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MHD Stability of Centrifugally Confined Plasmas

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An idea currently under investigation is to use the centrifugal force of a rotating plasma to augment magnetic confinement for thermonuclear fusion plasmas.[1] One of the key issues for the success of this approach is the MHD stability. We performed a 3D MHD simulation for a low β, low $M_A(\equiv u_\phi/V_A)$ centrifuge, which showed velocity shear stabilization of flute interchanges at $M_S \sim 4$ ($M_S \equiv u_\phi/C_S$). [2] For a high β, high M_A centrifuge, the magnetorotational instability (MRI) could be a concern. To resolve this issue, we studied the stability of a simplified, straight-field Dean flow model via eigenmode analysis.[3] In this model system, two distinct but coupled destabilization mechanisms are present: flow shear (magnetorotational instability) and magnetic buoyancy (Parker instability). The system is shown to be unstable for long axial wavelength modes when $M_S M_A \gtrsim \pi R/a$ (R/a is the aspect ratio). However, the fact that the system is stable in the incompressible limit (therefore the magnetic buoyancy is precluded) suggests that the instability won't lead to the typical turbulent behavior of the MRI; instead, it should behave as the Parker instability. This was confirmed by 2D simulations, in which a uniform plasma was seen to break and saturate into clumps. The clumping behavior of the instability indicates a spontaneous centrifugal confinement out of a straight-field configuration, rather than poses a limit to a centrifugal confinement device. Hence, one could expect a high β, high M_A centrfuge free of MHD instabilites to be possible.

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[2] Y. M. Huang and A. B. Hassam, Phys. Rev. Lett. **87**, 235002 (2001).

[3] Y. M. Huang and A. B. Hassam, Phys. Plasmas **10**, 204 (2003).