☒ POSTER presentation

Rheo-NMR micro-imaging in natural coordinates

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Abstract:

The Rheo-NMR is a unique device for non-invasive measurement of molecular displacements and spectra under controlled shear conditions [1]. By harnessing advantages of NMR spectroscopc methods and imaging, Rheo-NMR has found important niches in materials sciences and hydrodynamics [1].

An added benefit of Rheo-NMR is in imaging the medium under shear flow. Conventionally, MR images are sampled using a Cartesian k-space trajectory, and reconstructed in a Cartesian framework, (even if sampled in a non-Cartesian way). Here we suggest sampling and reconstructing the Rheo-NMR data in the natural coordinate system defined by the direction of fluid stream-lines, (i.e., cylindrical coordinates for the Couette cell and spherical coordinates for a cone-plate geometry).

In the Couette cell, the k-space samples, $M(k,\phi_k)$, are related to the local magnetization $M(r,\phi_r)$ by the Fourier relation:

$$M\left(k_r,\phi_k\right)=\int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy M\left(x,y\right) e^{-i\left(k_x x+k_y y\right)}=\int_0^{\infty} dr r \int_0^{2\pi} d\phi_r M\left(r,\phi_r\right) e^{-ikr\cos(\phi_r-\phi_k)}$$

$M(r,\phi_r)$ can be obtained by inversion and by expansion of the exponential factor, such that:

$$M\left(r,\phi_r\right)=\sum_{m=-\infty}^{\infty} i^m e^{im\phi_r} \int_0^{\infty} dk\, k\, J_m\left(kr\right) \int_0^{2\pi} d\phi_k M\left(k,\phi_k\right) e^{-im\phi_k}$$

where $J_m(kr)$ is the m^{th}-order Bessel function of the first kind. This combined radial sampling and reconstruction scheme is advantageous over the Cartesian framework by providing: (a) similar partial volume artifacts in all voxels, (b) identical angular and linear resolution for all voxels and at all angles, (c) no ghosting artifacts in the velocity plane (no phase-encoding [2]), (d) homogeneous spatial frequency content in r and ϕ, (e) convenient presentation for further analysis. This framework is a particular case of the general concept by which the sampling and reconstruction parameters are uniquely tailored to exploit the specific symmetry, geometry and other characteristics of the sample.

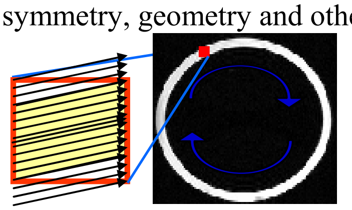

Figure 1: An axial cross section of the Rheo-NMR with 'zoom' on a Cartesian voxel. Notice that the partial volume of different stream-lines depends on the direction of flow within each voxel

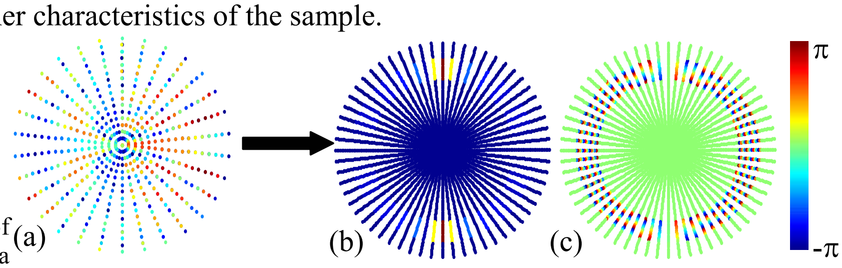

Figure 2: Simulation of a micro-imaging experiment of a rotating Rheo-NMR. (a) The sampled cylindrical k-space data. (b) The resulting cylindrical magnitude image, and (c) phase images.

1. Callaghan P.T., Rep. Prog. Phys. 1999, Vol. 62, pp. 599-670.
2. Xia Y., Callaghan P.T., Jeffrey K.R. AICHE Journal 1992, Vol. 38(9), pp. 1408-1420.