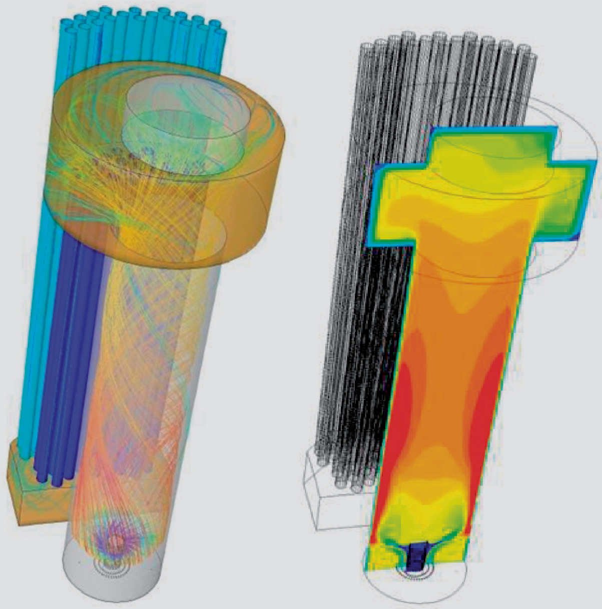
Department of Industrial Combustion Technology

gwi Gas- und Wärme-Institut Essen e.V.

www.gwi-essen.de

Numerical Simulation of Industrial Processes

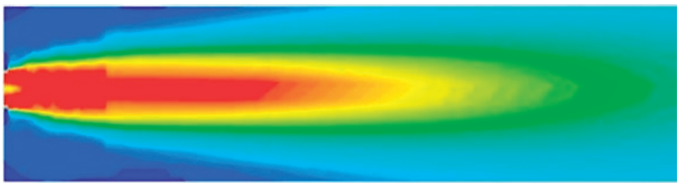
More than any other technology, computers have evolved dramatically over the last few decades. The benefits are obvious everywhere, both in everyday life and in the industrial sector. Today, numerical simulation is used as a matter of course not only in research, but also in the design, analysis and optimization of process engineering plants and their components. It allows insights that measurement techniques can often only deliver with great difficulty, at enormous expense, if at all. GWI has been using and validating modern simulation methods for many years, both in the context of publicly funded research projects and in collaboration with industry. By combining experimental investigation with numerical simulation, processes, plants and components can be viewed as a whole - a comprehensive system - for analysis and optimization.



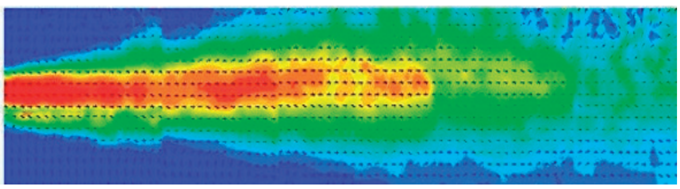
Streamlines and temperature distribution in an industrial boiler

CFD: From Reality to the Model - and Back

Computational Fluid Dynamics (CFD), i.e. the numerical modelling of turbulent flows, is based on the mathematical description of physical processes which occur in systems, such as for example industrial furnaces. The laws which underlie these processes can be expressed in the form of equations, however these equations and the interaction of the individual processes (flow, combustion, radiation, etc.) are so complex that they cannot be solved analytically. This is where numerical simulation comes in - using powerful solution algorithms and simplifying model assumptions, it is possible to calculate approximate solutions which reflect reality very well, as comparisons with actual measurements demonstrate. Using a numerical model of a furnace or processing plant, changes in operating parameters or geometries can easily be investigated in the computer, before any changes are implemented in real life. This allows for strategies for optimization and retrofitting to be thoroughly analyzed and tested; no downtime or associated production losses are incurred. Numerical simulation has advanced to become a state-of-the-art method for reconfiguring equipment and plants of all kinds. Time-consuming, costly experimental investigations are now mostly a thing of the past.



Simulation



Measurement

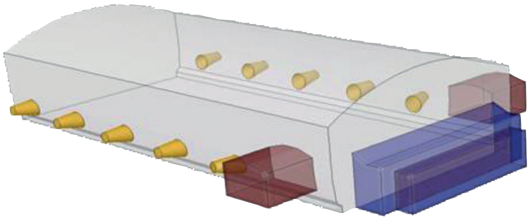
Comparison: Simulation vs. Measurement

Step 1: Current State

A CFD simulation is always based on the geometry and process parameters of the system under investigation. Both are determined in cooperation with the customer and are essential for the reliability of the simulation.

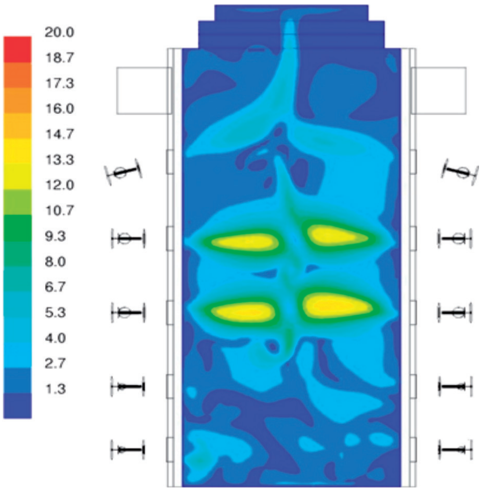
Step 2: The Numerical Model

A numerical model is then created, based upon the information available on the geometry, process parameters and boundary conditions. This model consists of a mesh representing the geometry and the computational domain, the boundary conditions for the simulation and the choice of appropriate mathematical models for processes such as turbulence, chemical reactions and heat transfer. However, a compromise between the simulation‘s level of detail and the required computational time needs to be made - this is where the user‘s experience comes in. Then, the simulation itself is carried out.



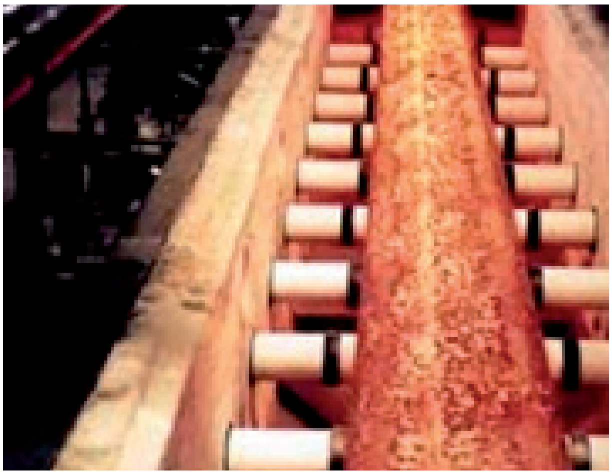
Step 3: Evaluation and Analysis

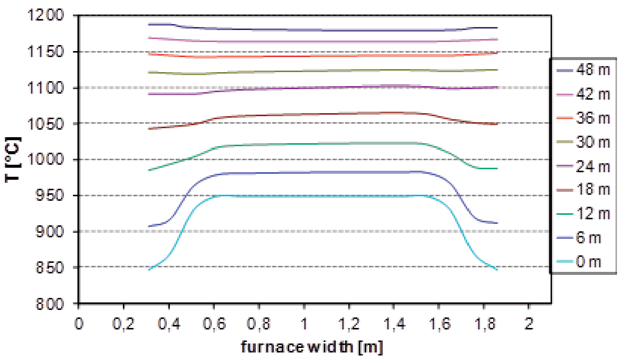
Upon completion of the simulation, the results are visulized and analyzed. A major benefit of CFD simulations is that they are not limited by measurement or design constraints, in stark contrast to an experimental investigation. In principle, properties at every point in the computational domain can be looked into in detail, irrespective of its position. This is impossible with a real-life system. The insights obtained by this detailed analysis are incorporated into an optimization process which may result in changes to geometry or parameters.



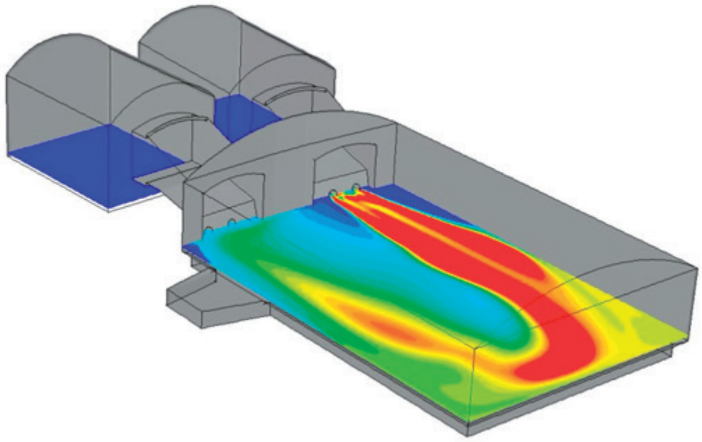
Post-Processing: More than Pretty Pictures

One of the major advantages of the simulation approach is that a simulation can provide large amounts of highly resolved data. The processes and properties at each point in the computational domain can be examined. In this way, CFD provides a far more comprehensive picture of the processes taking place in a plant than could be delivered by measurement techniques. In addition, parameters such as wall heat flux density distributions can be visualized, something that is almost impossible to capture experimentally. A great variety of different visualization options is made possible by the very high spatial resolution of the data set, such as contour plots, streamlines and iso-surfaces.

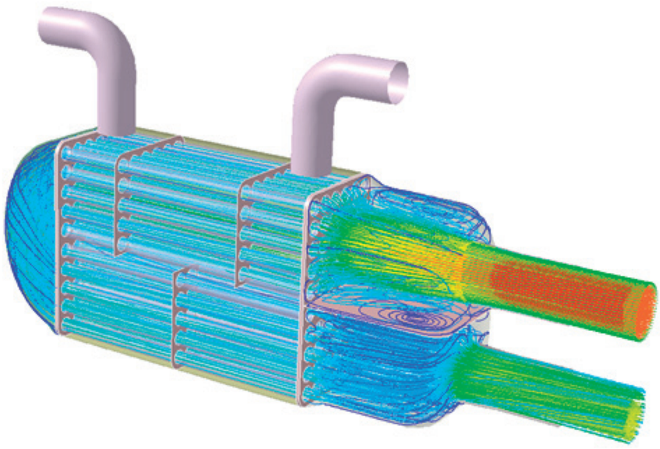




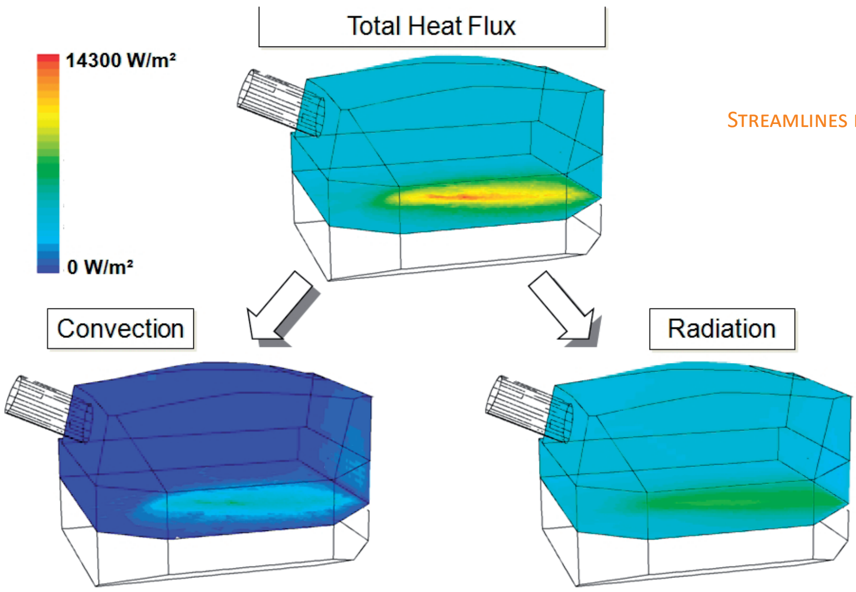
Simulated slab temperature in a roller hearth furnace



CO distribution in a glass melting furnace



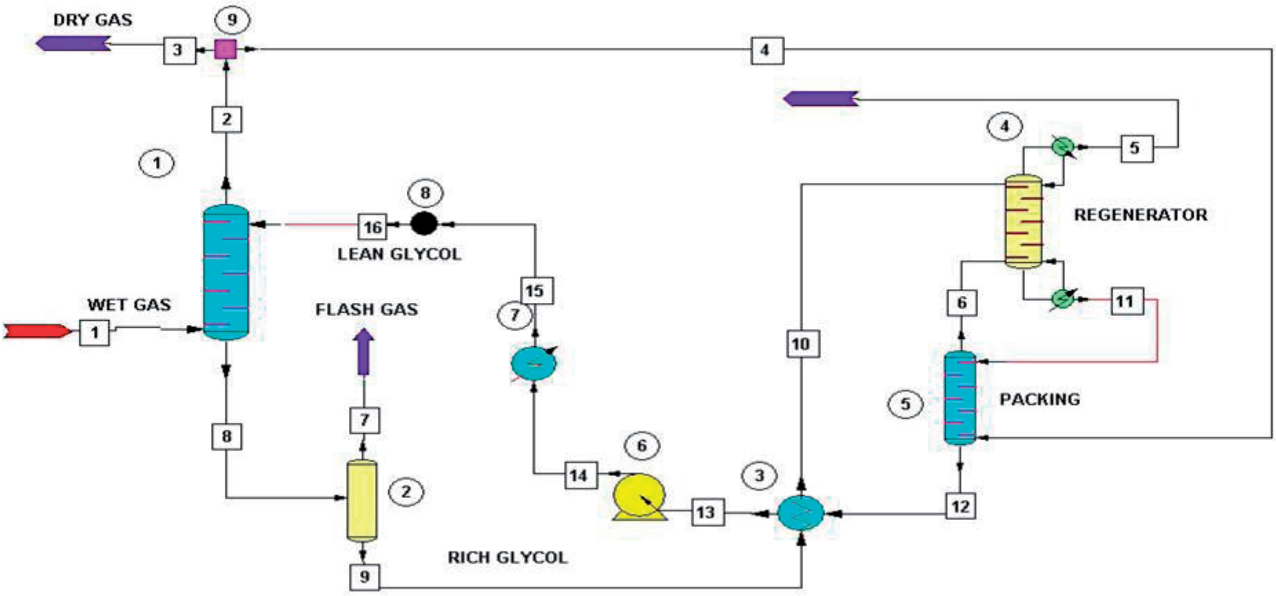
Streamlines in an exhaust gas heat exchanger



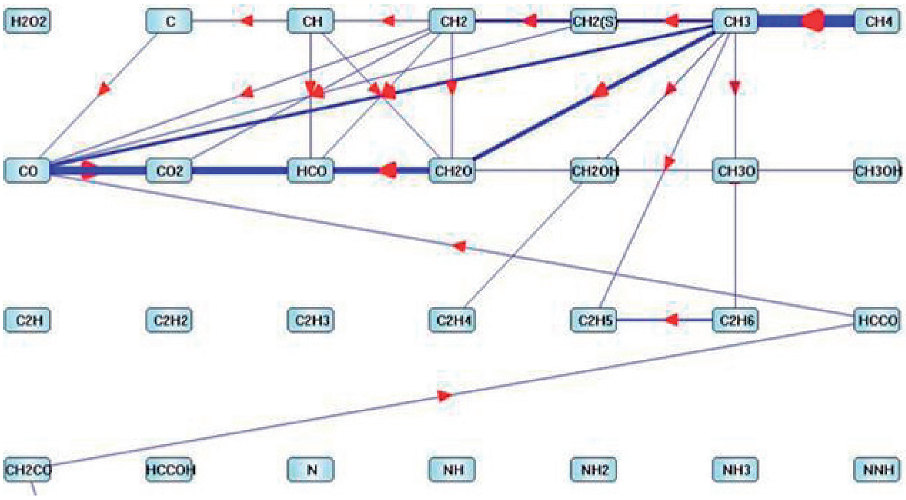
Wall heat flux density distribution in an aluminum smelter

Additional Simulation Capabilities

The numerical activities of GWI are by no means limited to the expert application of CFD methods. At GWI, simulations of the chemical kinetics of combustion processes are regularly carried out. Also, entire processing plants are simulated using dedicated process simulation tools.



PROCESS SIMULATION OF GAS DISTILLATION PLANT



ELEMENTAL FLUX ANALYSIS OF A NATURAL GAS FLAME (EXCERPT)

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We are looking forward to support you in providing solutions for your challenges - You are welcome to contact us!

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