Experimental Investigation and Identification of Material Parameters for Rubber Blends

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Overview

Capillary rheometry simulates polymer extrusion in a simplified way. It allows the characterisation of polymers by means of determination of the viscosity function and extrudate swell. As regards viscous properties, there is still a lack of constitutive characterisation of rubber blends. On this poster a new concept is presented how the viscous properties are computed without using common correction methods [1].
The so-called die swell is the determinant criterion for the production of rubber profiles by means of extrusion. Therefore its experimental investigation and numerical treatment is of high interest. This was one of the motivations for starting a research project in the field of rubber blend technologies [2]. The consideration of the die swell for the production of rubber profiles is necessary. Thus, the final goal of this project is the numerical prognosis concerning tools for the extrusion of rubber.

Literature:

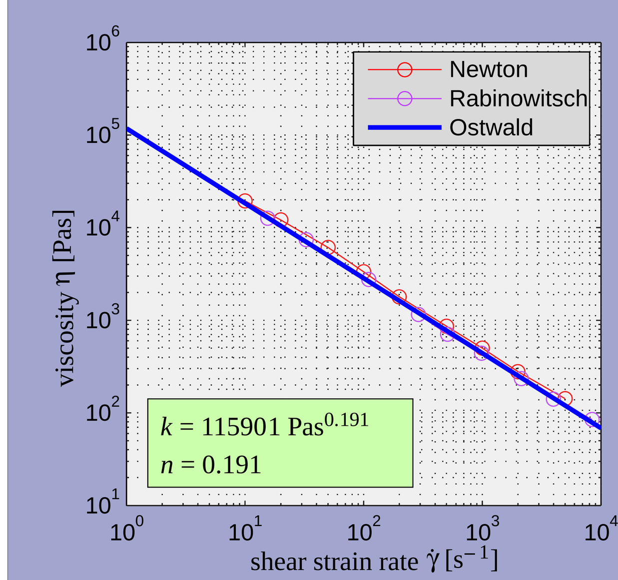
[1] W. Michaeli: Extrusion Dies for Plastics and Rubber - Design and Engineering Computations (2003), Carl Hanser Verlag.
[2] H.W. Müllner, J. Eberhardsteiner, A. Wieczorek: Constitutive Characterisation of Rubber Blends by means of Genetic Algorithms, Constitutive Models for Rubber IV (2005): 361-368.

Constitutive Characterisation by means of a Power Law

For the description of the pseudo-plastic material behaviour of rubber blends the power law by Ostwald and de Waele in [1] is used. Its application to the investigated rubber blends is possible for a common interval of the shear strain rate $\dot{\gamma}$.

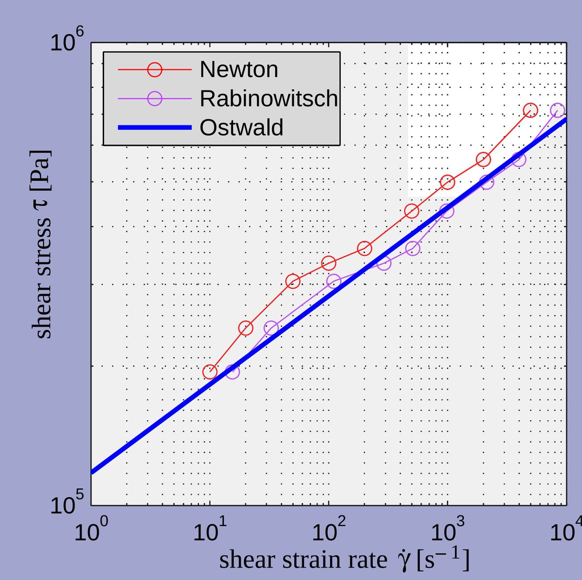
application to a viscosity curve

$$\eta = k\dot{\gamma}^{n-1}$$



application to a flow curve

$$\tau = k\dot{\gamma}^{n}$$



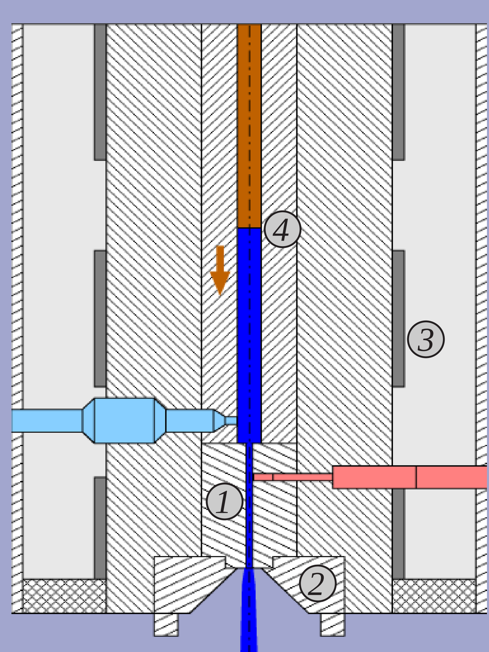
k ... consistency factor
n ... viscosity exponent

determination of power law constants by means of Gaussian quadrature

$$n = \frac{j\sum_{i=1}^{j}\lg\tau_i\lg\dot{\gamma}_i - \sum_{i=1}^{j}\lg\tau_i\sum_{i=1}^{j}\lg\dot{\gamma}_i}{j\sum_{i=1}^{j}\lg^2\dot{\gamma}_i - \sum_{i=1}^{j}\lg\dot{\gamma}_i\sum_{i=1}^{j}\lg\dot{\gamma}_i}$$

$$\lg k = \frac{1}{j}\left(\sum_{i=1}^{j}\lg\tau_i - n\sum_{i=1}^{j}\lg\dot{\gamma}_i\right)$$

Experimental Investigations

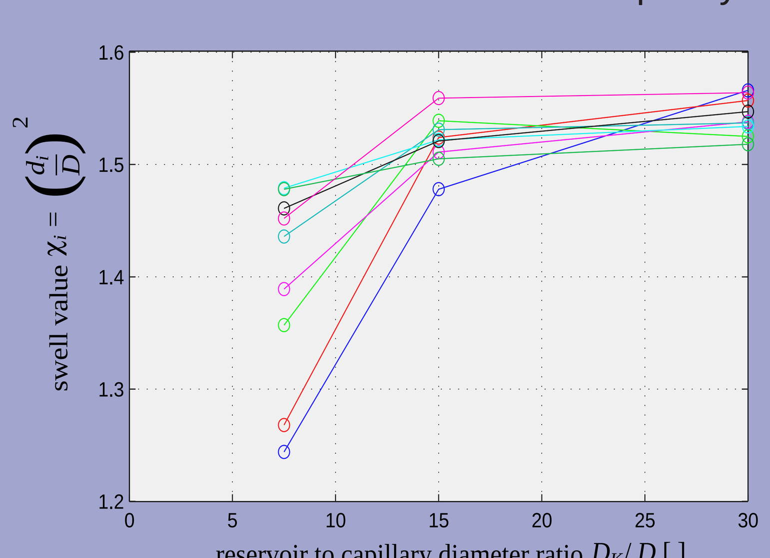


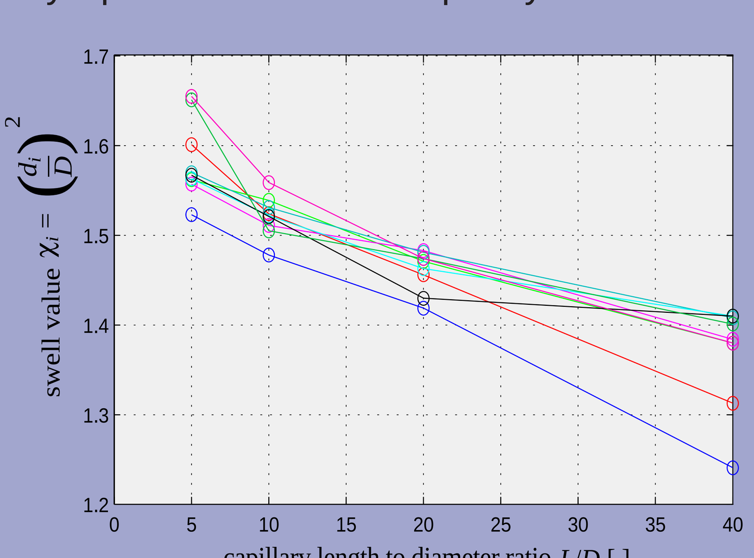
testing melt
test stamp
pressure sensor
temperature sensor
① capillary
② capillary nut
③ radiator
④ testing chamber

In order to determine the viscosity of rubber experiments with a capillary-viscometer are required. With a certain stamp velocity v the melt pressure p is obtained. Up to 100 experiments for each rubber blend with different capillary lengths L, capillary radii R and melt temperatures T were performed. They allow the development of a new material characterisation method.

The strand diameter after the exit of the capillary-viscometer was investigated by means of a high-speed camera, because the highest exit speed of the strand is about 1000 mm/s.

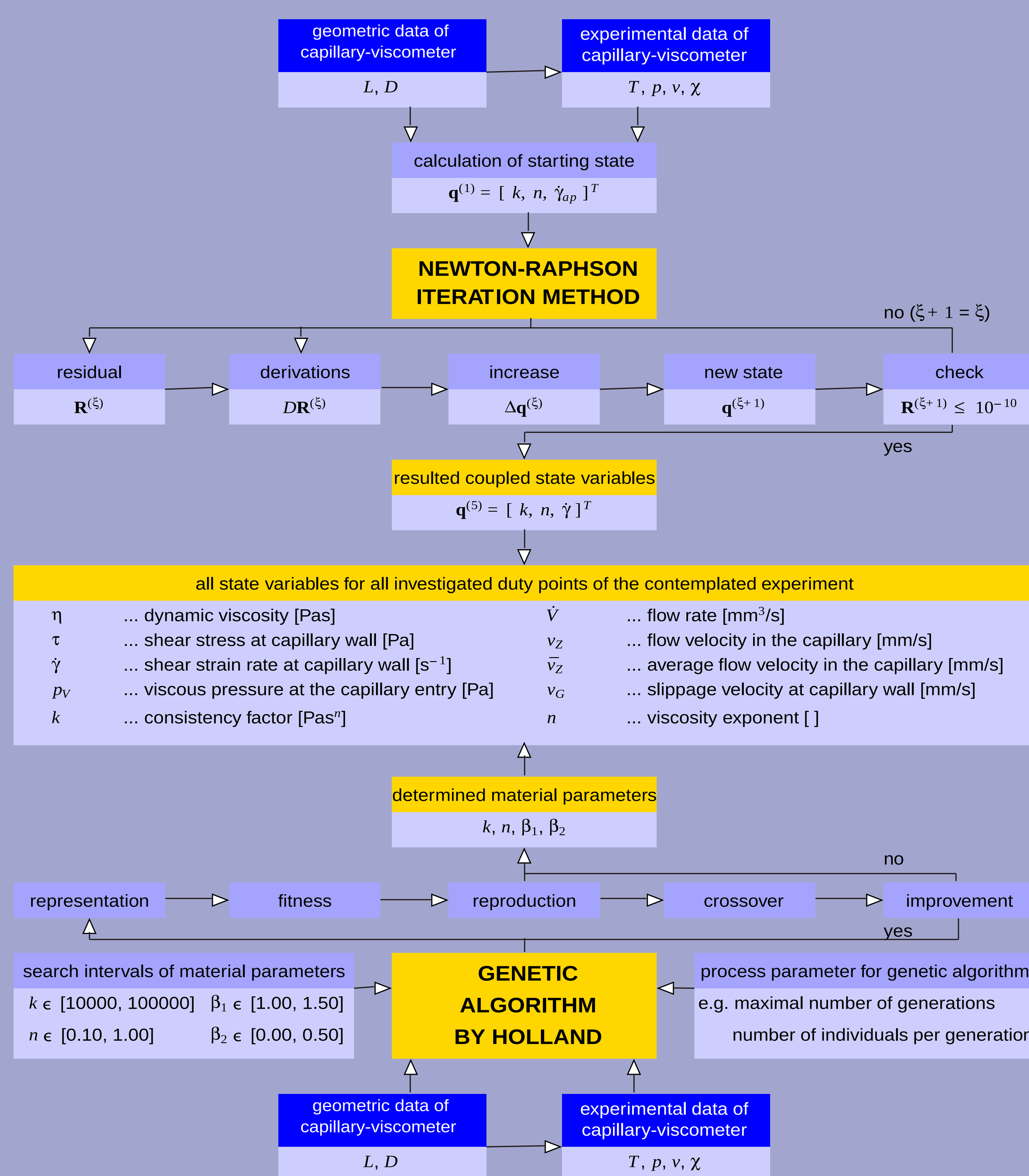
Alternative to the high-speed camera the strand diameter has been investigated by means of a laser beam with the so-called swell value measuring unit. The diameter of the investigated rubber blends increases after the capillary entry up to 16 % of the capillary diameter D.



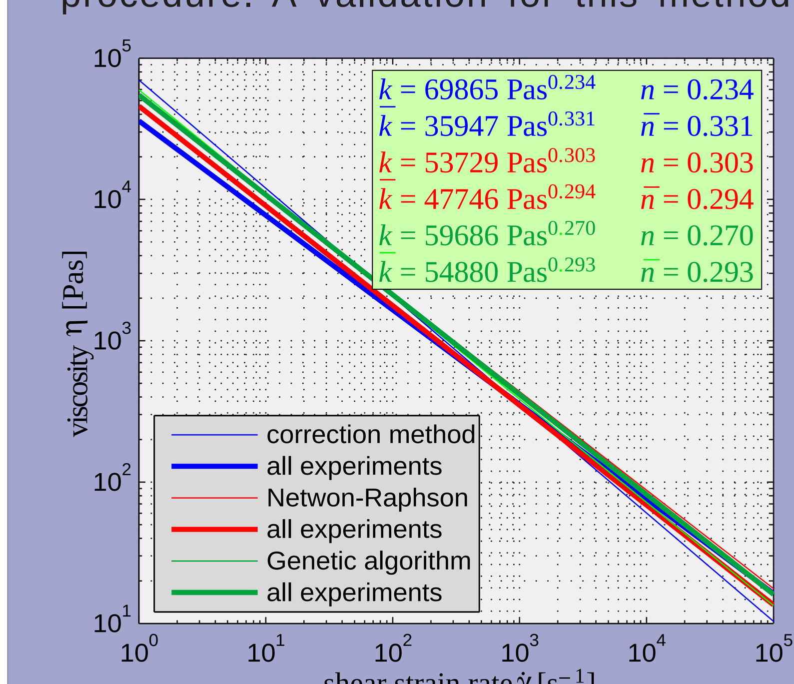


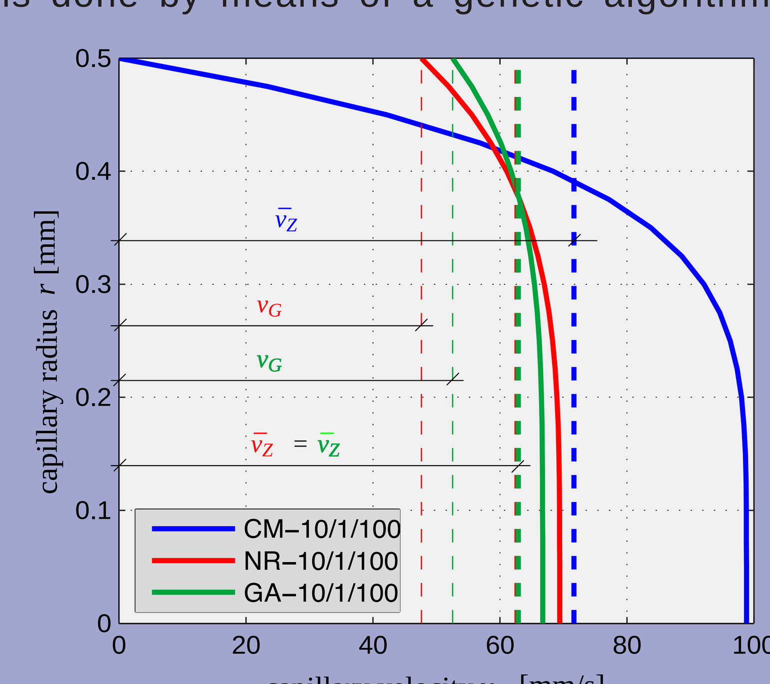
With the measured swell values various statements of the elastic behaviour of the investigated rubber blends are possible. From the rheological point of view the die swell occurs as a result of the recovery of the elastic deformation imposed in the capillary. The swelling of the strand after the exit from a capillary is typical for non-Newtonian viscoelastic materials like rubber.

Alternative Material Characterisation



The flow chart shows all required steps for the use of the generalized Newton-Raphson procedure. A validation for this method is done by means of a genetic algorithm.





The comparison of the obtained viscosity curves leads to a good conformity. The nonlinear coupling between the viscosity and the shear rate is in high gear. Because $n < 1$ rubber has a pseudo-plastic behaviour.

Contemplating the velocity profiles in the capillary shows that the results with the alternative methods hold the continuity condition. This fact increases the accuracy of numerical simulations of the extrusion process.