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Testing low viscosity fluids with the HAAKE Viscotester iQ Air Rheometer

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Introduction

Testing low viscosity fluids on a rotational rheometer always poses a challenge due to the very low torque values that are being applied in such tests. This is especially true for the smallest commercially available air bearing rheometer on the market, the Thermo Scientific™ HAAKE™ Viscotester™ iQ Air Rheometer. Equipped with a low friction double-sperical air bearing, the lower torque limit of the HAAKE Viscotester iQ Air Rheometer is 10 µNm and thus about 3 orders of magnitude higher compared to a research grade rheometer like the Thermo Scientific™ HAAKE™ MARS™ 60 Rheometer. Still, many relevant rheological QC tests conducted in industries like i.e. food, petroleum or coatings deal with ultra low viscosity fluids. In this application note it is shown how extremely low viscous fluids like i.e. water can be tested with the HAAKE Viscotester iQ Air Rheometer.

Material and methods

The setup used to perform the tests on water is shown in Figure 1. The HAAKE Viscotester iQ Air Rheometer was equipped with the 48 mm diameter liquid controlled temperature module for coaxial cylinder geometries TM-LI-C48 and the corresponding CC41DG double gap geometry. To obtain meaningful data on such a low viscous fluid the measuring routine has to be adjusted accordingly. Figure 2 shows the Thermo Scientific™ HAAKE™ RheoWin™ measurement routine used for the tests presented in this report. One of the most important parameters for such a test is the total duration for every single measuring point as well as the integration time. Here, a measuring time of 45 s was used in combination with an integration time of 15 s. Temperature Control was achieved via an external Thermo Scientific SC100-A10 refrigerated circulator. Measuring temperature was 20 °C and an thermal equilibration time of 3 minutes was chosen.

Figure 1: HAAKE Viscotester iQ Air Rheometer with TM-LI-C48 liquid cylinder.

In addition to the rheological test, the automated data evaluation and report functionalities of the HAAKE RheoWin software have been used.

Results and discussion

As can be seen in Figure 3 the results of the viscosity measurements are extremely reproducible starting from a torque of 10 µNm. The measured values are within a 10 % tolerance as indicated by the blue lines. Comparing the accessible shear rate range to that of a standard HAAKE Viscotester iQ Rheometer with a mechanical ball-bearing, one can see that the air-beared model adds more than one order of magnitude into the low-shear regime. Off course the accessible shear rate range is still limited, however water can be tested with the HAAKE Viscotester iQ Air Rheometer over roughly 2 orders of magnitude from approx. 30 to 3000 s^{-1}. Below 30 s^{-1} the torque reading is below specification, above 3000 s^{-1} an increase of viscosity can be monitored due to the onset of Taylor vortices (1). This onset arises exactly where it was predicted by the RheoWin Range Calculator as can be seen in Figure 4.

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To further emphasize the quality and reproducibility of the data, Figure 5 shows the same results like in Figure 3 again, however this time plotted on a linear scale.

As can be seen in Figure 5 the HAAKE Viscotester iQ Air Rheometer is easily able to measure water with a large diameter double gap measuring geometry. Before onset of the Taylor instabilities, the viscosity data is within ± 10% of the theoretical water viscosity of 1.00 mPas (cP) at 20 °C.

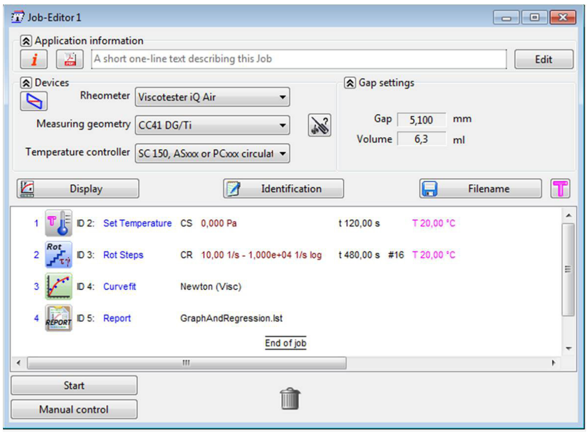

Figure 2: HAAKE RheoWin routine to test low viscosity fluids on the HAAKE Viscotester iQ Air Rheometer.

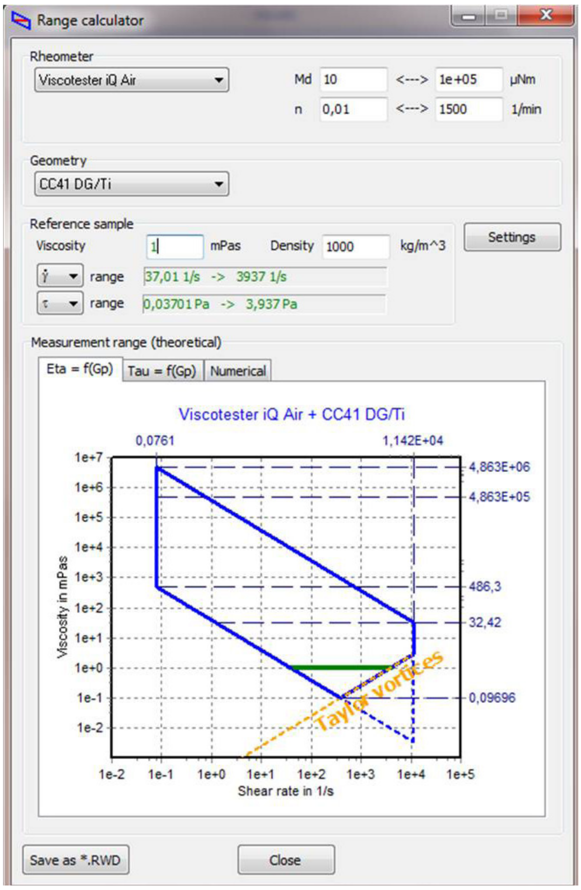

Figure 4: Calculated Measuring Range for the HAAKE Viscotester iQ Air Rheometer with rotor CCB41 DG with Taylor vortex prediction taken directly from the HAAKE RheoWin Software.

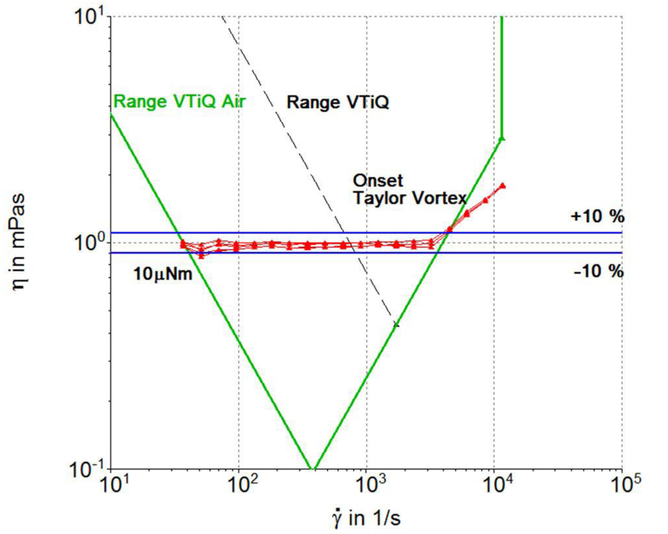

Figure 3: Viscosity as a function of shear rate for water at 20 °C on the HAAKE Viscotester iQ Air Rheometer. The data is plotted on a logarithmic scale.

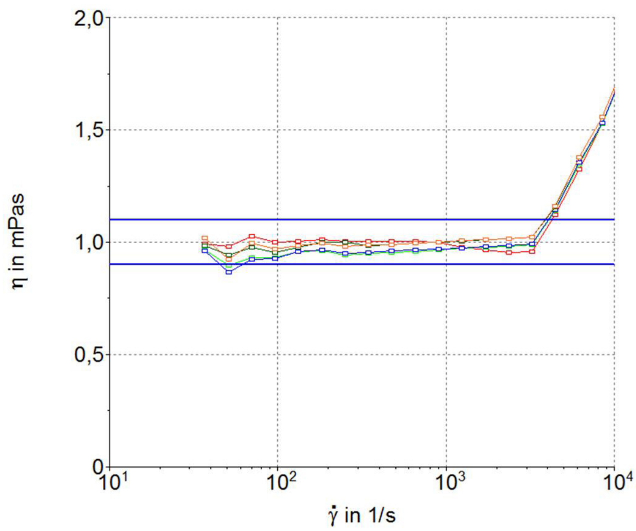

Figure 5: Viscosity as a function of shear rate for water at 20 °C on the HAAKE Viscotester iQ rheometer. The data are plotted on a linear scale.

Conclusion

The HAAKE Viscotester iQ Air Rheometer is a compact, easy to operate and accurate rheometer for Quality Control. It was demonstarted, that the smallest commercially available air-bearing rheometer in the market can be used, to determine the viscosity of extremely low viscosity fluids like water over a wide range of shear rates.

Reference

1. Taylor, G.I. "Stability of a Viscous Liquid contained between Two Rotating Cylinders", 1923. Phil. Trans. Royal Society A223 (605-615): 289–343.

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