Abstract Submitted
for the DFD12 Meeting of
The American Physical Society

Size-Dependent Couple-Stress Fluid Mechanics and Application to the Lid-Driven Square Cavity Flow AREZOO HAJESFANDIARI, GARY DARGUSH, ALI HADJESFANDIARI, University at Buffalo, State University of New York — We consider a size-dependent fluid that possesses a characteristic material length l, which becomes increasingly important as the characteristic geometric dimension of the problem decreases. The term involving l in the modified Navier-Stokes equations

$$\rho\frac{D\mathbf{v}}{Dt} = -\nabla p + \mu\nabla^2\mathbf{v} - \mu l^2\nabla^2\nabla^2\mathbf{v}$$

generates a new mechanism for energy dissipation in the flow, which has stabilizing effects at high Reynolds numbers. Interestingly, the idea of adding a fourth order term has been introduced long ago in the form of an artificial dissipation term to stabilize numerical results in CFD methods. However, this additional dissipation has no physical basis for inclusion in the differential equations of motion and is never considered at the boundary nodes of the domain. On the other hand, our couple stress-related dissipation is physically motivated, resulting from the consistent application of energy principles, kinematics and boundary conditions. We should note, in particular, that the boundary conditions in the size-dependent theory must be modified from the classical case to include specification of either rotations or moment-tractions. In order to validate the approach, we focus on the lid-driven cavity problem.

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Date submitted: 29 Jul 2012 Electronic form version 1.4