RPA rotational - Extension of the RPA for determining steady-state viscosity at high shear rates

Almost 50 years of experience in the rheological testing of elastomer compounds have led to a new testing instrument – the **RPA rotational**. The **Rubber Process Analyzer (RPA)** is used to analyze rubber compounds in both the plastic and vulcanized states as well as to characterize crosslinking behavior. In conventional RPAs, the lower die half is driven with a sinusoidal rotational motion (oscillation), while torque and normal force transmitted through the sample are measured at the upper die half. In addition, cure isotherms, temperature sweeps, relaxation, or ramp tests can be performed.
The new **RPA rotational** features a continuously rotating lower chamber equipped with an integrated temperature gradient sensor for determining shear dissipation — a unique feature on the market.

If dissipation is not recorded, the measurement results are already distorted in the medium and high shear rate range.

Transient Viscosity

The measurement is performed by an sudden change in angular velocity or shear rate, also referred to as a **step shear test**. The response to the imposed shear rate is the measured torque, which provides the shear stress as a function of time. The viscosity approaches equilibrium after a long enough time, as shown in **Figure 1**.

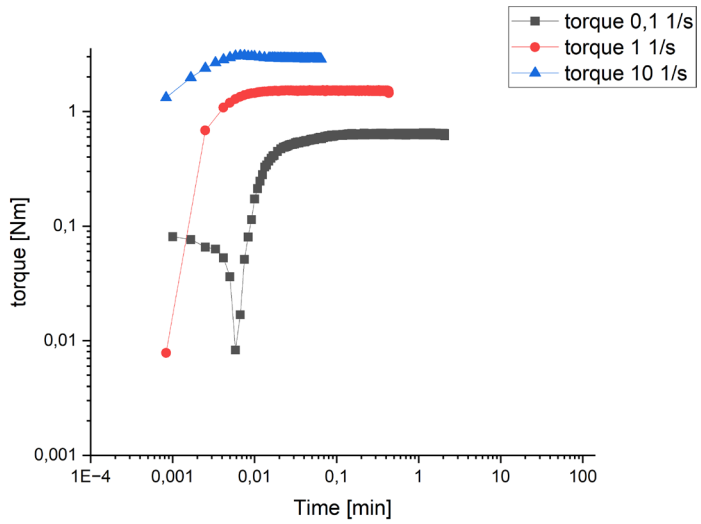


Figure 1: *Typical torque response during the measurement of transient viscosity*

This equilibrium value is referred to as the **transient viscosity**. In contrast to capillary rheometers, no corrections are required at low shear rates. Here several shear rates can be measured sequentially with RPA rotational, as the influence on the sample is minor.

At high shear rates, however, shear heating occurs within the small sample volume after only a few revolutions. This effect depends on the dissipated energy and, ultimately, on the viscosity of the sample.

This energy is detected by the **temperature gradient sensor** of the RPA rotational, which determines the resulting heat flow. Using an energy balance, the mean sample temperature is calculated and applied for **viscosity correction at high shear rates**. Due to the high shear energy, it is recommended to use a new sample for transient viscosity measurements at shear rates above approximately 20–50 s^{-1}.

Figure 2 compares the transient viscosity measured with and without shear heating correction for a highly viscous EPDM compound. The uncorrected viscosity curve shows a kink. In this example, the temperature increase of the sample reduces the viscosity by up to 40%.

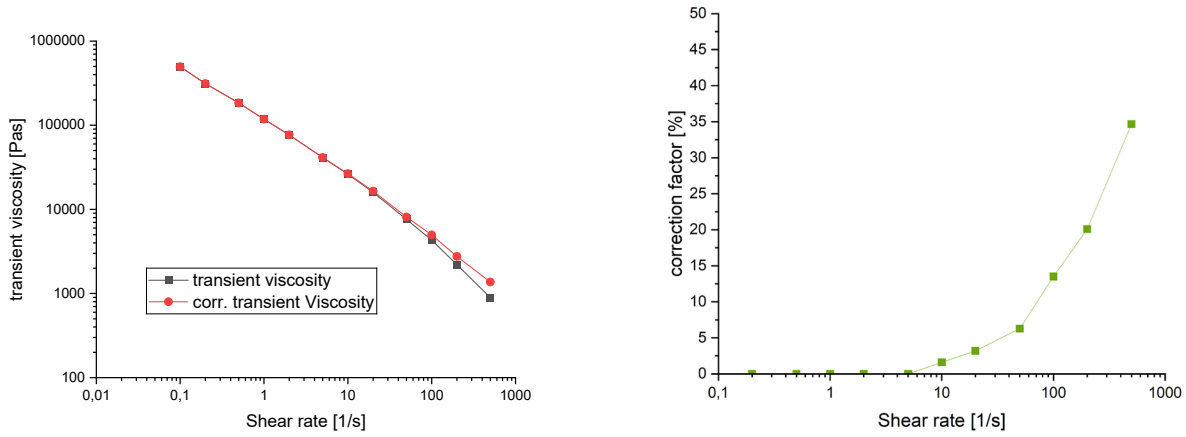


Figure 2: *Transient viscosity with and without correction for a highly viscous EPDM compound*

Figure 3 compares transient viscosity measurements for an EPDM compound with lower viscosity. Here, the effect of dissipation is less pronounced, resulting in a smaller correction effect.

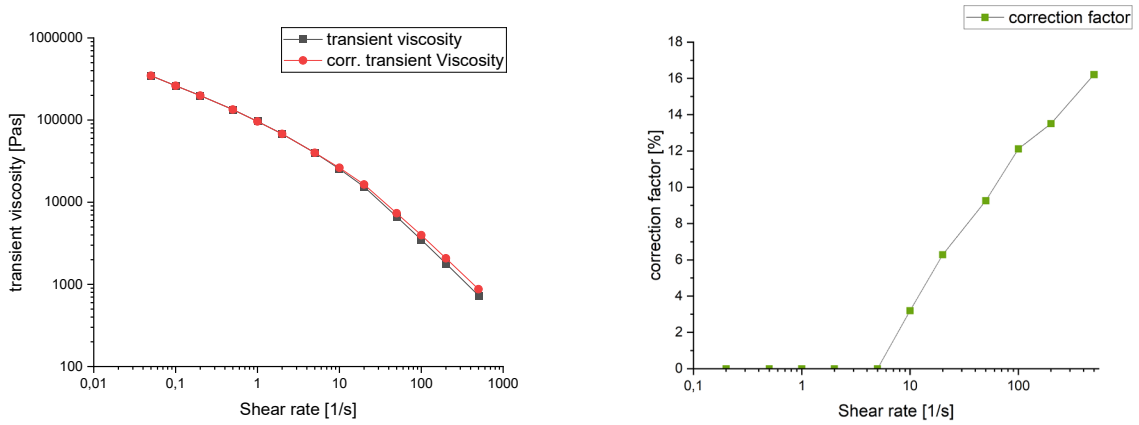


Figure 3: *Transient viscosity with and without correction for a lower-viscosity EPDM compound*

Figure 4 shows the temperature dependence of the transient viscosity. If dissipation is not considered, the viscosity measured at lower test temperatures can appear lower than that measured at higher temperatures due to strong shear heating. In this example, the uncorrected data at 80 °C lie below those at 90 °C and 100 °C. Such data would therefore not be used in a temperature shift analysis.

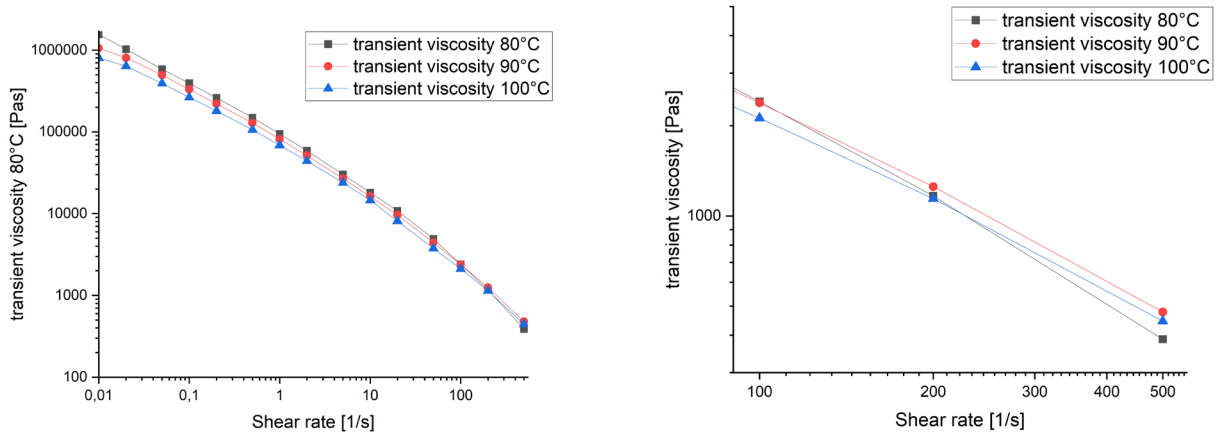


Figure 4: *Temperature dependence of viscosity showing the effect of dissipation correction*

The **corrected data** in **Figure 5** show the proper temperature ranking. These data can be compared with results from a high-pressure capillary rheometer — in this case, an **RG50 with Contifeed**. The capillary rheometer data are fully corrected, enabling a good correlation. In

practice, however, not all corrections can always be applied. The transient viscosity measurement therefore provides an **effective complement** and enables **process-relevant testing**, including the analysis of slip and adhesion behavior in pressure flow within the capillary rheometer.

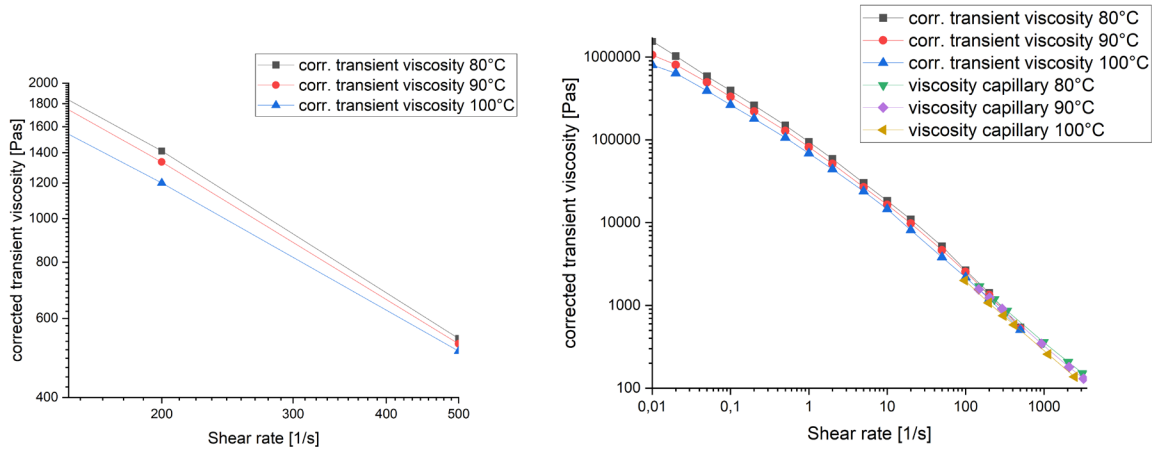


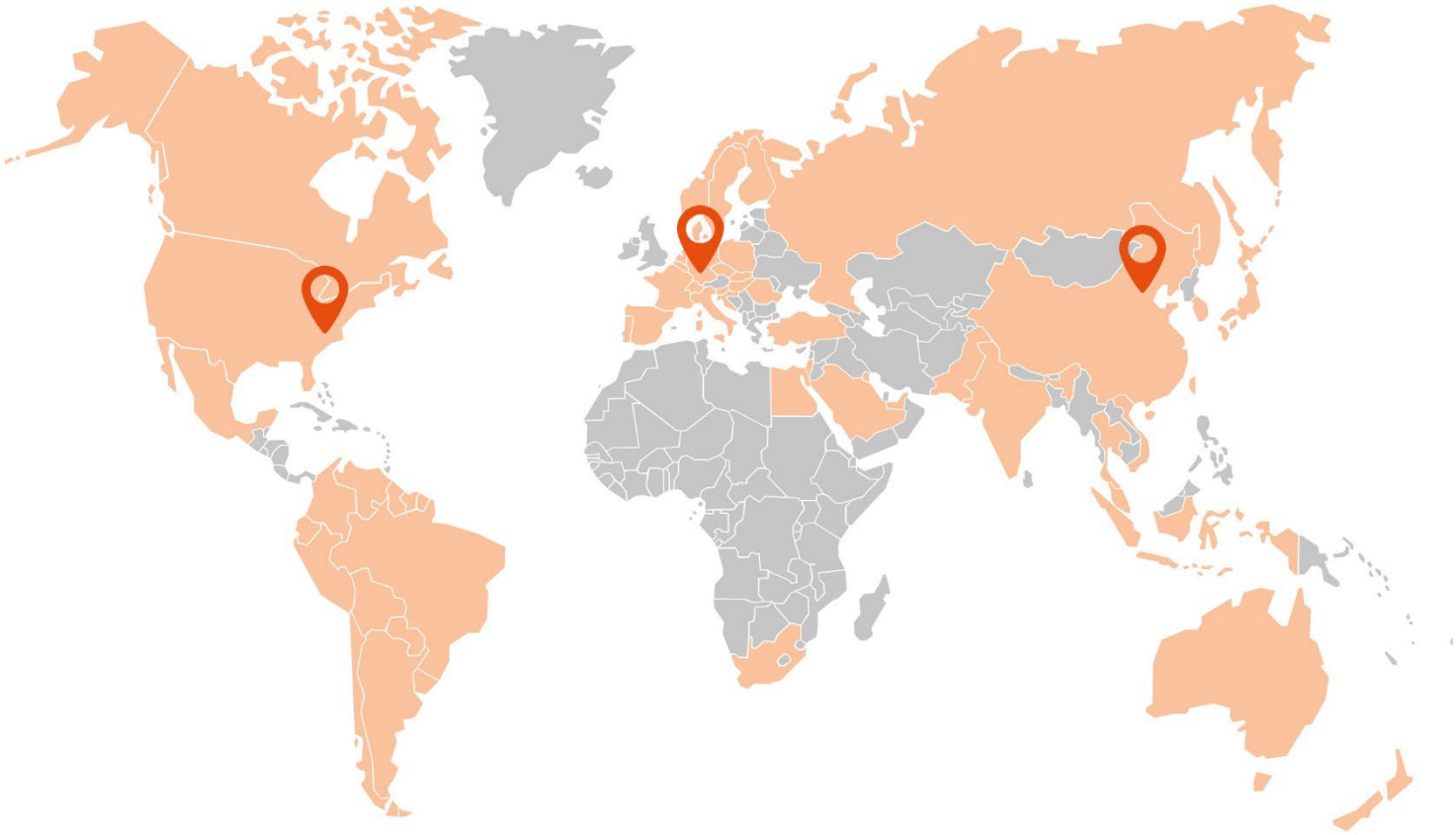
Figure 5: *Temperature correction shows correct temperature dependence and enables Cox–Merz verification*

Conclusion

The new **RPA rotational** has been enhanced with a continuously rotating lower chamber, extending the instrument's functionality beyond conventional RPA capabilities such as sweep, ramp/relaxation, and LAOS tests. This expansion significantly increases the measurable range for determining **transient viscosity**.

Thus, the RPA rotational provides an excellent complement for evaluating data obtained from **process-relevant capillary rheometer measurements**.

Only with the integrated **temperature gradient sensor** is a fast and effective correction of the measured transient viscosity possible — a prerequisite for achieving **accurate and reliable measurement results**.



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