FLUIDIC OPTIMIZATION OF PROCESSES AND SYSTEMS

THE TASK

Gases are used for many tasks in laser materials processing. Shielding gases protect the processing zone from the surrounding atmosphere. Process gases support the technical realization of many processes, such as the blow-out of molten material during laser beam cutting. Often they are used as secondary gases to protect processing optics or to purify the air in the process cabin. The latter aspect is important from a standpoint of health issues but also to maintain process stability and quality.

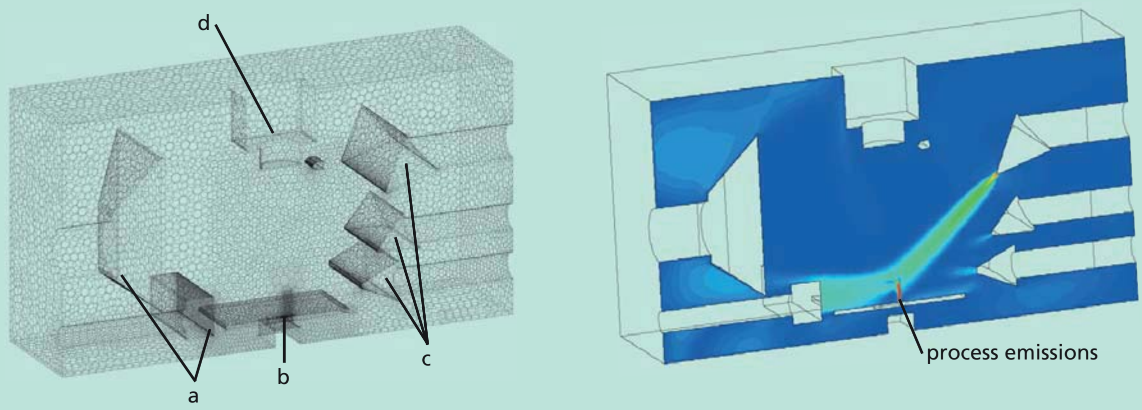
All these applications have in common the need to optimize gas flows depending on the particular circumstances. In addition to the desired functionality the gas consumption is an important cost consideration and of high interest. The technical dimensioning of machining stations and the analysis and optimization of the resulting gas flows are often difficult due to their complexity. The possibilities to visualize them are limited and it is often difficult to measure directly in the process zone. Alternative solutions are sought.

OUR SOLUTION

One possibility is the simulation of the flow conditions with problem adapted numerical models and powerful commercial CFD software. The state behavior of gases is sufficiently known. Thus the simulation predicts quite accurately the flow conditions and one expects good agreement with experimental data.

Figure 1 shows an example of a CFD model of a demonstrator processing station for remote laser welding. This model is used at the Fraunhofer IWS Dresden to study the effect of various ventilation components on the propagation and distribution of the process emissions. The simulation process can be automatically controlled and allows for the parametric setting of geometries and CFG meshing routines. This is useful for the design-of-experiment approaches that extensively analyze dependencies and study the effect of parameters.

Model of a remote laser processing station with a CFD mesh adapted to the problem: (a) exhaust air components, (b) process zone, (c) air supply components, (d) remote laser processing head



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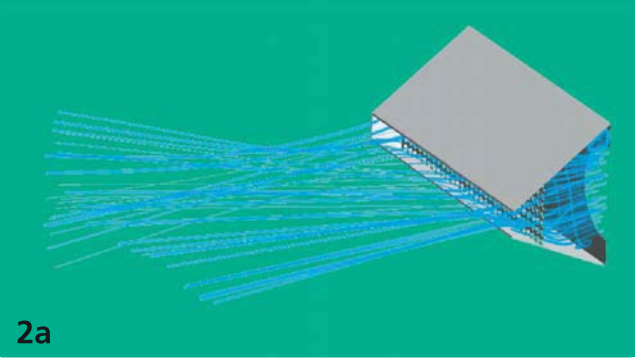
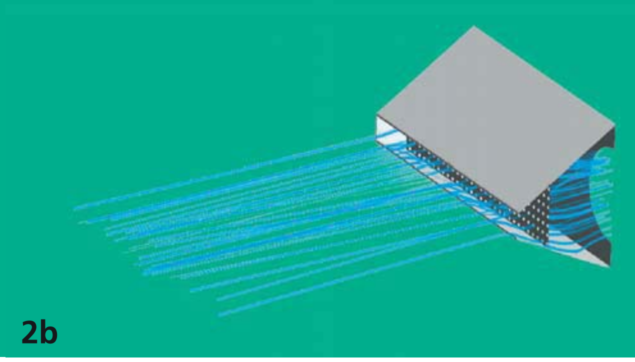


2a

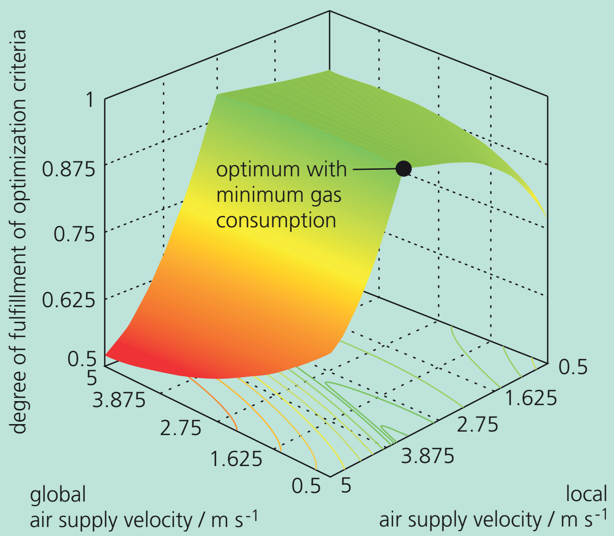


2b

RESULTS

The process gases are modeled using a multi component model. The supplied air is modeled matching the surrounding conditions (atmospheric pressure, room temperature). The process emissions are considered as an iron vapor at evaporation temperature that is introduced to the calculation region. Figure 1 shows an application considering the species transport through the process cabin as well as the heat transfer processes. What is not modelled are phase transitions, particle formation and chemical reactions. The target response is the spatial expansion of the process emissions within the laser beam, which helps to qualitatively judge the effect of different parameter constellations (Fig. 1, right).

Optimization of process criteria as a function of the flow velocity of supply air components



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Of special importance for the accuracy of the prediction of such global air flows is the detailed analysis of the used components (Fig. 2). The results serve both to optimize the individual components and to provide input data for the cabin simulation. The presented model was used to perform extensive statistically designed simulation experiments.

In the first phase numerous geometric and fluid-dynamical factors were studied with respect to their influence on the system behavior and the main factors were identified. The second phase focused on the statistically significant formulation of the system behavior with a complex nonlinear regression model. This model was used to optimize the process parameters (Fig. 3). Assuming an acceptable expansion of the process emissions, the model showed clear potential to reduce the gas consumption compared to existing machine concepts.

2 Supply air nozzle with integrated perforated plate (a) 8 mm, (b) 4 mm

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