Dissipation driven by precession and libration

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Rigorous upper bounds are obtained for precessing and librating fluid-filled cylinders and the case of a librating fluid-filled cylindrical shell is also considered. We make use of the "background flow" method developed by Doering & Constantin (1994) and apply it to this new geometry. We derive bounds on the dissipation which are independent of both the Ekman number and the magnitude of the precession - recovering the infinite cylinder result of Kerswell (1996). The case of a librating fluid-filled cylindrical shell is considered as a simplified model of Enceladus; a moon of Saturn that appears to have a global subsurface ocean of liquid water. The existence of such an ocean poses the question of how it can remain in a liquid state; the surface temperature of Enceladus at noon is < 100K. Previous work has focused on heating due to tidal flexing of the ice shell and other related heat generation methods (Nimmo 2007). Here we derive an upper bound on the dissipation for a librating fluid-filled cylindrical shell and show that, for the range of parameter values suitable for Enceladus, it is not possible for libration alone to account for the high heat fluxes observed by Cassini.