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Homogenization of self-acting air bearing problems for patterned magnetic recording media

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The design of modern gas bearings used in magnetic recording sliders for hard disk drives relies heavily on highly optimized computational tools to solve a specialized version of Reynolds' equation with free molecular flow effects. One of the bearing surfaces is a spinning disk which is smooth on a nanometer scale. In order to create lift, current air bearing designs feature a small number of steps (near-discontinuities) in the bearing gap.

Near these discontinuities boundary layers exist and mathematical rigor requires that one should locally solve a 3D lubrication flow problem (compressible Stokes flow), but the effect of ignoring 3D lubrication flow near the near-discontinuities on integrals of the flow is negligible, at least on the current, smooth, disks. As expected, engineers are hugely in favor of solving the Reynolds equation on a 2D domain over solving Stokes flow in a 3D domain.

To increase recording density there is a distinct possibility that future recording disks will be "patterned": no longer be flat and smooth on a nanometer scale. Air bearing design is now facing the computationally expensive task of analyzing air bearing gap distributions that involve planar features in the disk surface tens of nanometers in size on a slider that has an overall size of approximately one millimeter. Future disk patterns fall in two broad categories: discrete track media (DTM) and bit-pattern media (BPM). Further pattern distinctions exist based on the type of data locally stored on the disk (servo information or actual data).

One way to incorporate disk patterns into the lubrication problem is to adapt the computational mesh to reproduce all features and trust that Reynolds equation remains reasonably valid everywhere. The accuracy of the computed flow in gas bearings is drawn into question because the cumulative effect of small errors incurred at thousands of gap discontinuities on engineering quantities of interest (total lift, shear force and properties) could be unacceptable. If gas bearings are simulated "properly" using methods based on free molecular flow (DSMC, LBM) the solution times are so large - even on large clusters and super-computers - that design optimization of the slider's air bearing design becomes impractical.

At the workshop we will to explore practical ways of numerically tackling air bearing problems on patterned media at low Reynolds number and high Knudsen number. We are especially interested in mathematical homogenization techniques that may make it possible to retain Reynolds' equation but with modification to account for the patterns in the media.

The attached references [1]-[6] span both the justification for patterned media and the challenges it has created for air bearing designers and modelers.

References:

[1] Bandic, Z.Z., Dobisz, E.A., Wu, T-W., Albrecht, T.R. "Patterned magnetic media: impact of nanoscale patterning on hard disk drives," SolidState Technology, Sept. 2006

[2] Harwood, R.F., Hendriks, F. Keller, C.G. "Disk drive with passive multiple fly height slider and cooperative disk pattern," U.S. Pat. 6,075,683 to IBM Corp. Filed Apr. 26, 1993.

[3] Mundt, M.D., Chapin, M.A., Bement, G.E., Denker, B.D., Jones, P.M., "Method and Apparatus for minimizing slider fly heights over patterned media," U.S. Pat. 6,563,673, May 13, 2003.

[4] J.H. Vohr, C.H.T. Pan, On the Spiral–Grooved, Self-Acting Gas Bearings, MTI Technical Report, MTI63TR52, 1963.

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[6] B.J. Hamrock, D.P. Fleming, Optimization of self-acting herringbone grooved journal bearing for maximum radial load capacity, in: 5th Gas Bearing Symp, vol. 1 (13), 1971.