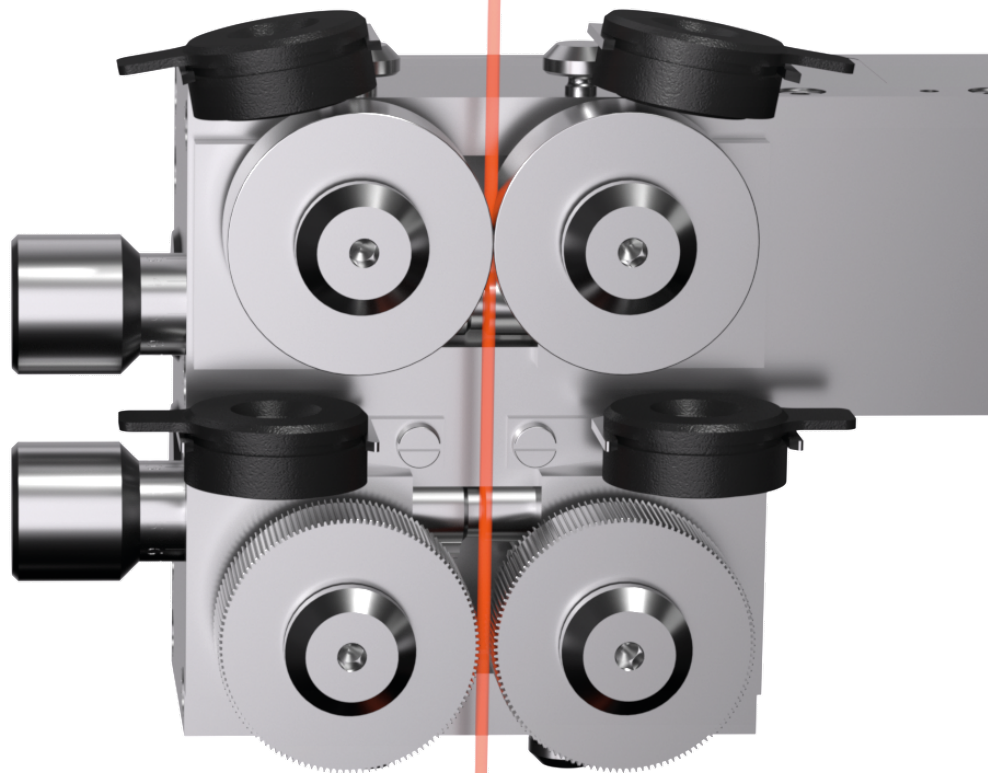



viscosity


elongation


continuous
process

ELONGATION



GÖTTFERT
 THIS IS RHEOLOGY

MELT ELONGATION

Key parameter for many processes in plastics production and processing

TECHNICAL ELONGATION TESTERS

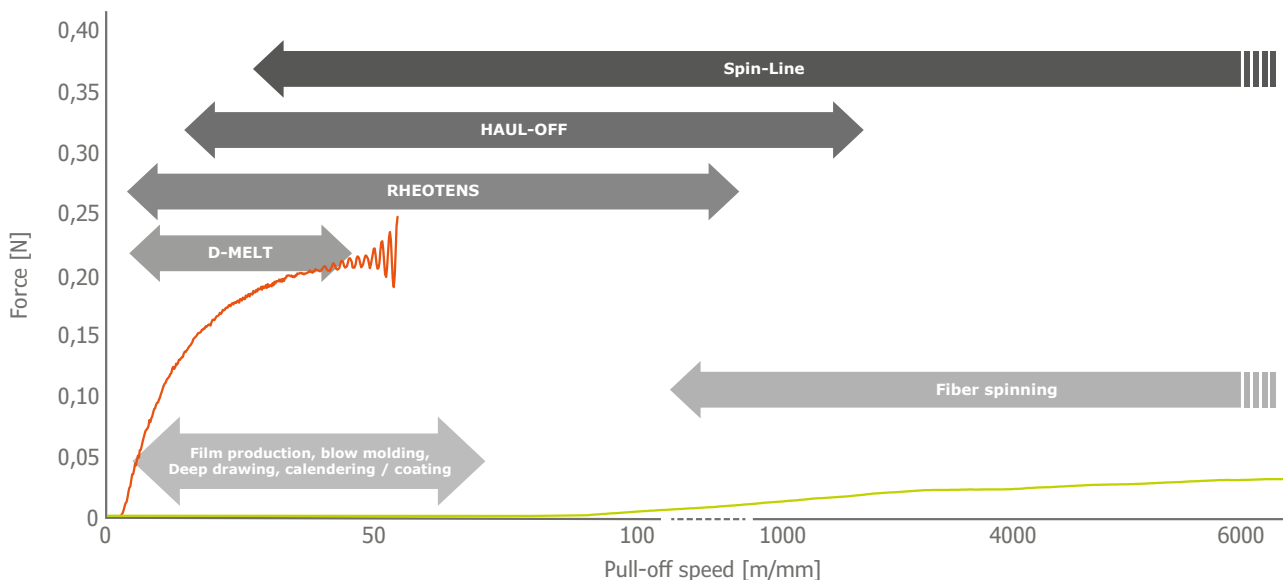
The constant rise in productivity means material elongation is becoming increasingly important. In plastics processing, melt pull-out – as occurs in film production, blow molding, deep drawing, calendering/coating and fiber spinning – is one of the most common production processes alongside forming in shear and expansion flows in extruders and tools during extrusion and injection molding.

In order to describe these processing procedures, it is essential to determine the elastic properties of the melt. Within this context, determination of the viscosity or even the melt index is simply insufficient.

The most important requirements of the test method applied are:

- Short testing time
- Simple operation
- Elongation rates similar to the process conditions
- Suitability for product development
- Suitability for quality control

OVERVIEW OF PROCESSING RANGES AND TEST PROCEDURES

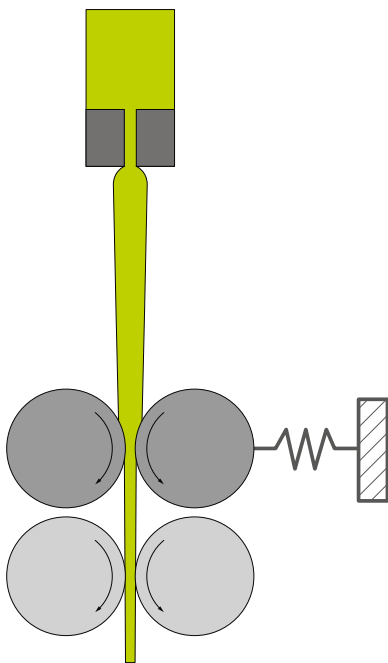


ELONGATION TESTER FOR POLYMER MELTS

The pull-out capability of polymer melts is a key parameter for many processes in plastics production and processing.

The patented RHEOTENS procedure has proven to be an extremely sensitive measuring principle, which delivers reproducible results to demonstrate even the smallest of batch fluctuations.

THE RHEOTENS 71.97 OFFERS, FOR EXAMPLE, THE FOLLOWING INNOVATIVE FEATURES:



Tandem pull-off wheels (* patented)

A second pair of rolls has been integrated in order to also be able to elongate highly adhesive polymer melts. This second pair of rolls has the task of pulling off the strand after passing through the first pair of rolls.

Extended speed range

Compared to its predecessor, the speed range has been extended by 60%, wherein a continuously adjustable speed of up to 1900 mm/s (114 m/min) at a maximum acceleration of 3200 mm/s² can now be achieved.

Measuring range

The force measuring range extends from 0 to 2 N with a resolution of 0.001 N. Calibration takes place automatically.

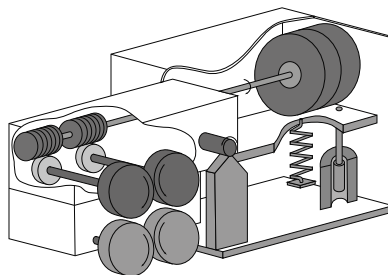
Software

The WINDOWS user interface of the RHEOTENS and HAUL-OFF software has been developed with maximum user-friendliness in mind. The evaluation functions have been integrated into EXCEL. This provides a convenient, easily adaptable display and further processing. A joystick supports control and the measuring process.

Test execution and evaluation functions

In addition to the already existing linear, constant pull-off speed and constant acceleration, exponential speed control has been integrated. The determination of the elongational viscosity function according to Prof. Wagner is an integral part of the RHEOTENS and the HAUL-OFF.

RHEOTENS WITH TANDEM PULL-OFF WHEELS



The functional diagram shows the RHEOTENS 71.97 with tandem pull-off wheels, which can also be retrofitted to older devices.

D-MELT

Determination of the melt index and elongational viscosity in just one measurement



HIGHLIGHTS

- Determination of the melt index and melt elasticity in just one measurement
- Speed range from 0 to 44.8 m/min (D-Melt, Haul-Off)
- Meaningful individual parameter as a result of the Haul-Off measurement
- Graphical display of the force and speed curve during the measurement
- Recording of force, speed and time
- Simple, pre-defined measuring principle enables an automatic measuring program
- Freely definable speed profile
- Operation and data recording via separate PC software D-MELT Console (optional MFRHost and RHEOTENS E)
- Precise and high-resolution force sensor

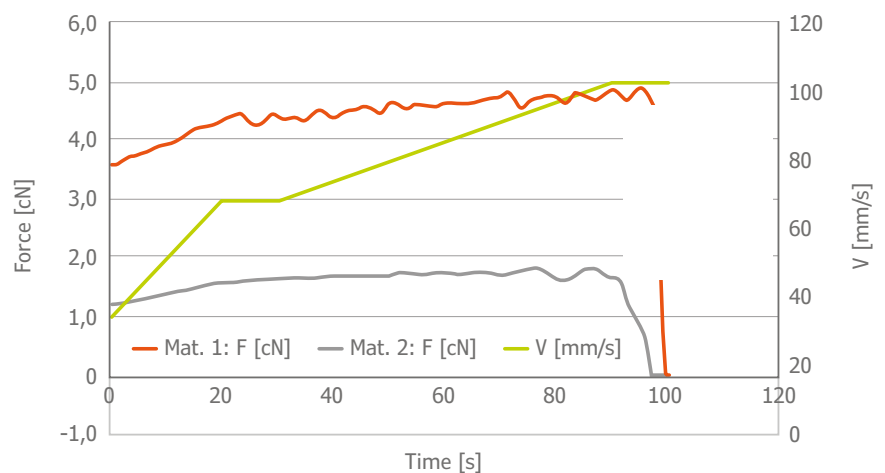
D-MELT

D-Melt enables the determination of the melt index and elongational viscosity in just one measurement. This combination is particularly interesting as a rapid test for inspecting incoming goods in polymer processing.

The melt index measurement is an internationally standardized procedure for determining the flow property of plastic melts. The sample is melted in a heated test barrel and then extruded through a capillary with a test piston and a defined weight on top. Based on this, the MVR (melt volume rate) is then determined in $\text{cm}^3/10\text{min}$. This value can be converted with the melt density into the MFR (melt index) in $\text{g}/10\text{min}$.

In addition to the melt index, the D-MELT, which consists of a mi40 and an adapted haul-off system, enables the determination of the elongational viscosity with just one measurement or just one filling of the test barrel. To shield the HAUL-OFF from external influences during the test, it is installed in a closed case below the mi40, which is easily accessible from the front via doors. The cover is made of transparent polycarbonate. The case is permanently connected to the mi40 and the HAUL-OFF is already aligned upon delivery. The process enables a quick, simple and cost-effective comparison of a quality parameter. This provides information about the extrudability of a material. The defined value is ideally suited for the process control of material manufacturers or for material processors when inspecting incoming goods. Aligned cleaning tools for optimum results

D-MELT OR MELT INDEX MEASUREMENT



The following comparison shows the considerably higher selectivity of the test method compared to the pure melt index measurement. The simple operation, short measuring time and low speeds make this method particularly suitable for quality assurance during compound release or in incoming goods inspections.

RHEOTENS

Elongational rheometer for determining the elastic properties of polymer melts



HIGHLIGHTS

- Infinitely adjustable pull-off speed
- Freely selectable linear or exponential acceleration
- Setting, measurement control and evaluation via the Windows program RHEOTENS 97
- Various pull-off wheels – to be specified depending on the application
- Tandem pull-off wheels
- Existing RHEOTENS devices can be retrofitted with a new electronics box and the "RHEOTENS 97" program

RHEOTENS

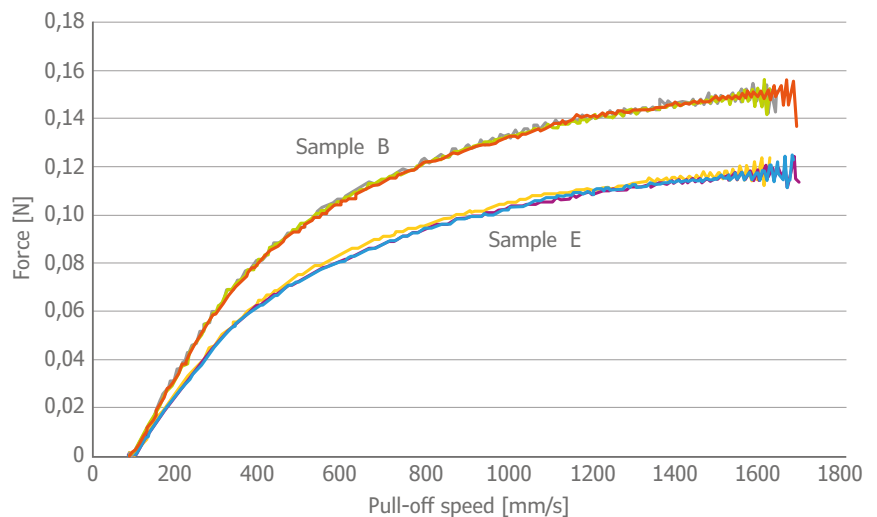
The pull-out capability of polymer melts is a key parameter for many processes in plastics production and processing. The patented RHEOTENS procedure has proven to be an extremely sensitive measuring principle, which delivers reproducible results to demonstrate even the smallest of batch fluctuations.

The RHEOTENS is particularly suitable for the characterization of materials used in film production, blow molding, deep drawing, calendaring and coating. The device is designed as a beam balance. Here, the pull-off wheels and the drive motor are arranged on a pivoting beam.

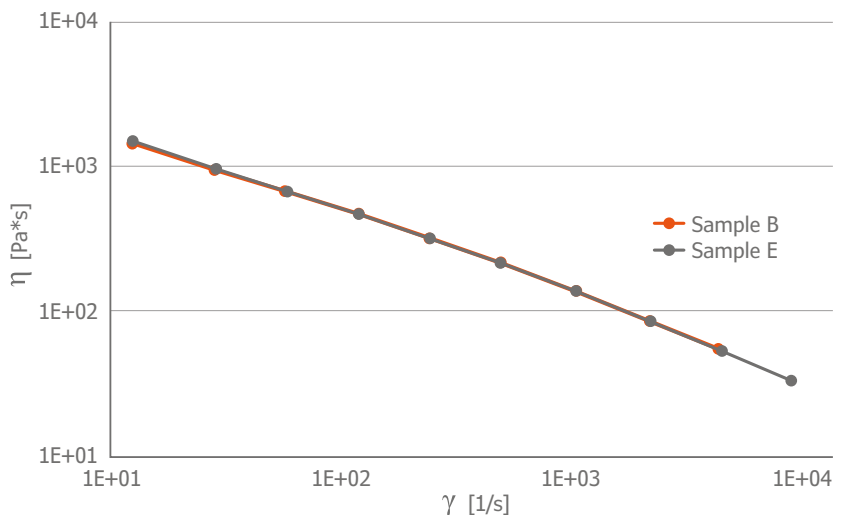
Due to this special arrangement, the melt strand is, in contrast to the HAUL-OFF, not deflected at the pull-off wheel but guided straight downward. This means that the melt can be pulled out from the zero point of force even at the lowest rates of elongation. The spinning length, i.e. the distance between the capillary outlet and the pull-off wheels, is usually only 100 mm, meaning a compact arrangement underneath the capillary rheometer is possible and isothermal conditions can be assumed at higher extrusion speeds. For this device, Prof. Wagner developed a model to determine the elongational viscosity from the measured force and pull-off speed. Through modeling, the data can be reduced to the pure material dependency, as the following diagrams show.

RHEOTENS CURVES

Even the slightest batch differences lead to significantly different RHEOTENS curves, which cannot be determined in the shear experiment.



According to the manufacturer, sample B indicates a somewhat broader molecular mass distribution ($M_w/M_n=11.1$) than sample E ($M_w/M_n=10$). The RHEOTENS curves, each reproduced three times, indicate a clear increase in the melt strength of sample B compared to sample E.

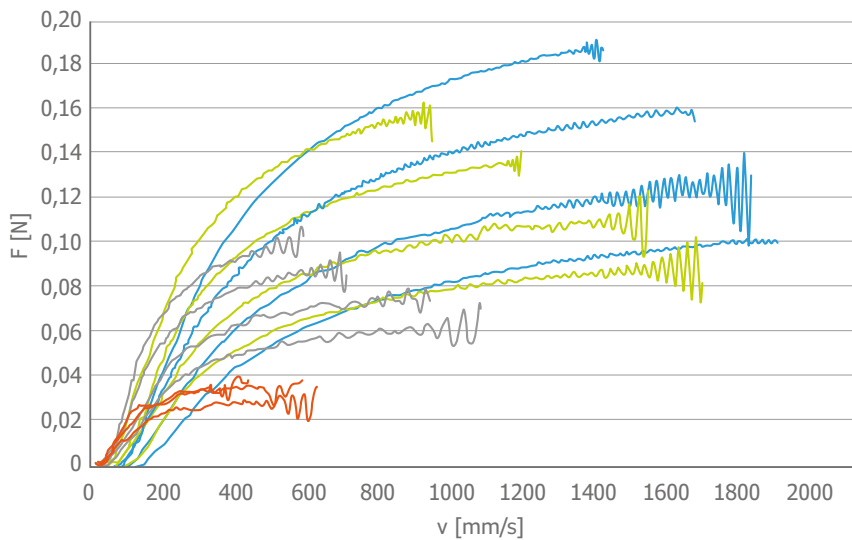


This correlation could not be determined from the viscosity functions.

RHEOTENS

RHEOTENS curves with master curve formation

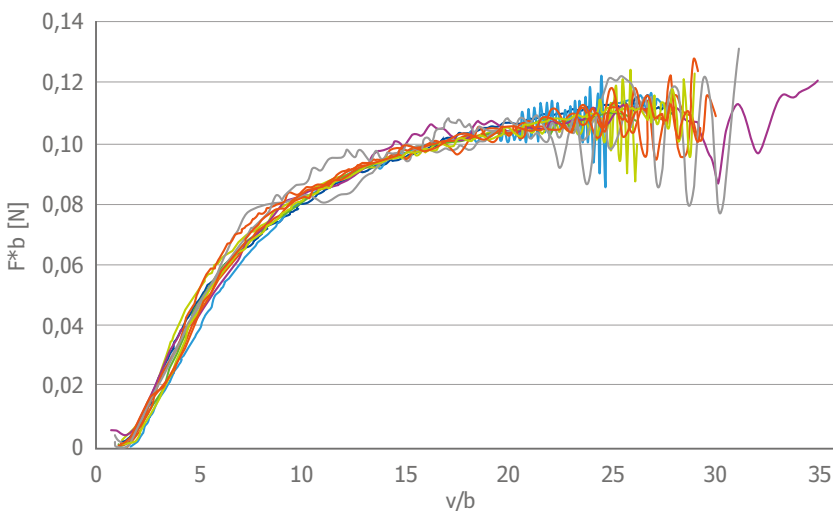
TECHNICAL ELONGATION DIAGRAM



In the technical elongation diagram, the speed or velocity v is a relative measure of the "elongation" of the melt. The maximum force F delivers a relative value for the tensile strength. The simple RHEOTENS experiment is first of all a complex function of the polymer property, the die geometry, the length of the spinning line and the extrusion history.

$$F = F(\text{polymer, geometry, process})$$

GRAND MASTER CURVE

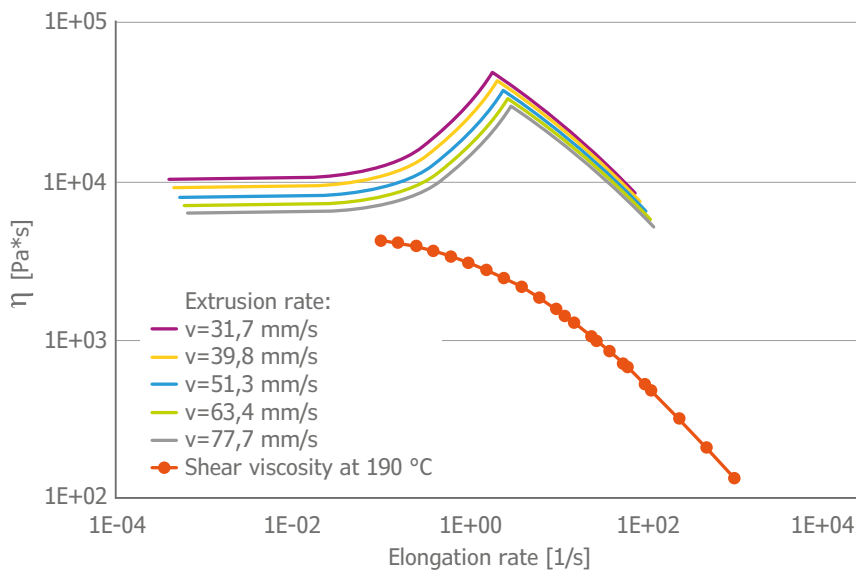


A further normalization determines the influence of the die geometry and the length of the spinning line. Finally, all 16 RHEOTENS curves are reduced to a single elongation curve, the RHEOTENS Grand Master Curve, by scaling the pull-off force F and elongation; now based on:

$$F = F(\text{polymer})$$

DETERMINATION OF THE ELONGATIONAL VISCOSITY

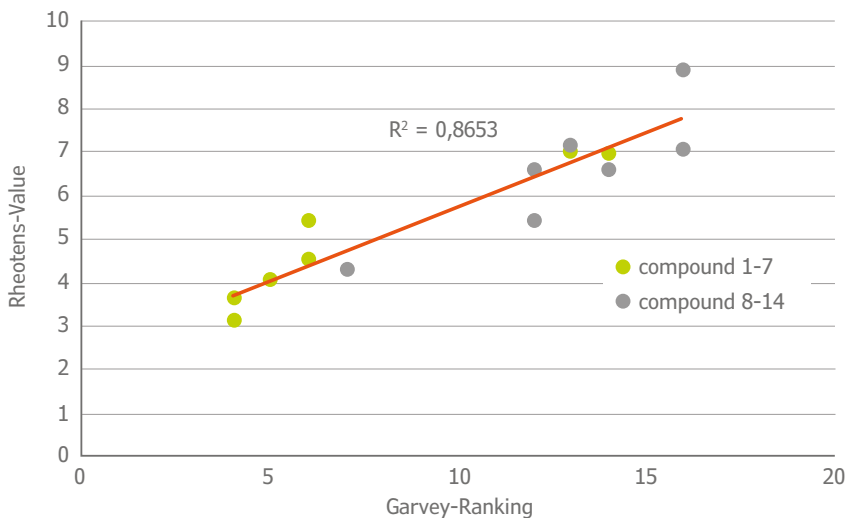
The elongational viscosity is also determined from the master curves using the Wagner model. The data depend on the history and can, for example, be determined for various extrusion conditions.



Using a simple analytical model, the effective elongational viscosity function can now be determined. As a function of the elongational rate, it is composed, depending on the extrusion history, of the "visco-elastic start-up" with increasing elongational viscosity and the purely viscous elongation with decreasing viscosity.

Furthermore, the parameters draw-down ratio, max. pull-off force and start speed ratio offer a very interesting method for evaluating the process stability. In particular for elastomers, the Rheotens number for weighting the parameters was determined from the aforesaid key figures:

$$\text{RHEOTENS-Value} = \frac{\text{forcemax}^{0,8}}{\text{start speed ratio} * \text{max draw down ratio}}$$



For elastomers, this results in a good correlation to the extrudate quality manually evaluated using the complex extrusion test with the Gravey die, which is also more prone to errors due to this manual evaluation.

HAUL-OFF

Measurement of the elongation of melts under constant pull-off speed or under linear or exponential acceleration of the pull-off strand



HIGHLIGHTS

- Infinitely adjustable pull-off speed from 0–2000 m/min
- Freely selectable linear or exponential acceleration
- Non-stick coated surface of the pull-off wheels
- Measuring range of up to 1 N, resolution 0.05 mN
- Software for settings, measurement control and evaluation

Supported by:



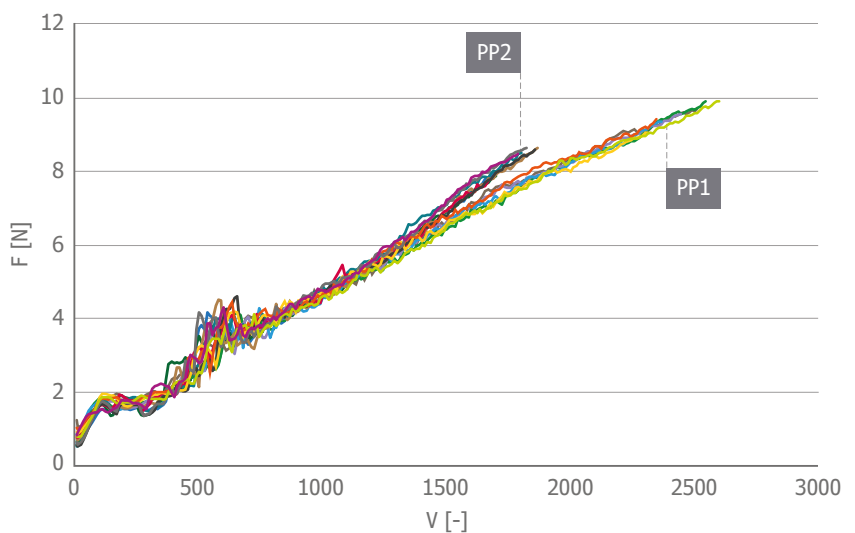
on the basis of a decision
by the German Bundestag

HAUL-OFF

The HAUL-OFF has been specially designed for measurements at high pull-off speeds and is applied in particular for fiber spinning, but can also be used to characterize the materials that are formed by film production, blow molding, deep drawing, calendering and coating. In contrast to the RHEOTENS, the experiment cannot be started at zero speed. The strand already needs to be pre-tensioned for the deflection at the pull-off wheel. Operation is much easier than with the RHEOTENS. The compact design is also suitable for installation underneath the capillary rheometer. However, the spinning length is already 230 mm, so that isothermal conditions can no longer be assumed and modeling with isothermal conditions does not seem to make sense without further measures. For fiber spinning materials, the measured forces are significantly lower than with the other methods, so that the force resolution is 20 times better than that of the RHEOTENS. The nominal range of the force measurement with the HAUL-OFF is half that of the RHEOTENS.

MEASUREMENT: TWO SPINNABLE PP

The following graphic shows the measurement (force vs. pull-off ratio) of two PP materials, which are only significantly different at very high pull-off speeds, as can be achieved with the HAUL-OFF or the Spin Line Rheometer described below.



SLR

Spinning tests under process-like conditions



HIGHLIGHTS

- Pull-off force of up to 7000 m/min
- Use of a high-resolution force transducer with a resolution of 0.05 mN
- The strand is lifted from the pull-off wheel via a Venturi nozzle
- The SLR is supplied with melt by an extruder with a deflection head
- Determination of the elongational viscosity from strand force and strand geometry
- Optimization of the spinning process in the production of synthetic fibers
- Optional measurement of the extruded profile via an optical measuring system

SLR

SLR = Spin Line Rheometer

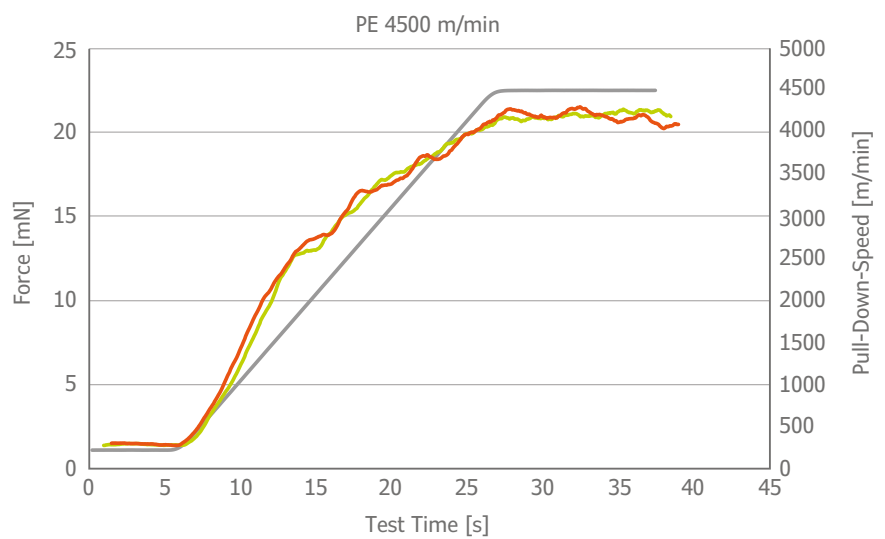
Fiber spinning is carried out in modern spinning systems where speeds of up to 8000 m/min can be achieved. Common spinning processes usually run in the range of 5000–7000 m/min. So far, these materials have been produced almost exclusively from synthetic plastics whose process capability is well known. However, these synthetic plastics are now being increasingly replaced by biopolymers in the interest of sustainability. This results in the necessity of close-to-process testing conditions. The Spin Line Rheometer has been specially developed for this application and can achieve pull-off speeds of up to 7000 m/min. The material is melted in a small laboratory extruder and fed to the Spin Line Rheometer via a spinning line measuring approx. 1300 mm in length. This device is also equipped with a high-resolution force transducer for measuring the small strand forces.

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by the German Bundestag

RAMP TEST OF A MONO FILAMENT



A typical test method is the ramp test up to the desired pull-off speed with a short speed holding phase. In the case of a mono filament, the material can also be wound up at the pull-off wheel without any appreciable increase in speed.

APPLICATIONS

General applications and suitability of the testers

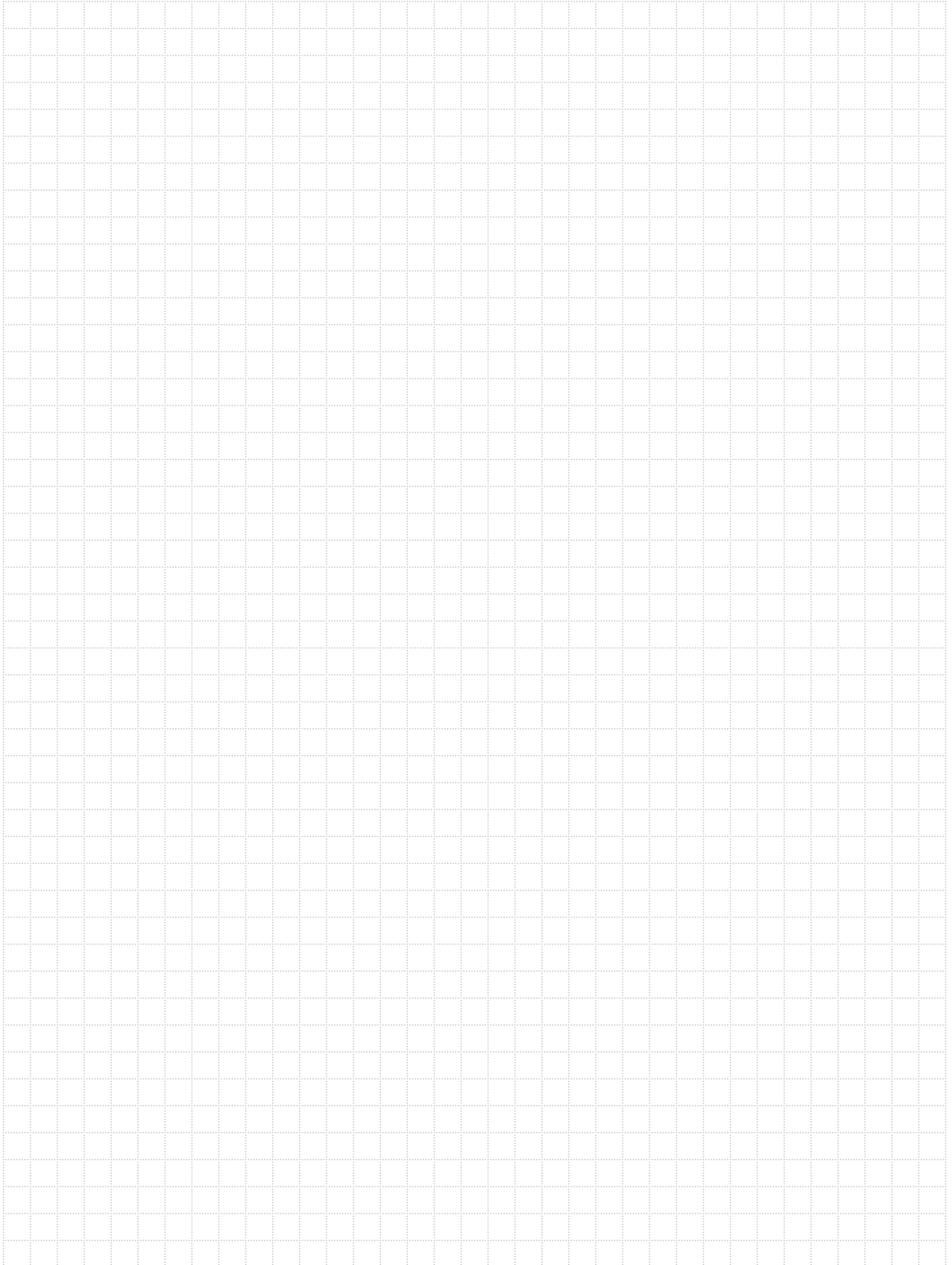
The following table provides a general overview of the application and suitability of the various elongation testers for quality assurance (QA), process and material optimization of different production processes and modeling.



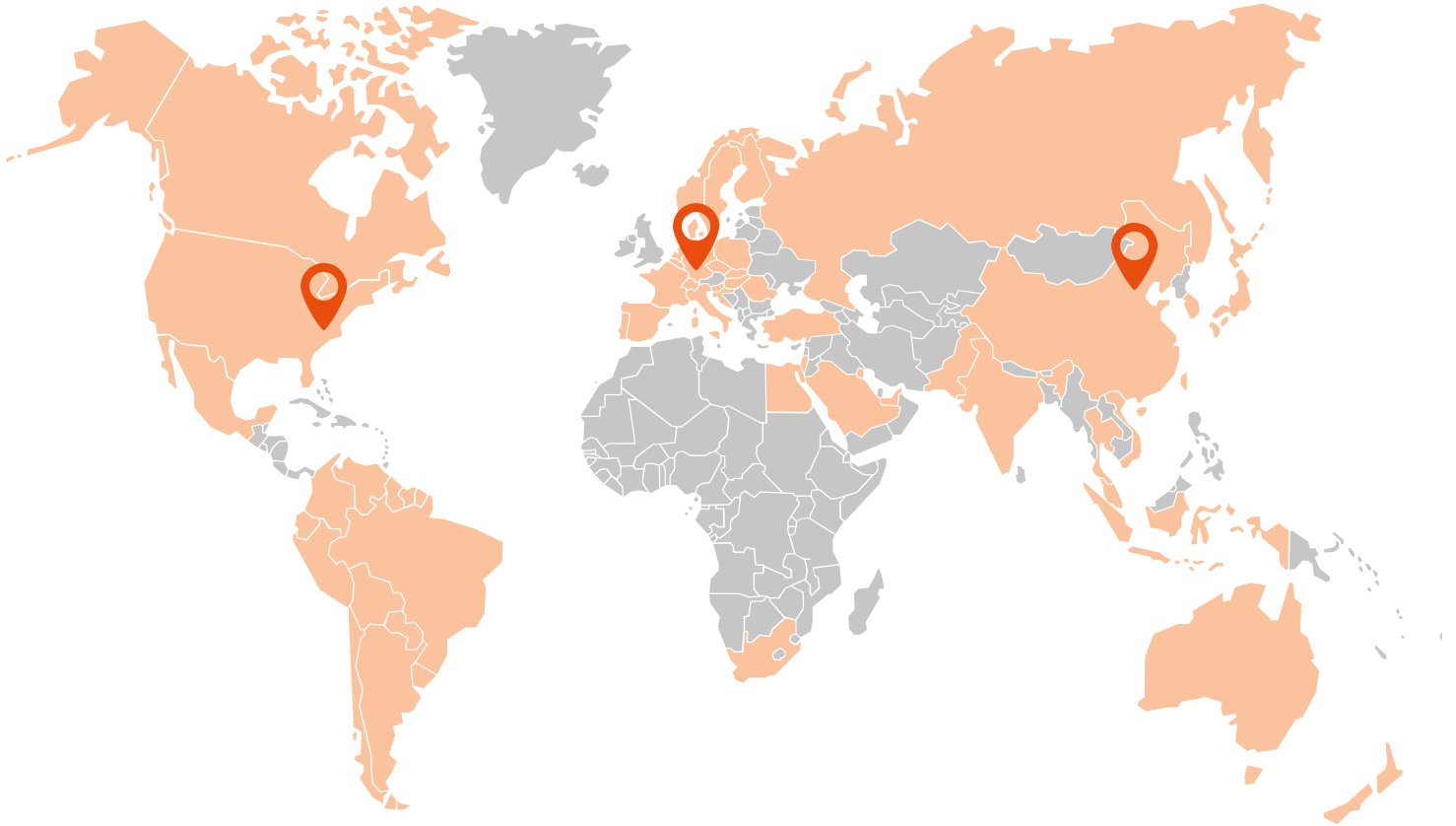
Application	D-MELT	RHEOTENS	RHEOTENS Online	HAUL-OFF	Spin-Line
QA release	●●●	-	●●●	●●	-
Calendering	●	●●●	●●●	●	-
Blow molding	●	●●●	●●●	●	-
Blow film	●	●●●	●●●	●●	-
Deep drawing	●	●●●	●●●	●	-
Spinning	-	●	●	●●●	●●●●
Modeling	-	●●●	●●	●	●

- ideally suitable
- very suitable
- well suitable
- suitable
- less suitable

NOTES



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