Application Note
V-231

Improved torque sensitivity and normal force resolution for routine measurements

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HAAKE RheoStress 6000

The new HAAKE RheoStress 6000 benefits from the latest MARS technology developments. The improved specifications are regarding two components, improved air bearing specifications and the change of the normal force sensor technology.
The normal force sensor of the HAAKE RheoStress 6000 is based on temperature-compensated strain gauge technology and enables normal force measurements in the range of 0.01 to 50 N in both positive and negative direction. This technology offers the possibility to perform sensitive normal force measurements even on samples with low viscoelasticity.
In addition the new sensor enables to control the normal force in the sample to compensate for sample shrinkage and expansion when measuring semisolids.
The patented 4th generation air bearing in the HAAKE RheoStress 6000 is the result of more then 25 years of experience with the design and manufacturing of porous carbon air bearings. The air bearing consists of three individual air bearings:
One axial air bearing that supports the motor shaft in the vertical (axial) direction and is responsible for excellent axial stiffness.
Two widely spaced radial air bearings that support the motor shaft in the radial direction and prevent the shaft from tilting.

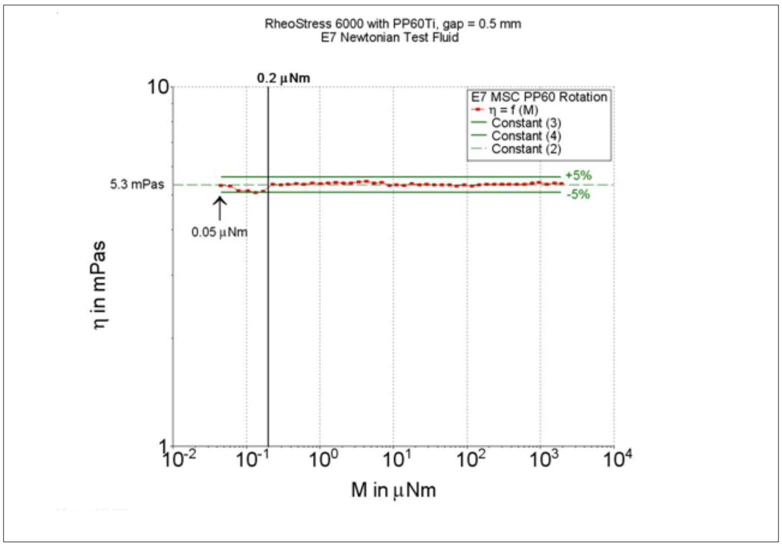

Figure 1: Viscosity curve of a 5.3 mPas oil at 20 °C

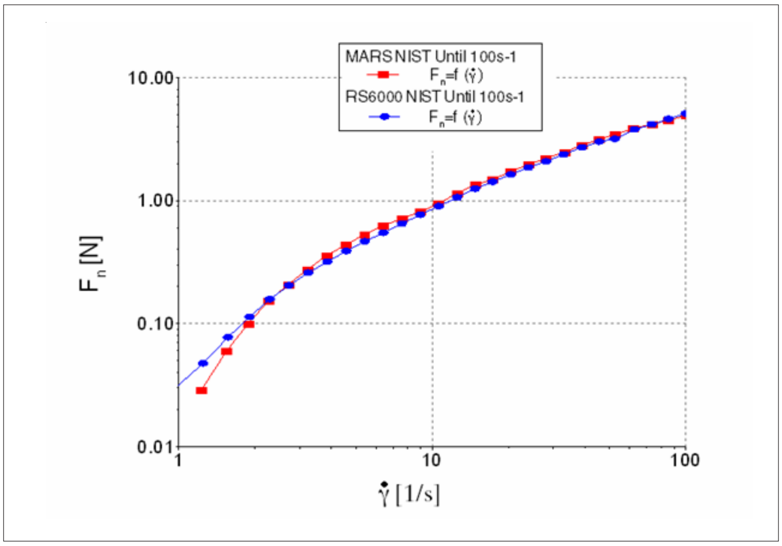

Figure 2: Normal force measurements of the standard reference material NIST 2490

Viscosity curve

CS (Controlled stress) – Mode
Our latest advances in air-bearing technology plus accurate residual torque correction (MSC = Micro Stress Control), enable measurements down to 0.2 µNm.

Figure 1 shows the result of an experiment in which the shear stress was stepwise increased. Even at a torque value of 0.05 µNm (clearly below the specified lowest torque) the measured viscosity is still within ±5 % from the specified value.

Normal Force measurement

The HAAKE RheoStress 6000 is equipped with a new normal force sensor based on robust and very sensitive strain gauges with integrated temperature compensation and a measuring range from 0.01 N to 50 N in positive and negative directions.

The curves in figure 2 show a very good correspondence between the normal force measurement with the HAAKE MARS and the normal force measurement with the HAAKE RheoStress 6000. The tests were performed at T=20 °C, CR-rot steps, Waiting 10 s, integration 3 s, log scale.

In a rotational measurement the centrifugal forces acting on the sample will result in a negative normal force F_{nc} on the rotating cone given by

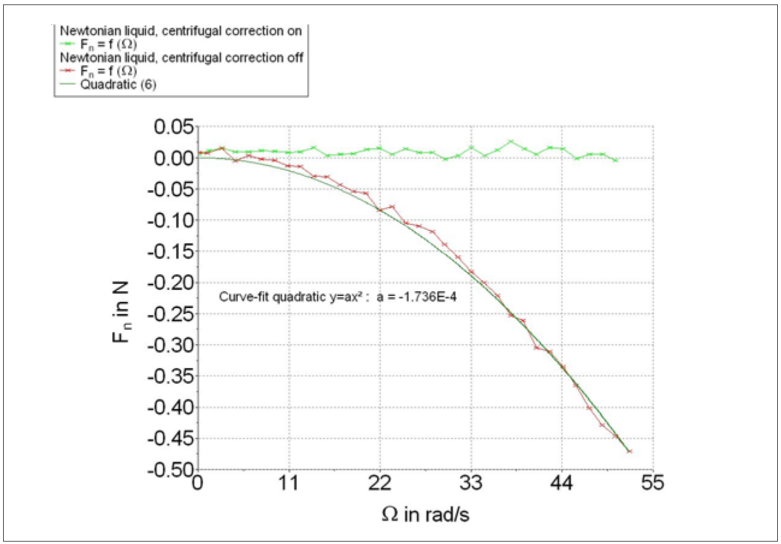

Figure 3: Normal force measurements of an oil at 20 °C

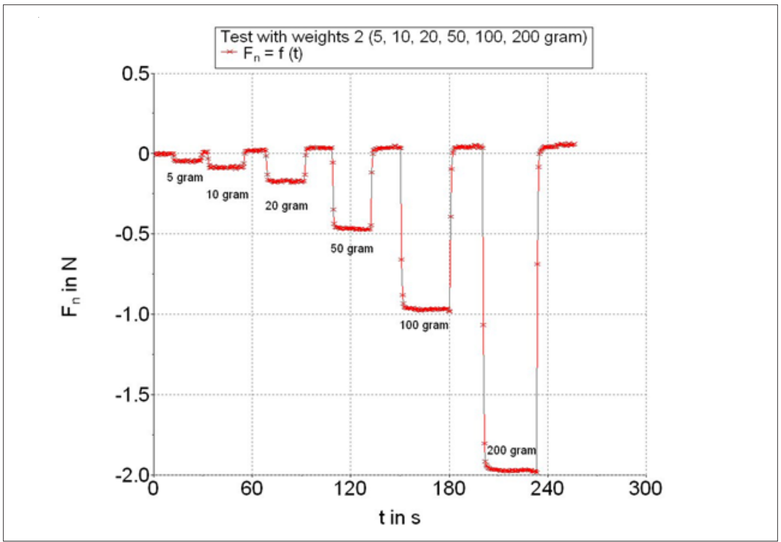

Figure 4: Normal force measurements after placing different weights on the rotor plate

equation [1] in which ρ is the density of the sample, Ω the angular velocity and R the radius of the cone.

$$F_{nc} = \frac{-3\pi\rho R^4}{40}\Omega^2 \qquad [1]$$

This effect can be used to demonstrate that the normal force sensor is working correctly by measuring a Newtonian fluid (for which the first normal stress coefficient $N_1 = 0$) with the centrifugal force correction in the software disabled (by setting the density to zero).
The measured data should then correspond with equation [1]. Figure 3. shows that this is the case: with the density of the sample ρ = 901 kg/m³ and the radius of the plate R = 0.03 m equation [1] becomes $F_{nc} = -1.72\ 10^{-4}\ \Omega^2$, this corresponds nicely with the parameter a = -1.736 10^{-4} from the quadratic curve fit in figure 3.

With the centrifugal correction in the software enabled the measured normal force signal F_n-F_{nc} should be zero, figure 3 shows that this is the case.

Figure 4 shows the measured normal force after consecutively applying weights of 5, 10, 20, 50, 100 and 200 g to the motor shaft. Applying a weight of 200 g correctly results in a measured normal force of F = m · g = 0.2 · 9.81 = 1.962 N.

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