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Instability by Weak Precession of the Flow in a Rapidly Rotating Sphere

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Abstract : We consider the flow of an incompressible viscous fluid in a precessing sphere whose spin and precession axes are orthogonal to each other. The flow is characterized by two non-dimensional parameters, the Reynolds number Re and the Poincare number Po. For which values of (Re, Po) will the flow approach a steady state from an arbitrary initial condition? To answer it we are searching the instability boundary of the steady states in the whole (Re, Po) plane. Here, we focus the rapidly rotating and weakly precessing limit, i.e., Re >> 1 and Po << 1. The steady flow was obtained by the asymptotic expansion for small ε=Po $Re^{1/2}$ << 1. The flow exhibits nearly a solid-body rotation in the whole sphere except for a thin boundary layer which develops over the sphere surface. The thickness of this boundary layer is of O(δ), where $\delta=Re^{-1/2}$, except where two circular critical bands of thickness of O($\delta^{4/5}$) and of width of O($\delta^{2/5}$) which are located away from the spin axis by about 60°. We perform the linear stability analysis of the steady flow. We assume that the disturbances are localized in the critical bands and make an expansion analysis in terms of ε to derive the eigenvalue problem for the growth rate of the disturbance, which is solved numerically. As the solution, we obtain an asymptote of the stability boundary as $Po=28.36Re^{-0.8}$. This agrees excellently with the corresponding laboratory experiments and numerical simulations. One of the most popular instability mechanisms so far is the parametric instability, which turns out, however, not to give the correct stability boundary. The present instability is different from the parametric instability.

Keywords : boundary layer, critical band, instability, precessing sphere
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