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Improved control over the residence time distribution in pipings for the

Production of Chemical Fibres

One of the key factors for the successful production of chemical fibres of highest quality is a homogenous polymer melt, particularly before the spinning nozzle. The Polypeeler® of Fluitec is a novel static flow inverter. It combines surpassing performance with little energy consumption. It is mounted in individual units behind each other into the long pipings. Directly before the spinneret, however, the melt is thoroughly homogenised by using the well-established CSE-X mikromakro® mixer. This unique combination ensures a constant high quality of the polymer fibres at low energy consumption. It is therefore especially dedicated for the processment of polymers of higher viscosities (IV > 0.8).

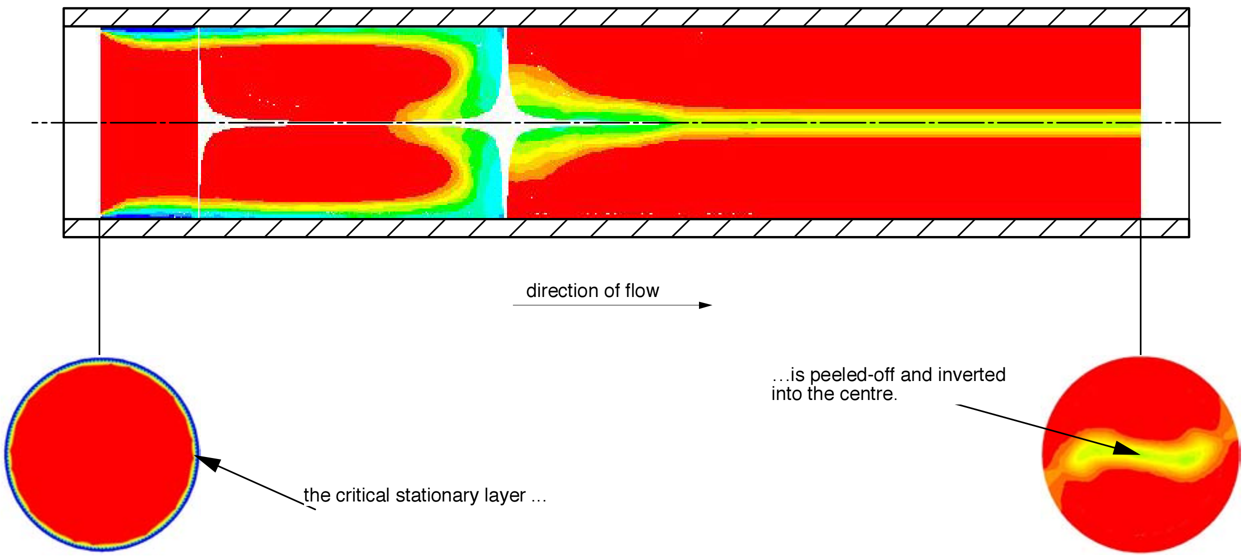

Fig. 1 CFD calculation of a Fluitec Polypeeler® for the inversion of stationary liquid films

Introduction
Polymers often have the tendency to decay during processing and compounding steps, thus forming oligo- and monomers. The rate of depolymerisation is a factor of the polymer type itself, of the residence time, of the melt temperature and of the already existing monomer concentration.
These degradations often cause problems in the industrial production of chemical fibres, such as the rupture of filaments or the inhomogeneous distribution of dye. Especially if processing critical polymers, such as PET or PA6 and PA66, it is therefore of high importance to control the distribution of the residence time and of the temperature as exactly as possible. A homogeneous melt before the spinneret is the most important factor for the production of fibres of highest quality.

Static mixers are used for many years in pipings to homogenise polymer layers with different residence times, unequal temperatures and thus variegating viscosities. Due to the length of the pipings and the high pressure drop of the mixing elements, new concepts of the piping and of the homogenisation devices must be found.

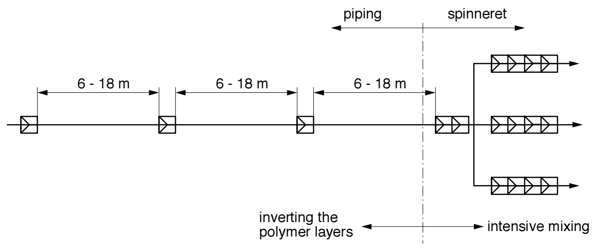

Fig. 2 First inverting, then mixing the polymer

Problems caused by long pipings

The increasing dimensions of polymerisation plants also involve longer pipings. If analysing the laminar flow regime in empty tubes, it is evidently that the flow velocity in the core of the polymer is very high while the polymer near the tubes wall is almost motionless. The resulting parabolic velocity profile over the cross sectional area is a function of the rheological properties of the polymer.

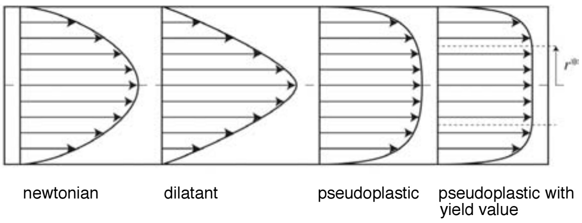

Fig. 3 Velocity profiles of polymers with different rheological properties

Fibre polymers often have almost Newtonian or slightly pseudoplastic properties. Fig. 3 indicates that the polymer film close to the tubes wall is almost stationary.

If changing the polymer production to a next campaign (e.g. from black to white), H(θ) is used to describe the concentration of the polymer which has left the empty tube. $\theta = t/\tau$ is the ratio of the residence time measured in the process to the mean theoretical residence time. Experiments in an empty tube of DN 25 gave the following results:

- $\theta = 0.5$ The fastest polymer stream in the core (white colour) only needs half of the mean theoretical residence time.
- $\theta = 1$ 75% of the volume (black) has already left the empty tube. The remaining thickness of the black polymer at the tubes inner wall is approx. 1.8 mm (tube of øID = 27.3 mm).
- $\theta = 2$ 5% of the volume (black) has a 4-times longer residence time than the fastest polymer stream. The thickness of the remaining polymer film at the tubes inner wall is about 0.3 mm.
- $\theta = 5$ 11% of the volume (black) has a 10-fold longer residence time than the fastest polymer stream. The thickness of the remaining polymer film at the tubes inner wall is still about 0.15 mm.

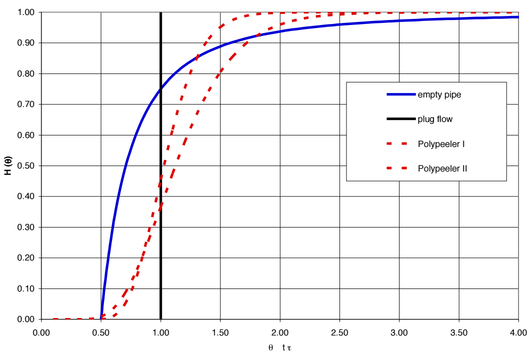

Fig. 4 Residence time distribution (Polypeeler®)

Improved plug flow at low pressure drop

The residence time distribution can be reduced significantly if applying the novel Polypeeler®. The Polypeeler® is mostly installed as series of units with defined distances between each other. Its performance is based on the consequent peeling-off of polymer from the tubes wall and guiding it to the tubes core and vice versa. The continuous inversion of the slow and of the fast polymer layers is leading to a much more uniform residence time distribution and thus an increased product quality. Fig. 4 indicates the improved residence time distribution if using the Polypeeler®. Polypeeler®-mixers are mostly used as a series of units with gaps of empty tubes in-between. Its performance can be optimized to customized pipe-sections by using CFD calculations.

For the quantitative description of the residence time distribution, the Bodenstein-Number Bo is often used. It is the value for the quality of the residence time distribution if using the dispersion model. Bodenstein-Numbers of 20 to 100 can easily be reached if using CSE-XR mixer/heat exchangers, Polypeelers® and CSE-X mixing elements. These values indicate very narrow residence time distributions, almost equal to prefect plug-flow. Nowadays, a fibre-spinning plant can be designed as follows:

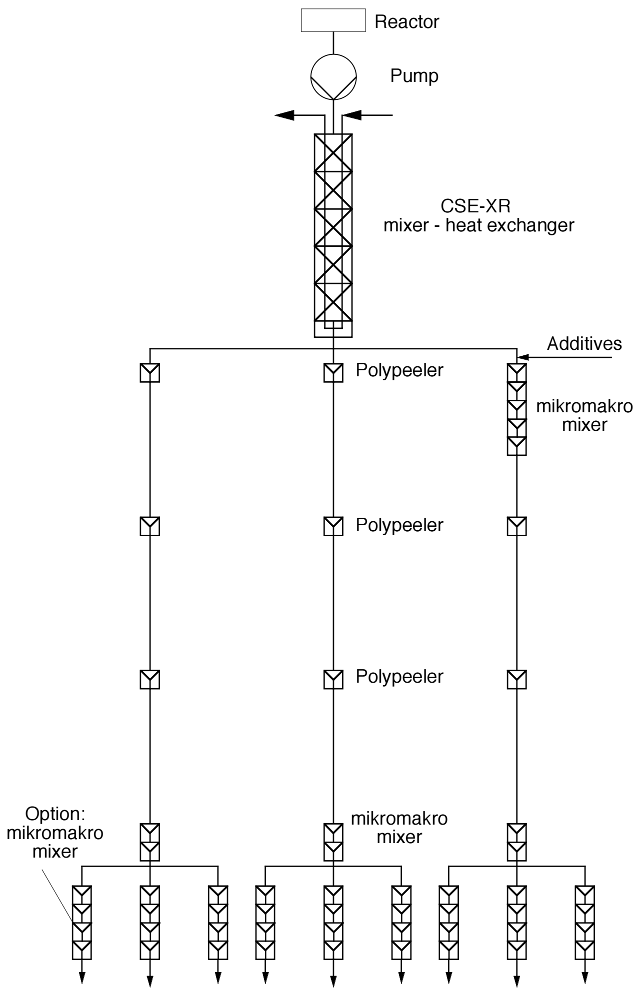

Fig. 5 Fibre-spinning plant acc. to Fluitec concept