Center for Fluid Mechanics, Division of Applied Mathematics
Fluids, Thermal and Chemical Processes Group, School of Engineering
Joint Seminar Series

TUESDAY – AUGUST 14, 2012
1:00pm
Barus & Holley, Room 190

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DESTABILIZATION OF FREE CONVECTION BY WEAK ROTATION

This study is motivated by several recent observations of steep destabilization of convective flow in Czochralski crystal growth models by a very slow rotation of the crystal. We seek an explanation of this effect. Existing experimental and computational evidence shows that the destabilization takes place in a wide range of the Prandtl number, starting from semiconductor melts with $Pr \sim 10^{-2}$ and ending with experiments on very viscous silicone oils with $Pr > 10^{3}$. We study several models where flows are driven by the simultaneous action of convection and rotation considering, in particular, flows in cylinders driven by a non-uniform heating of the bottom or sidewall together with rotation of the top or bottom. Examination of several flow models shows that the destabilization is observed in cases where centrifugal force acts against main convective circulation. This allows us to define a generic model that exhibits the destabilization for a wide range of the Prandtl numbers. The generic model is flow in a cylinder with parabolic temperature profile at the sidewall and rotating top. Further observation of the flow and disturbance patterns shows that at relatively low Prandtl numbers the counter action of buoyancy and centrifugal forces can split the main vortex into two counter rotating vortices, whose interaction leads to instability. At larger Prandtl numbers the counter action of the centrifugal force steepens an unstable thermal stratification, which triggers the Rayleigh-Bénard instability mechanism. Both cases can be enhanced by advection of azimuthal velocity disturbances towards the axis, where they grow and excite perturbations of the radial velocity. These explanations are extended to the destabilization effect for rotating magnetic field driven non-isothermal flow and to the melt flow in a Czochralski crystal growth model.