Nanorheological studies of xanthan/water solutions

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The main objective of this study is to develop a method to measure rheological properties of a medium in a specific range of viscosity, shear moduli and oscillation frequencies for food thickeners using magnetic nanoparticles (MNPs) that enables non-contact sensing.

Introduction

Magnetic particle nanorheology is an interesting approach to study the flow and properties of non-Newtonian fluid. These measurements are carried out using AC susceptometry (ACS) experiments at 25 °C using the DynoMag system. It is crucial for this method to use magnetically blocked particles to make sure that the relaxation predominantly occurs by particle rotational diffusion (Brownian relaxation mechanism). The method is fast, it requires only a small sample volume of 200 µl and a minimal amount of tracer particles.

In this study we continue the nano-rheological analysis on different xanthan/water solution concentrations [1]. Different MNP sizes (using iron oxide based multi-core particles with mean particle sizes of 80 nm and 100 nm) are used to investigate the particle size effect on the viscoelastic properties of the solutions.

Frequency dependent rheological properties, including viscosity and shear modulus, of the solutions were obtained by fitting the data using a model based upon Raikher at al [2]. Thus, the resulting frequency dependent AC susceptibility data are analyzed to obtain frequency dependent rheological properties including viscosity and shear modulus.

Result

The MNP system consists of commercially available iron-oxide multi-core particles with a mean particle size of 80 nm and 100 nm (BNF, micromod Partikeltechnologie GmbH) with dextran as particle matrix material. For the ACS analysis we used the DynoMag system where all measurements were carried out at room temperature.

The out-of-phase components of the AC susceptibility versus frequency for the 80 nm MNP system, at different xanthan concentrations are shown in Figure 1 (right). As can bee from Figure 1, there are frequency shifts and broadening of the out-of-phase peaks when increasing the xanthan concentration. The result of the determined viscosity and shear modulus can bee seen in Figure 2 and agrees well with traditional oscillatory rheological measurements.

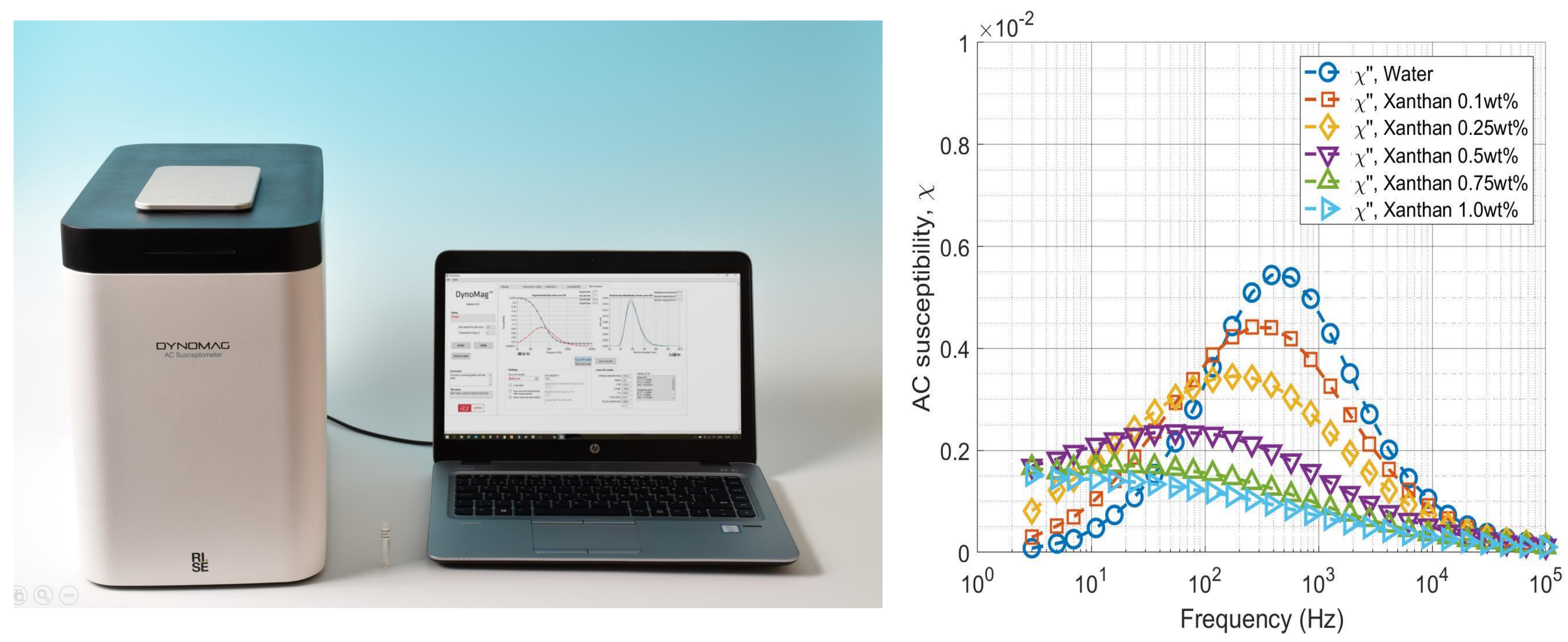

Figure 1. Left: DynoMag system developed by RISE for AC susceptometry (ACS) measurements. Right: Out-of-phase component of ACS versus frequency of magnetic excitation field for MNPs BNF-Dextran 80 nm. The MNP iron concentration is 1 mg/ml in all prepared samples.

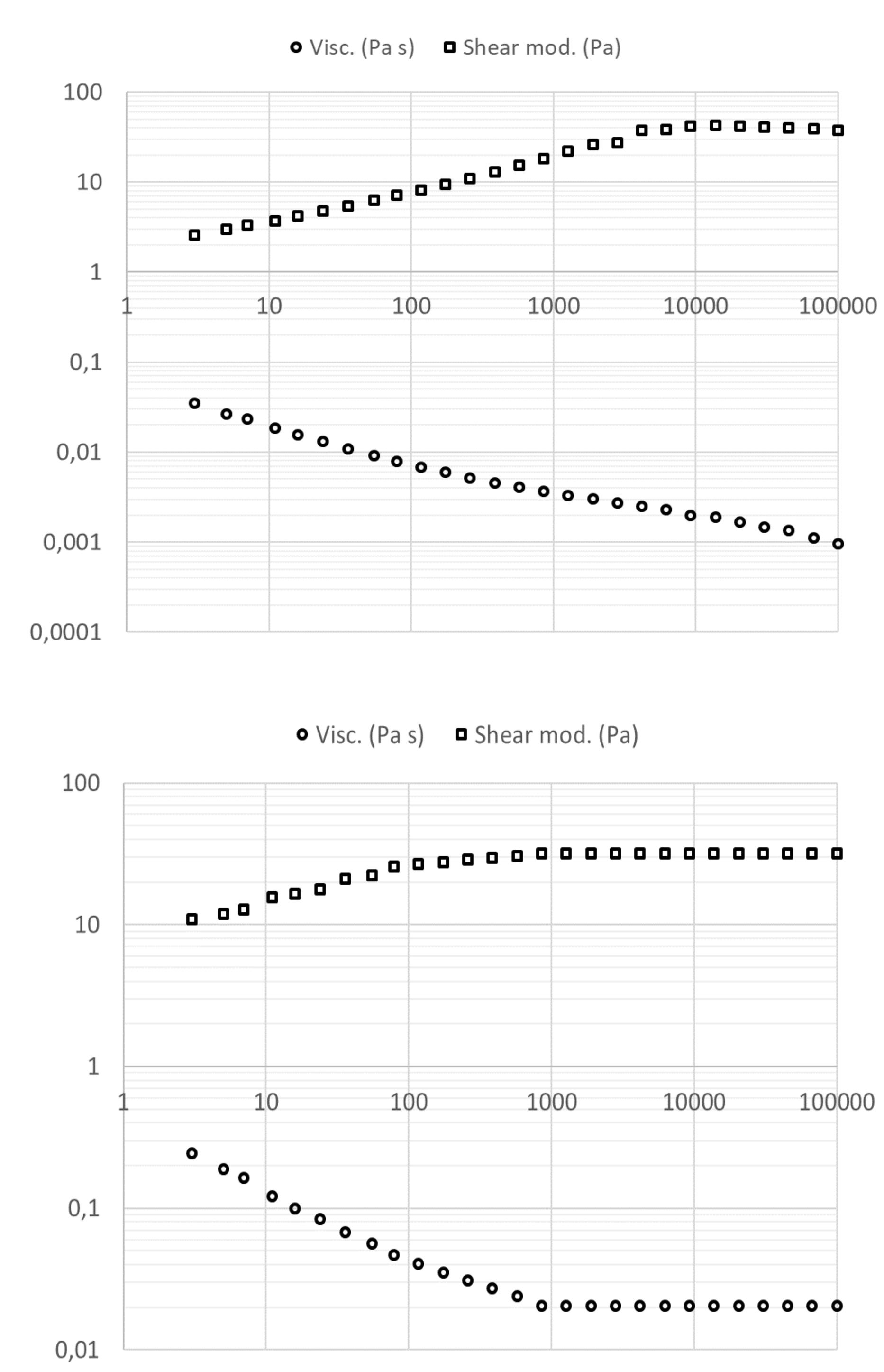

Figure 2: Viscosity (circles) and shear modulus (squares) versus frequency (in Hz) for MNPs BNF-Dextran 80 nm (top) and 100 nm (bottom), and xanthan/water concentration of 0.5 wt %.

CONCLUSIONS

The nanorheological studies have been performed in aqueous xanthan solutions for oscillation frequencies up to 10 kHz using MNPs with different particle sizes to study the response in different concentration of xanthan/water matrix. The use of MNP systems that undergo Brownian relaxation (stochastic particle rotation) enables us to remotely sense local viscoelastic properties.

References

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