Superior Products via Flow Simulation

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High-temperature furnaces for the creation of powder metal products generally have important key markets in the automotive industry. An essential parameter for the subsequent product properties is represented by the cooling process. By means of computational fluid dynamics and computer-aided solutions, the requests for product throughput and quality are investigated and verified. As one application, the flow optimisation in a rapid cooling process is analysed subsequently.

In the automotive industry and further technical sectors, the demands for standardisation, reproducibility, production reliability and availability are very high. Best-possible product quality is an absolute must. The rapid cooling segment constitutes an important process step during the production of powder metal parts. From the heating zones of a roller hearth furnace, graphite carriers get into the cooling zone through a sluice system. The product's cooling gradient then determines the product properties, thus distortion, microstructure and strength. High cooling rates lead to hard and brittle materials, mild rates yield more ductile materials. To control the cooling gradients as precise and reproducible as possible, a well-defined and identified flow guidance of the cooling medium and the optimum flow velocity is essential.

In the rapid cooling zone, a circulation fan serves for the continuous agitation of the atmosphere. A heat exchanger is used for the heat dissipation. The main challenge is to maximise the convective heat transfer from gas to product. Therefore, the flow condition of the circulating gas is a key factor for the cooling efficiency in order to reach a specified cooling gradient with a preferably low circulating gas rate.

At the beginning of a simulation study, boundary conditions and process parameters of the investigated furnace sections are reconsidered together with the customer. After that, basic ideas are discussed with the design department and a CAD model with sufficient accuracy is created. This representative model generates the framework for the preparation of a discrete computational grid with finite-volume elements. High emphasis should be taken to this step as a too rough grid could neglect local flow effects and a too fine grid results in huge computation times.

Furthermore, the discretized bodies are assigned with physical properties and constitutive equations. Generally, the relevant discretized furnace segment has to indicate all significant flow phenomena to achieve a high reliability of the simulation results. For complex analyses, high performance workstations and clusters are used in order to save computation time.

As mentioned at the beginning, given boundary conditions are necessary for the iterative solution of the differential equation systems. For the rapid cooling process, the conditions are rotational fan speed respectively volume flow, temperatures or magnitude of heat transfer.

As a possible study, the temperature distribution after 5, 20 or 50 s respectively can be predicted. The evaluation of the streamlines discovers inappropriate design parts, for example in the illustrated case where the vertical flow onto the product is negatively influenced by small gaps at the channel sides. As this loss in cooling efficiency can be detected in the design phase, the construction can be adjusted and optimised at an early stage.

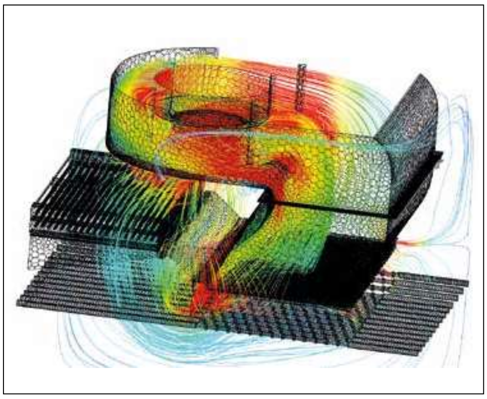

Fig. 1 The flow simulation is based on a CAD model with a discrete computational grid

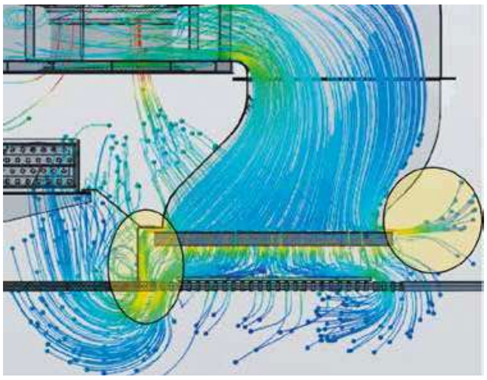

Fig. 2 In the present case, the vertical flow onto the product is negatively influenced by small gaps: the construction could be optimised and the problem solved quickly

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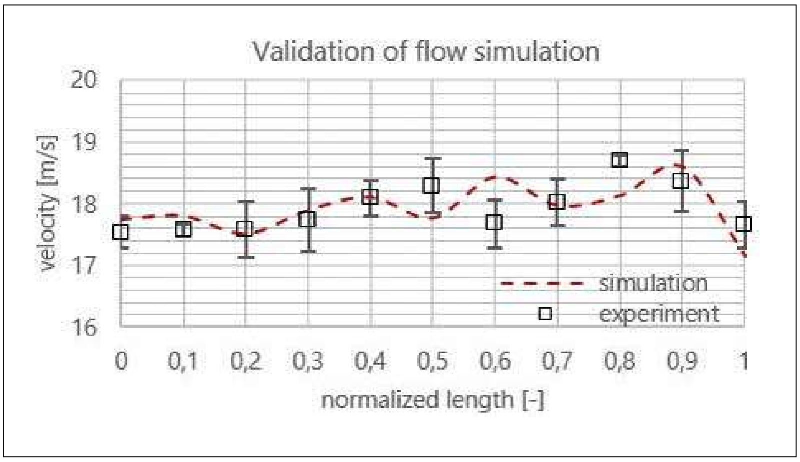

Fig. 3 Validation of flow simulation

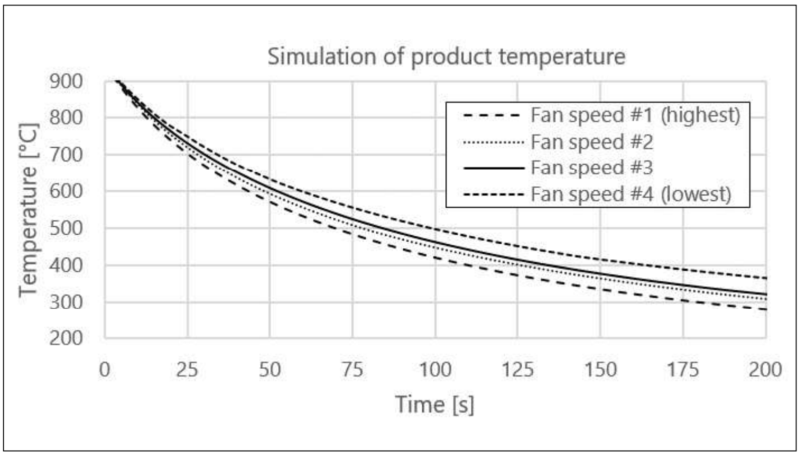

Fig. 4 Simulation of product temperature at different fan speeds

Fig. 5 Eisenmann One-Solution sintering kiln

Hence, the steps to an optimum furnace rest upon the cooperation between furnace operator, plant engineering, design and simulation department.

Customer specifications and boundary conditions are investigated accurately so that occurring process inconsistencies can be detected very early before running the process in production mode. Certainly, thermal and flow problems at existing furnaces can be identified and corrected via simulation.

Multiplex benefit by simulation

The simulation-based dimensioning and optimisation of furnace technology accompanied by measurements for validation of the simulation models is a specialty of Eisenmann Thermal Solutions.

The plant engineering company which is based in Böblingen is a technical leader in the development and realisation of continuous and discontinuous furnaces in the high-temperature sector, like roller hearth, shuttle, pusher type, lifting bar, lift-bottom and other furnaces. So, the manifold constructions have brought a large know-how which is incorporated in every new product development or in advancements of existing technology.

The consequent inclusion combines the expert know-how with state-of-the-art modeling approaches and thus provides the customer with useful process information at an early project phase. Eisenmann holds a lot of additional simulation references in thermal processes regarding ceramic sensors, particle filters or oxidative treatment of carbon fibres.

Model-based design-engineering promises technical and commercial benefits to the plant operators. Early information about the "inner life" of a furnace are visualised so that possible flow and temperature problems can be identified and both quality and production reliability can be secured. Finally, this implies time and cost savings for engineering, efficient cooperation with design department as well as fast and reliable decision-making for the best-possible furnace solution.

At commissioning of novel high-temperature furnaces, the customer specifications can be obtained quickly. So, Eisenmann is able to give guidelines for the optimum production parameters to their customers, already in the proposal phase.