

# Chain rotational dynamics in MR suspensions

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Magnetic fluids exhibit interesting dynamical behavior when subjected to rotating magnetic fields as has been reported in previous studies on magnetic holes [1,2], magnetic droplets [3,4] and magnetorheological (MR) suspensions [5,6]. Similar to the behavior of liquid crystals [7,8], these systems show synchronous and non-synchronous regimes depending on the value of the driving frequency. J.E. Martin et al. [9-11] developed 3D computer simulations of colloidal suspensions subjected to biaxial fields. They predicted the formation of particles into two-dimensional, sheetlike structures aligned in the field plane when the frequency of the field is sufficiently high so that particles migrate less than their own diameter during a field cycle. J.C. Bacri et al. [3] found unexpected spiny, starfish shaped magnetic droplets when a high frequency rotating magnetic field was applied. At lower frequencies, O. Sandre et al. [4] found that the magnetic droplets break up to decrease their viscous drag and facilitate tracking the field rotation.

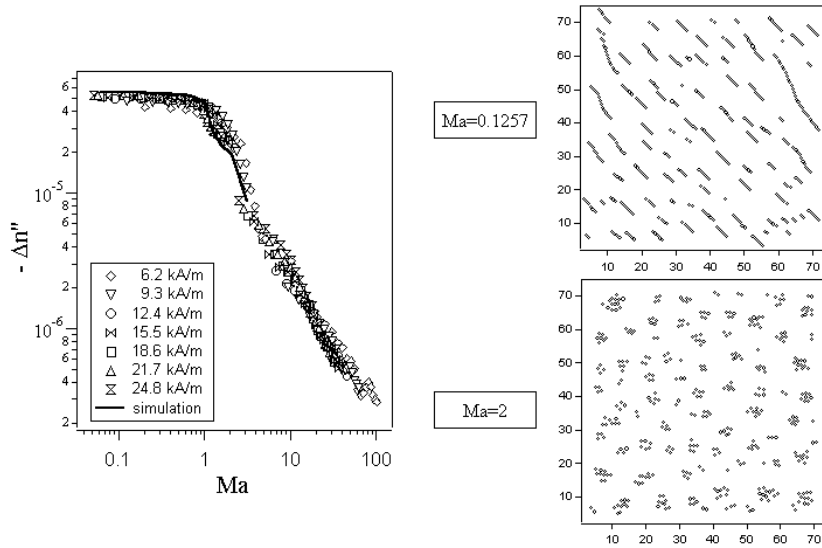
In our previous works [5,6], we studied the orientation dynamics of concentrated MR fluids using scattering dichroism. Dichroism is the anisotropy of the imaginary part of the refractive index and is a measurement of the difference between the absorption of the incident light in the parallel and in the perpendicular directions relative to the long axis of the aggregates [12]. The time evolution of the dichroism and the orientation angle of the structures were measured simultaneously and it was observed that the structures followed the rotating magnetic field with a phase lag that was independent of time for all frequencies measured. This phase difference increased with frequency over the whole range of frequencies.

In this work, we report on an experimental video microscopy study of the aggregation and orientation dynamics in dilute suspensions of magnetic dipolar particles under rotating magnetic fields. We analyze the behavior of the average length of the chainlike structures induced by the rotating magnetic field. We found that the sizes of the structures induced at small frequencies are larger than at zero rotating frequency, i.e. when a uniaxial magnetic field is applied. However, at higher frequencies, the average size of the aggregates decreases with frequency following a power law behavior with an exponent close to -0.5. Comparison of the experimental results with numerical simulations show good agreement.

Scattering dichroism and video microscopy experiments have been combined to study the dynamics of induced dipolar chains in magnetorheological suspensions subject to rotating magnetic fields. Direct observations show that chains adjust their size to decrease their viscous drag and rotate synchronously with the field but with a constant phase lag. The average size of the aggregates decreases with rotational frequency following a power law behavior with an exponent -0.5, the same exponent found in steady shear experiments with constant fields. Break up and recombination processes are observed for all the frequencies measured. The *S* shape developed by the chains before to break up into smaller ones has been studied.

With scattering dichroism experiments we simultaneously measured the dichroism (a linear function of the total number of aggregated particles) and the orientation angle of the structures (from which we can compute the phase lag). The Mason number (ratio of viscous to magnetic forces) governs the rotational dynamics. Two different behaviors for the dichroism and the phase lag are found below or above a critical Mason number,  $Ma_c = 1$ . Our experimental results have been also interpreted with particle dynamics simulations showing good agreement.

Above  $Ma_c$ , the rotation of the field prevents the particle aggregation process from taken place being this one the mechanism responsible for the decrease of dichroism.



**Figure:** On the left, we show the dichroism versus Mason number in a log-log plot for different magnetic field amplitudes (markers) and the simulation results (solid line). For these measurements we used a suspensions of super-paramagnetic particles of 1.01 microns of diameter in a solution with 82.5 % glycerol content. On the right, simulation results show the positions of the particles for two different Mason number at an arbitrary time.

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