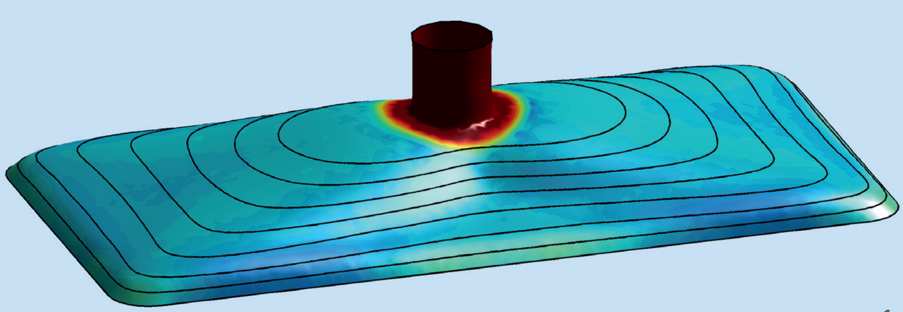
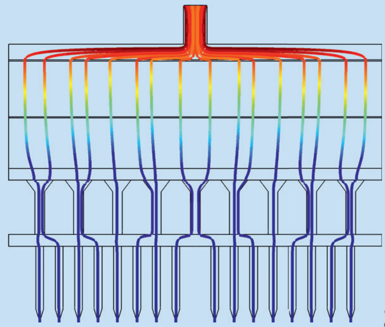
Fraunhofer
ITWM

FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS



1



2

1 Optimal cavity design for a polymer distributor without dead zoness

2 Visualization of the polymer paths within the spin pack (reference design)

OPTIMAL SPIN PACK DESIGN

Computational fluid dynamics and simulation based optimization can play an important role in the design and improvement of spin packs for the production of filaments and nonwovens. Since detailed measurements of the polymer flow within the spin pack are impossible, problems in the spinning process can only be resolved by trial and error methods. At this point flow simulations can be an important tool, because they enable the engineer to look into the spin pack itself and examine complex flow situations. In the following we want to provide some specific examples, where flow simulations can speed up the design process and help to improve the quality of polymer spin packs.

Automated design of cavities to avoid dead zones and polymer degradation

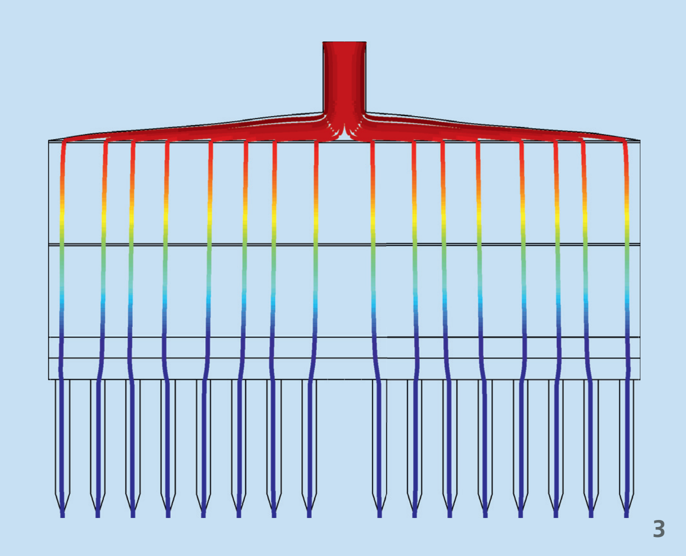
Dead zoness within the spin pack or regions with slow flow velocity can have extremely negative effects on the filament quality and the overall performance of the spin pack. Since the occupation time in these regions is high, polymer degradation can take place. Degraded polymer can reach or block the fine capillaries. Finally, this may lead to filament breaks, frequent cleaning cycles and production stops. Flow simulations are a reliable tool to identify dead zones and regions with significantly slow velocities. The cure is of course a modification or redesign of the spin pack geometry. However, the optimal geometry can be very complex and a derivation by hand is not practicable. For this reason, Fraunhofer ITWM has developed a tool for automated geometry design, which is tailored for the construction of spin pack geometries. This tool is able to design flow geometries with homogeneous wall shear stress profiles. The pressure drop within cavities is primarily generated by the friction at the walls. Therefore, with some simplifications we can say that a homogeneous wall shear stress leads to a homogeneous pressure drop. In the same way the resulting flow velocities become more uniform and especially regions with slow velocities are eliminated. See fig. 1 for such an automated geometric design of a spin pack cavity without any dead zones and

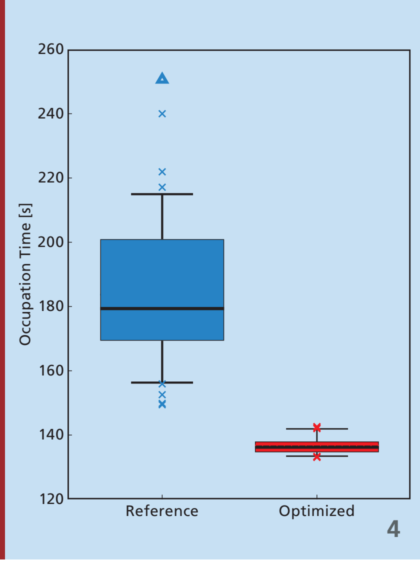
Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM

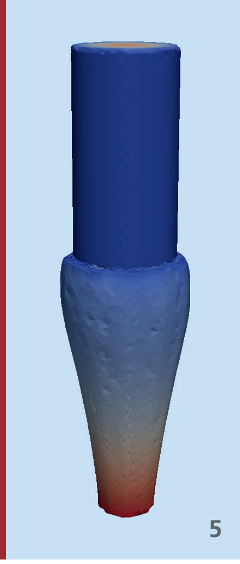
Fraunhofer-Platz 1
67663 Kaiserslautern
Germany

Contact
Dr. Christian Leithäuser
Phone +49 631 31600-44 11
leithaeuser@itwm.fraunhofer.de

www.itwm.fraunhofer.de







3 *Visualization of the polymer paths within the spin pack (optimized design)*

4 *Differences in the occupation time in the reference and optimized spin pack*

5 *Polymer extrusion with die swell*

with an optimal pressure gradient. This is an effective tool to avoid polymer degradation.

Uniform filament properties

The characteristic properties of high quality filaments must be very similar and the deviations, for example in diameter, tenacity and elasticity, must be as small as possible for all filaments. To achieve this, already the polymer conditions inside the spin pack should be equal along every polymer path. This includes pressure gradients, temperature as well as occupation time. Different pressures or temperatures at the capillary entries lead to variations in the flow rate and thus to different filament diameters. On the other hand variations in the polymer occupation time influence filament characteristics.

Naturally, there are always differences in the flow paths, for example between capillaries at the central and outer parts of the spinneret plate. But potential problems arising from these differences can be identified and reduced with the help of flow simulations: If deviations in the diameter are generated by non-uniform pressure gradients, the geometry of the spin pack or the positions of filter elements can be modified to reduce these effects. If temperature variations are the cause, the heating can be adapted. And if differences in occupation time are a problem, dead zones should be removed. All modifications improve the uniformity of the filaments and thus their quality. The effects of every modification can be verified by flow simulations and therefore a construction and real experiments are only necessary in the final step.

See fig. 2 and 3 for a visualization of the polymer paths through two different spin pack designs. The second design has been optimized such that the polymer occupation time within the spin pack is as homogeneous as possible for every path (see fig. 4).

Die swell and viscoelastic effects

Another critical step for the filament quality is the extrusion from the capillaries itself. Small diameters of the capillaries and high flow velocities lead to high shear rates and therefore complex rheologic effects play an important role. Viscoelastic material properties lead to the formation of a die swell. Such detailed simulations are challenging because of the complex rheology and the difficulties arising from the free surface flow at the air-polymer interface. On the other hand, simulations are important to answer questions about the best length to diameter ratio or the optimal nozzle design for bicomponent extrusion. At Fraunhofer ITWM we are able to answer these questions with the help of our own fluid solver FPM ("Finite Pointset Method"). FPM is a meshfree method and is therefore very well suited for free surface flows. Addition-ally, the necessary rheologic relations are included to represent viscoelastic effects and the resulting die swell. Fig. 5 shows such a detailed simulation of the polymer extrusion from a single capillary.