Hydromagnetic Taylor-Couette Experiments in Liquid Sodium

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Turbulent shear flow + restoring force can lead to an instability...

\[ N - S + \frac{N}{R_m} \left( \nabla \times \vec{B} \right) \times \vec{B} \]

\[ N = \frac{B_0^2 L}{\rho \mu_0 \eta \Omega r_i} \quad \text{Magnetic Interaction Parameter (Stuart Number)} \]

\[ R_m = \frac{\Omega r_i L_{gap}}{\eta} \quad \text{Magnetic Reynolds Number} \]

\[ S = \frac{B_0 L_{gap}}{\sqrt{\rho \mu_0 \eta}} \quad \text{Lundquist Number} \]

\[ Re = \frac{\Omega r_i^2}{\nu} \quad \text{Reynolds Number} \]

Strength of Lorentz Force
Strength of Magnetic Advection
Dimensionless applied field (Rm for Alfven)
Magnetorotational Instability From A Turbulent Background

Onset of Organized Patterns

Magnetic Field Threshold

$R_m$

$tb$

$S$

$O_1$

$E_0$

$E_1$

$E_2$

$O_2$
Results motivate new geometry...

Hall Probe Arrays (Radial Magnetic Field)

Ultrasound Velocimetry (Axial Velocity 3/4 Gap)

\[ N \sim 0.05-30 \]
\[ R_m \sim 3-14 \]
\[ \text{Re} > 10^5 \]

Radius Ratio = 1/2
Aspect Ratio = 4
Units and experimental realities...

~1400 gauss (140mT)
~32 Hz Maximum Rotation Rate
Standard Deviation Midplane Induced Field

\[ B_c = \sqrt{\rho \mu_0 L r^3 (\Omega/2)^3 / \eta} \]
Axial Fourier Coefficient Amplitudes: $R_m = 6.8$

Mean Radial Induced Field Reconstruction $C_0 + \sum_{k=1}^{k=6} S_k \sin(kz) + C_k \cos(kz)$ (gauss)
Induced Field Spectrogram
(One vertical cut = One Power Spectrum)

Axial Velocity Spectrogram (depth ~7cm)
Preliminary Phase Plane?

$N=2 \ m=0$

$R_m = 10.00$

$S (\sim B_0)$

$m=1$

$m=2$

$m=2$ dom.
Comparison With Sisan et. al

A rich region of parameter space...
In conclusion:

Liquid Sodium Taylor-Couette shows significant effect of applied magnetic field on the flow beginning at a well defined value of N and shows instability to organized oscillatory states as N is further increased, all starting from a base state of fully developed hydrodynamic turbulence.

This behavior occurs in the same region of parameter space where instabilities to rotating patterns were observed in a spherical Couette flow.

And further on:
Properly characterize oscillatory states and fill out phase plane
Investigate angular momentum transport (torque!)