Davies, P. B., and Leonard, R., 1970, "The Dynamic Behavior of Multi-Recess Hydrostatic Journal Bearings," *IMechE Tribology Group Convention*, Vol. 184, Pt3L, May, pp. 139–147.

Dzodzo, M., 1991, "Laminar Natural Convection in Some Enclosures of Arbitrary Cross Section," Ph.D thesis, Faculty of Mechanical Eng., University of Belgrade.

Ettles, C., 1968, "Solutions for Flow in a Bearing Groove," *Proc. Inst. of Mech. Eng.*, Vol. 182, Part 3N, pp. 122–133.

Franchek, N. M., and Childs, D. W., 1994, "Experimental Test Results for Four High-Speed, High-Pressure, Orifice-Compensated Hybrid Bearings," ASME JOURNAL OF TRIBOLOGY, Vol. 116, pp. 147–153.

Goryunov, L., and Belousov, A., 1969, "Certain Design Features of Radial Hydrostatic Bearings for High-Speed Machines," *Izvestiya VUZ. Aviatsionnya Tehnika*, Vol. 12, No. 2, pp. 162–168.

Heckelman, D. D., Ettles, C., 1987, "Viscous and Inertial Pressure Effects at the Inlet of a Bearing Film," ASLE Preprint No. 87-AM-2A-1.

Heller, S., 1974, "Static and Dynamic Performance of Externally Pressurized Fluid Film Journal Bearings in the Turbulent Regime," ASME JOURNAL OF LUBRICATION TECHNOLOGY, Vol. 96, July, pp. 381–390.

Hendricks, R. C., Steinetz, B. M., Athavale, M. M., Prekwas, A. J., Braun, M. J., Dzodzo, M. B., Choy, F. K., Kudriavtsev, V.V., Mullen, R. L., Pragenau von, G. L., 1994, "Interactive Development of Seals, Bearings, and Secondary Flow Systems with the Power Stream," *5th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery* (ISROMAC-5), May 8–12, Maui, Hawaii.

Ho, Y. S., and Chen, N. N. S., 1979, "Performance Characteristics of a Capillary-Compensated Hydrostatic Journal Bearing,", *Wear*, Vol. 52, pp. 285–295.

Ho, Y. S., and Chen, N. N.S., 1980, "Dynamic Characteristic of a Hydrostatic Journal Bearing," *Wear*, Vol. 63, pp. 13–24.

Ho, Y. S., and Chen, N. N. S., 1984, "Pressure Distribution in a Six Pocket Hydrostatic Bearing," *Wear*, Vol. 98, pp. 89–100.

Hunt, J. B., and Ahmed, K. M., 1968, "Load Capacity, Stiffness and Flow Characteristics of a Hydrostatically Lubricated Six Pocket Journal Bearing Supporting a Rotating Spindle," *Proc. IMechE*, Vol. 182, Part 3N, pp. 53–62.

Khosla, P. K., and Rubin, S. G., 1974, "A Diagonally Dominant Second-Order Accurate Implicit Scheme," *Comput. Fluids*, Vol. 2, pp. 207–209.

Leonard, R., and Davies, P. B., 1971, "An Experimental Investigation of the Dynamic Behavior of a Four Recess Hydrostatic Journal Bearing," *IMechE Externally Pressurized Bearings*, Paper C29, pp. 245–261.

Pan, C. H. T., 1974, "Calculation of Pressure, Shear, and Flow in Lubrication Films for High Speed Bearings," ASME JOURNAL OF LUBRICATION TECHNOLOGY, Vol. 96, pp. 80–94.

Patankar, S. V., Spalding, D. B., 1972, "A Calculation Procedure for Heat, Mass and Momentum Transfer in Three-Dimensional Parabolic Flows," *Int. J. Heat Mass Transfer*, Vol. 15, p. 1787.

Patankar, S. V., 1980, *Numerical Heat Transfer and Fluid Flow*, McGraw-Hill, New York.

Peric, M., 1985, "A Finite Volume Method for the Prediction of Three-Dimensional Fluid Flow in Complex Ducts," Ph.D thesis, University of London.

Pratap, V. S., and Spalding, D. B., 1976, "Fluid Flow and Heat Transfer in Three-Dimensional Duct Flows," *Int. J. Heat Mass Transfer*, Vol. 19, pp. 1183–1188.

Redecliffe, J., and Vohr, J., 1969, "Hydrostatic Bearings for Cryogenic Rocket Engine Turbopumps," ASME JOURNAL OF LUBRICATION TECHNOLOGY, July, pp. 557–575.

Rhie, C. M., 1981, "A Numerical Study of the Flow Past an Isolated Airfoil with Separation," Ph.D. thesis, University of Illinois, Urbana-Champaign.

San Andres, L. A., 1990, "Analysis of Turbulent Hybrid Bearings with Fluid Inertia Effects," ASME JOURNAL OF TRIBOLOGY, Vol. 112, pp. 699–707.

San Andres, L. A., Velthuis, J. F. M., 1991, "Laminar Flow in a Recess of a Hydrostatic Bearing," STLE preprint 91-TC-3B-3, STLE/ASME Tribology Conference, St. Louis, MO, Oct. 14–16, 1991.

Scharrer, J. K., Tellier, J., and Hibbs, R., 1991a, "A Study of the Transient Performance of the Hydrostatic Journal Bearings: Part I—Test Apparatus and Facility," STLE preprint No. 91-TC-3B-1.

Scharrer, J. K., Tellier, J., and Hibbs, R., 1991b, "A Study of the Transient Performance of the Hydrostatic Journal Bearings: Part II:—Experimental Results," STLE preprint No. 91-TC-3B-2.

Shinkle, J., and Hornung, K., 1965, "Frictional Characteristics of Liquid Hydrostatic Journal Bearings," ASME *Journal of Basic Engineering*, Vol. 87, pp. 163–169.

Shyy, W., 1985, "Numerical Outflow Boundary Condition for Navier-Stokes Flow Calculations by a Line Iterative Method," *AIAA Journal*, Vol. 23, No. 12, December, pp. 1847–1848.

Shyy, W., 1987, "Effects of Open Boundary on Incompressible Navier-Stokes Flow Computation: Numerical Experiments," *Numerical Heat Transfer*, Vol. 12, pp. 157–178.

Spica, P. W., Hannum, N. P., and Meyer, S. D., 1986, "Evaluation of Hybrid Hydrostatic Bearing for Cryogenic Turbopump Application," NASA TM872254.

Tichy, J. A., and Bourgin, P., 1985, "The Effect of Inertia in Lubrication Flow Including Entrance and Initial Conditions," ASME *J. of Appl. Mech.*, Vol. 52, pp. 759–765.

DISCUSSION

M. M. Athavale[1] and A. K. Singhal[1]

This is an interesting study of the flow interaction in pockets of hydrostatic bearings and offers considerable insight into the complexity of the flow that exists in these pockets under different flow regimes considered in the paper. There are two issues that the discussers would like the authors to comment on:

1) Effects of the curvature of the shaft on the flow dynamics. These effects are expected to be small for the flow in the clearance, but can become important for the deep pockets.
2) The present simulation is done using a 2-D approximation. The pocket is in actuality three-dimensional. Although the 2-D study is an important step in the understanding of the pocket flows, how far is the applicability of such a study to an actual pocket?

Authors' Closure

The authors want to thank Drs. Athavale and Singhal for their comments and insightful questions. In order to effectively answer we have exercised a novel computer model, written by the authors, that allows the three-dimensional (3-D) parametric modeling of hydrostatic pockets, their restrictors, and adjacent lands. In fact this is the 3-D version of the two-dimensional code used in the writing of this paper. Figure 11 presents the geometry of the 3-D pocket. The effects of the curvature of the shaft on the flow patterns and pressure distribution as well as 3-D effects are presented in Figs. 12 and 13 for the deep pocket geometry shown in Fig. 11.

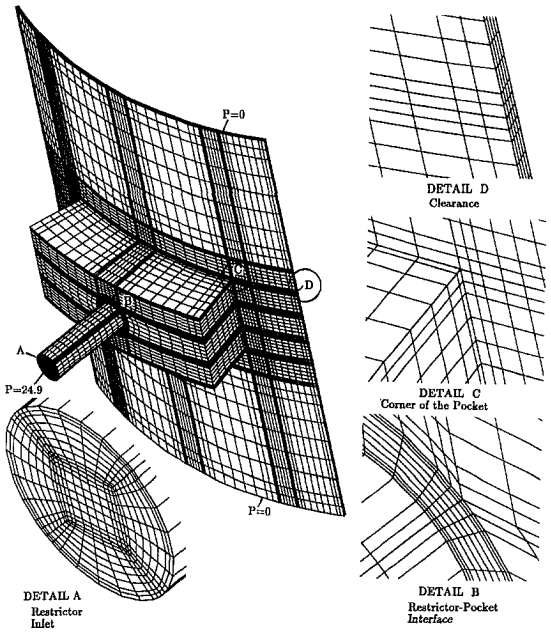

Fig. 11 Geometry of the three-dimensional pocket

[1]CFD Research Corporation.