Thermal Convective Instabilities in a Magnetic Viscoelastic Fluid

L. Perez*, **J. Bragard**†, **D. Laroze**‡,$, **J. Martinez-Mardones**#, **and H. Pleiner**‡

* Depart. de Ingenieria Metalurgica, Universidad de Santiago de Chile, Santiago, Chile

†Depart. de Fisica y Matematica Aplicada, Universidad de Navarra, Pamplona, Spain

‡Max Planck Institute for Polymer Research, Mainz, Germany

$Instituto de Alta Investigacion, Universidad de Tarapaca, Arica, Chile

#Instituto de Fisica, Pontificia Universidad Catolica de Valparaiso, Valparaiso, Chile

ABSTRACT

Rayleigh-Benard convection in magnetic viscoelastic liquids is studied. We systematically investigate the role of various rheological and magnetic properties (including external magnetic fields) and their mutual interplay for the instability and bifurcation behavior. For the investigation of the linear instability behavior, viscoelasticity is described by a linear Oldroyd model. The thresholds for the stationary and the oscillatory convection are determined. For simplified boundary conditions analytical results can be given, while for realistic ones numerically spectral methods are used. For weakly viscoelastic fluids the critical Rayleigh number for the oscillatory convection is much higher than that for the stationary one, while for high Deborah numbers the oscillatory instability always precedes the stationary instability. For a certain range of parameters the two thresholds are equal and a codimension-2 bifurcation appears. The viscoelastic properties have a distinct influence on the oscillatory instability, in particular its very existence is restricted to Deborah numbers above a certain lower limit, and to stress relaxation times being larger than the retardation time of the strain rate. Due to the presence of various destabilizing effects, i.e. buoyancy and magnetic forces, and of additional relaxation channels due to the Oldroyd model, the discussion of the stability curves becomes rather intricate [1]. The threshold of the oscillatory instability decreases with 1/magnet field strength squared, while the critical frequency and wavevector are rather insensitive on an external magnetic field. The use of realistic flow boundary conditions does not qualitative, but quantitatively change the critical values. Similarly, the use of realistic magnetic boundary conditions is of only very limited impact. For the nonlinear aspects of the instabilities we use a generalized viscoelastic hydrodynamic description in terms of a strain tensor description [2] that comprises most of the common rheological models. On the nonlinear level, the viscoelastic properties also influence the stationary instability. In addition, magnetic and viscoelastic properties are effectively connected and influence together the bifurcation behavior.

REFERENCES

[1] L.M. Perez, J. Bragard, D. Laroze, J. Martinez-Mardones, and H. Pleiner, *Thermal convection thresholds in a Oldroyd magnetic fluid*, J. Magn. Magn. Mater. **323**, 691 (2011).

[2] H. Pleiner, M. Liu, and H.R. Brand, *Nonlinear Fluid Dynamics Description of non-Newtonian Fluids*, Rheologica Acta. **43**, 502 (2004).