Title:

A Low-Field-NMR Capillary Rheometer

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Abstract:

A capillary rheometer based on a commercially available low-field-NMR system, the Bruker minispec mq10, has been developed. Velocity-distribution measurement of flow through a cylindrical capillary using pulsed gradient spin-echo (PGSE) methods enables the direct calculation of flow curves.
The use of unshielded gradient systems imposes problems due to the generation of eddy currents as well as permanent changes in the magnet system homogeneity. These effects are dealt with using a pulse program based compensation method as well as by the design of an actively shielded gradient coil.

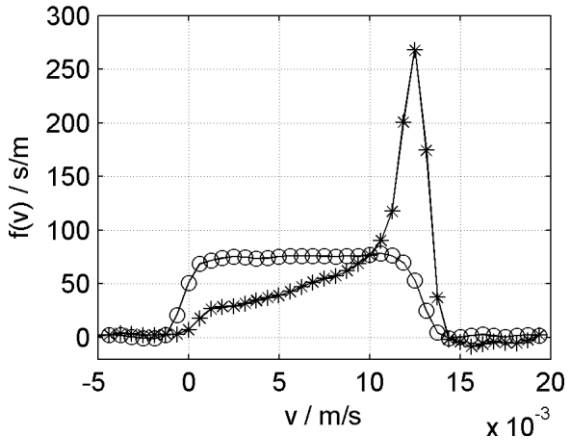

Fig. 1 Velocity probability density function of glycerol (o) and mayonnaise (*)

In fig. 1 the velocity probability density functions of the reference fluid glycerol (Newtonian fluid) as well as for mayonnaise are shown, measured with an unshielded gradient system. The expected constant probability for all velocities between zero and two times the average velocity is reproduced for glycerol. The mayonnaise sample flowing through the capillary shows increased probability at high velocities. An additional pressure drop measurement enables the calculation of viscosity as a function of shear rate.

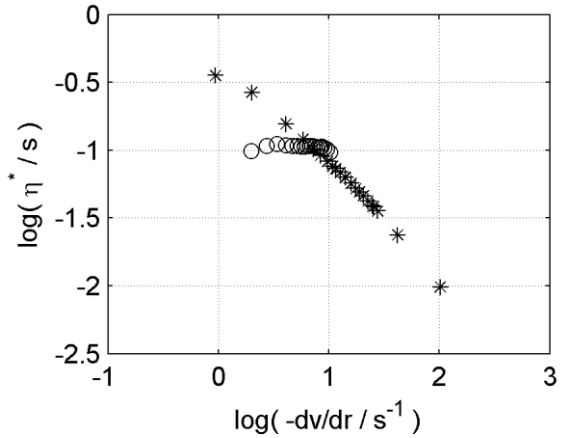

Fig. 2 Viscosity as a function of shear rate for glycerol (o) and mayonnaise (*)

Fig. 2 shows the resulting viscosity data normalized to the wall shear stress. Glycerol (Newtonian fluid) shows the expected constant viscosity over the shear rate, mayonnaise exhibits a shear-thinning (power law) behaviour.

The new, compensated, PGSE-based pulse sequence shows significant improvement measuring flow and diffusion using unshielded gradient systems. The capillary rheometer has the potential for various NMR-based inline applications.

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