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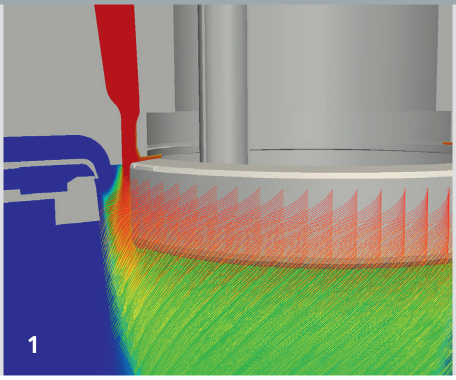
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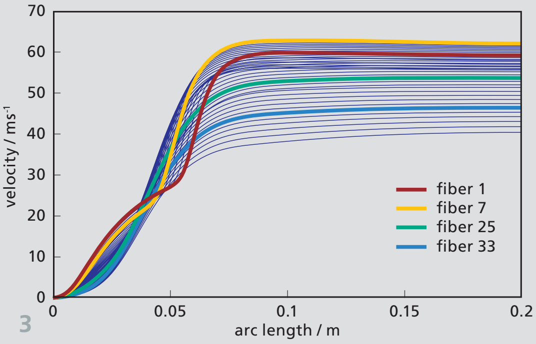

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1 Simulation results of a rotational spinning process, Woltz GmbH

2 Rotational spinning machine

3 Velocity of filaments discharged from nozzles in different positions, Woltz GmbH

SIMULATION AND OPTIMIZATION OF INDUSTRIAL SPINNING PROCESSES

The spinning processes are important industrial processes with applications ranging from staple fibers and nonwovens to industrial textiles. After the molten polymer, with or without solvent, exits the spin pack, the spinning process is the crucial step in the production of fibers and filaments. Computer simulations can be used to optimize spinning processes. Sample results of simulations performed at Fraunhofer ITWM are shown for three different examples.

Rotational spinning process

In the rotational spinning process the extrudate is first distributed onto a rotating disc as a glass film. Then it is pressed out by centrifugal force through thousands of holes and frayed out in a stream of air created by a hot gaseous flow near the disc and a surrounding curtain of cold air. This process can be optimized to find the distribution of nozzle diameters which leads to a uniform distribution of fiber diameters in the final product. This optimization requires accurate simulation of the spinning process which entails a high degree of coupling due to the aerodynamically determined filament curves, as well as coupling with the glass film inside the rotor. In figure 1 simulation results for such a process at the company Woltz GmbH are demonstrated. A photo of an industrial rotational spinning is shown in figure 2. The speed of filaments from different nozzle positions are visualized in figure 3. The filaments have different speeds at the nozzle outlet due to the variation of temperature and centrifugal pressure. Simulations at ITWM made it possible to identify which nozzle positions lead to resulting diameters. The hole distribution was redesigned to achieve a uniform diameter in the final product.

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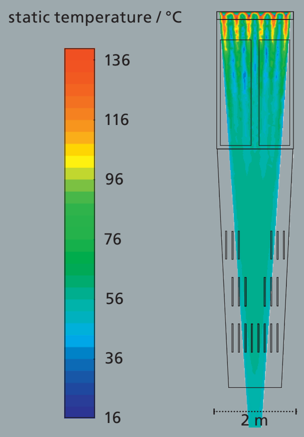
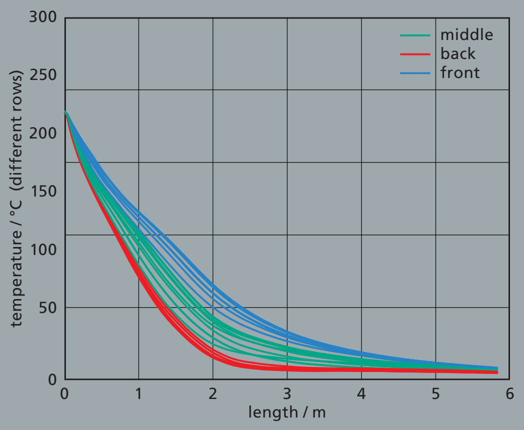
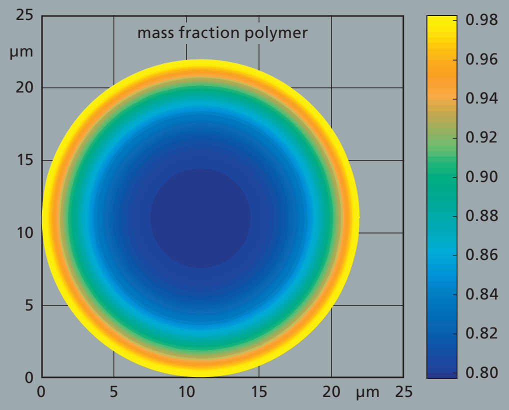


4 *Temperature contours of air, Van de Wiele*



5 *Temperature profile of the fibers discharged from nozzles in different positions, Van de Wiele*



6 *Typical polymer concentration in fiber cross-section*

Melt spinning in the duct

In this process, a hot melt is fed to nozzles at the top of the cabinet. Viscous filaments are then discharged from the nozzles in the vertical direction. Over a distance of one meter, a stream of cold air injected from the side cools the filaments. The solidified fibers are then collected by the take-up wheel at the bottom. Computational models are used to simulate the aerodynamic and thermal interaction of the fibers and the cooling air. Based on simulations, the duct geometry can be optimized in order to achieve homogenous cooling of the fibers and reduce, or ideally eliminate, fiber “dancing“ due to turbulence. In figure 4 the spinning duct used by the company Van de Wiele is simulated. The variation of air temperature clearly shows the interaction between fibers and air flow. The cold air entering the cabinet at about 20 °C is heated by the fibers to 140 °C. The six spin packs appear as heat sources in the duct. By modifying the duct geometry it was possible to achieve a homogenous cooling in each spin pack and reduce turbulence in the bottom section. Figure 5 shows the fiber temperature along the duct for different positions in the spin pack. The fibers closer to the cold air inlet are cooled faster down. The spin pack is circular. Therefore, there is a large temperature difference between fibers along the edge of the spin pack and fibers in the middle; the filaments at the edge are cooled faster. Based on simulations, optimization of the nozzle positions in the spin pack led to a more homogenous cooling of all fibers.

Dry spinning

The main goal of the drying process is to remove the diluent from the fibers. Similar to the melt spinning process the solution (polymer with diluent) leaves the nozzles into the cabinet. It is then dried by a gas flow and taken-up at the bottom. In contrast to melt spinning, the radial profile of polymer concentration has a significant impact on drying. Generally mass diffusion is so slow that even in microscale fibers, there is a significant gradient in the radial direction; see figure 6. Often the surface of the fiber becomes dry very close to the nozzle, while the center is still wet. In this case, further mass loss can change the shape of the fibers.

In dry spinning, temperature and diluent concentration of the gas determine the viscosity of the fibers. If there are too many fibers, the humidity level increases and the fibers are not dried completely. As a result, the fibers may even break. Another aspect to consider is turbulence in the gas flow, which can also lead to breakage. Generally the machines run for weeks without interruption, but this is only possible if proper conditions of temperature and humidity are reached in the stationary state. With simulation it is possible to analyze the drying behavior of the fibers as well as the gas flow and especially the humidity in the duct. The duct geometry can hence be optimized to reduce turbulence.