Suppressing chemical-shift artefacts in rheo-*micro*MRI measurements of dense oil -in- water emulsions

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Introduction: The well-known advantages of rheo-MRI velocimetry make it suitable to quantitatively characterize complex fluids under shear in terms of their time-dependent physico-chemical structure formation/degradation and spatial flow-heterogeneities, that all remain inaccessible by conventional rheometry only [1-3]. Yet, when using the rheo-*micro*MRI setup for high-field spectrometers, in combination with strong PFG gradients with the aim to achieve microscopic spatial resolution, several artefacts are encountered that arise from the strong field gradients, the mechanical instabilities of the sample during shear, and/or from the chemical complexity of the investigated material itself. The latter, known as chemical-shift artefact, may (i) affect the measured velocities, thus leading to significant errors in the estimated local shear rates propagated by the *derivative* of the velocity, and (ii) even prevent the use of simple rheological fitting models, that are ultimately needed to extract relevant structural parameters, such as local yield stress and viscosity (red points in Fig. 1). Hence, minimizing artefacts in rheo-*micro*MRI is a necessary pre-requisite for obtaining a quantitative and accurate characterization of local flow behavior in complex fluids.

In this work, we focus on minimizing chemical-shift artefacts observed in rheo-*micro*MRI measurements of high oil volume fraction oil -in- water emulsions. To this goal, we propose a chemical-shift selective (CSS) method that fully suppresses the water signal, and uses the remaining signals from the oil phase to acquire an artefact-free flow-encoded profile.[4]

Methods: ^{1}H CSS rheo-*micro*MRI one-dimensional (1-D) velocimetry measurements [4] at 7 T using a commercial rheo-MRI accessory. Standard strain-controlled rheology measurements.

Results and discussion: By combining the CSS 1-D rheo-*micro*MRI method with standard torque measurements, it is possible to construct reliable local flow curves that can be successfully modelled (blue points in Fig. 1), from which even subtle effects, such as wall-slip, can be disentangled from changes in the constitutive material properties during time-dependent rheological measurements. The validity of the proposed approach is here demonstrated on a model high oil volume fraction oil -in- water emulsion to quantify the impact of emulsifiers and depletants on the spatially heterogeneous flow behaviour.

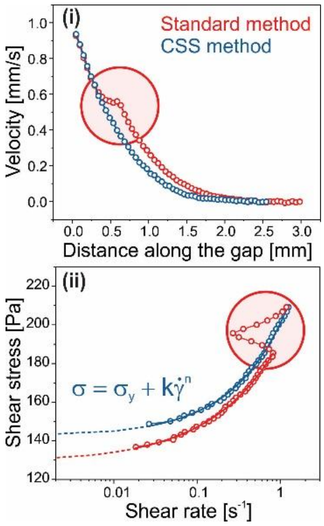

Fig. 1: 1-D velocity profiles (i) and local flow curves (ii) for a commercial mayonnaise at a constant shear rate of 0.62 s^{-1}, employing the standard (red) or the proposed CSS (blue) rheo-*micro*MRI method. All experiments were performed in a 2.5-mm gap Couette cell

Conclusions: The proposed CSS rheo-*micro*MRI approach is shown to successfully eliminate chemical-shift artefacts in velocimetry measurements of high oil volume fraction oil -in- water emulsions, in turn enabling a quantitative determination of local viscosities that otherwise would not be feasible. This approach opens a new way towards aiding the rational design of formulations and processing routes for oil -in- water emulsions, where well controlled flow properties of either water or oil are desirable.

References: [1] de Kort et al, Modern Magnetic Resonance (2017). [2] Nikolaeva et al, Langmuir (2019). [3] Nikolaeva et al, Food & Function (2018). [4] Serial et al, Magn. Reson. Chem. (2019).