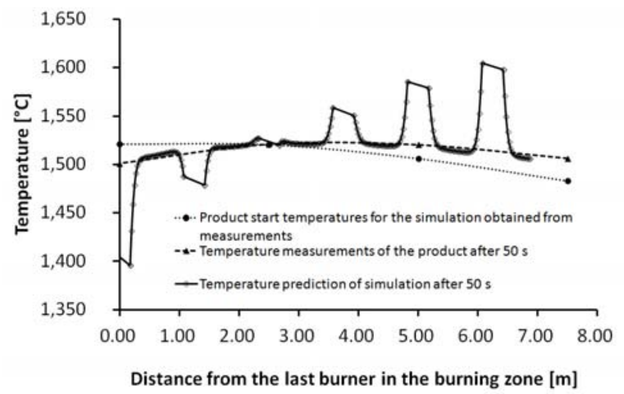

Fig. 3. Predicted product temperatures (continuous line) compared with measured kiln tracker temperatures at a hight of 0.53 m along the middle product row in the burning zone.

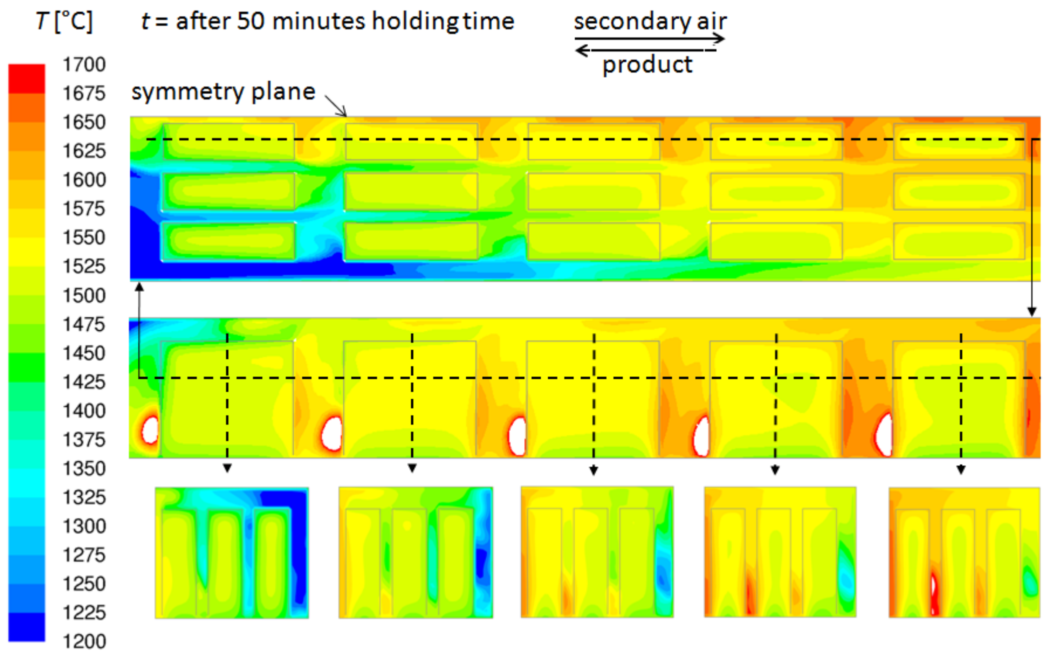

Fig. 2. Temperature distribution in the burning zone of a tunnel kiln filled with products.

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It is shown that the models are fast and accurate for industrial scale combustion prediction as well. The unsteady combustion and burning conditions for the burning zone of an empty and filled tunnel kiln are predicted. Here, the turbulent flow and convective/radiative heat transfer to the product in the burning zone is of interest. In Fig. 2 the predicted temperature in the burning zone of a tunnel kiln is shown. The effect of less through heating at the bottom region near the tunnel kiln car, which causes deficient products in this region, could be shown.
The temperature of the heated and burnt products shows good agreement with kiln tracker measurements for this kind of furnace. Fig. 3 shows the comparison of the product temperature at a height of 0.53 m along the middle product row in the burning zone.

Next Steps

The growing concerns about environmental pollution make it necessary to develop a tool for emissions calculation. As shown in the first period the modeling of NO_x formation gave over-predicted results. The challenge is an improvement of the model concerning an accurate prediction of NO_x formation.
In addition the combustion model studied in the first period model will be applied to several industrial combustion processes for its applicability, for further model development, evaluation and for improving these combustion processes. The processes are

- combustion in a radiation tube burner fired with coke oven gas and the effect on the tube material,
- preheating of submerged entry nozzles for steel continuous caster,
- further improvement of the combustion in the burning zone of a tunnel kiln and
- to optimize a copper scrap remelting process.

Further model development and expansion of reaction mechanism for several gases will broaden the range of application.

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