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Received: 30 August 2000
Accepted: 21 December 2000

Flexible magnetic media for high density information storage are made by coating a ‘magnetic ink’ onto a polymer film. Rapid improvements in this technology are responsible for new, extremely high density storage media such as those used to back-up and archive very large amounts of data. This technological innovation is accelerating and is being led by production of smaller and better magnetic particles, better ordered microstructure in the dispersion, and thinner and smoother coatings.

Magnetic inks are colloidal dispersions containing sub-micron sized magnetic particles, polymer, organic solvents, and other materials (O’Grady et al. 1991). The dispersions can be classified as ‘ferrofluids’ in the sense that the dispersed particles have permanent magnetic moments (Rosensweig 1985). The dispersions are also non-Newtonian and viscoelastic; they display a rich variety of behavior under flow and in the presence of external magnetic fields. In the manufacture of flexible storage media, an ink is coated onto a polymer substrate, the substrate and wet coating are passed through one or more magnetic fields to orient the magnetic particles, and the solvent is removed by drying to produce final tape or disk material. A critical step is the actual coating process because of the need to produce very thin films of extremely uniform thickness (to optimize the signal to noise properties of the media).

The need to produce uniform coatings has usually dictated that the coating be performed by a slot-die type of process, and the deformation rates that the ink experiences under the coating head are enormous. As the medium leaves the coating head, the shear rate abruptly drops to a very small value, so the non-Newtonian viscosity plays an important role in the process. Unfortunately, it is very difficult to measure the viscosity of the dispersions at the high shear rates present in the coater. It is less difficult to measure the linear viscoelastic behavior of the dispersions at high frequencies. From the point of view of deformation, measurements of linear viscoelastic properties probe a much different response of the material than steady shear properties, but, from the point of view of deformation rates, the two types of experiment may probe similar behavior. This is the thinking behind the Cox-Merz rule (Cox and Merz 1958) which might be used to exploit the relative ease of linear viscoelastic measurements over steady shear measurements in the regime of high deformation rates.

The Cox-Merz ‘rule’ is really a hypothesis stating that the functional dependence of the complex viscosity’s magnitude expressed as a function of frequency is identical to the functional dependence of the steady shear viscosity expressed as a function of shear rate (Bird et al. 1987). That is:

\[ |\eta^*(\omega)| = \left. \eta(\dot{\gamma}) \right|_{\dot{\gamma} \to \omega} \]  

\[ (1) \]
where $\eta^*(\omega) = \eta'(\omega) - i\eta''(\omega)$ is the complex viscosity at frequency $\omega$ [z] indicates the magnitude of complex quantity $z$, and $\eta(\dot{\gamma})$ is the steady shear viscosity at shear rate $\dot{\gamma}$. Clearly, this relation would be of great utility in the analysis of coating flows for which one needs viscosity at high shear rate, because of the relative ease of obtaining complex viscosity data at high frequencies. However, given the phenomenological nature of the relation, it must be tested for magnetic inks.

A distinguishing characteristic of magnetic inks is the presence of strong magnetic forces between the particles. These acicular (i.e., cigar shaped) particles, such as $\gamma$-Fe$_2$O$_3$, should be thought of as magnetic dipoles with opposite poles on the ends. The particles tend to form small primary aggregates in which particles are connected in a side-to-side manner. The primary aggregates are not separated by milling or high shear. In the dispersions, they come together to form transient networks as confirmed by linear viscoelastic measurements (Potanin et al. 1998) and by direct imaging. Small-scale structure includes individual particles, their neighbors, and attached polymer chains. Large scale structure includes the network of weakly interacting flocs (particle bundles). However, under large deformations we must