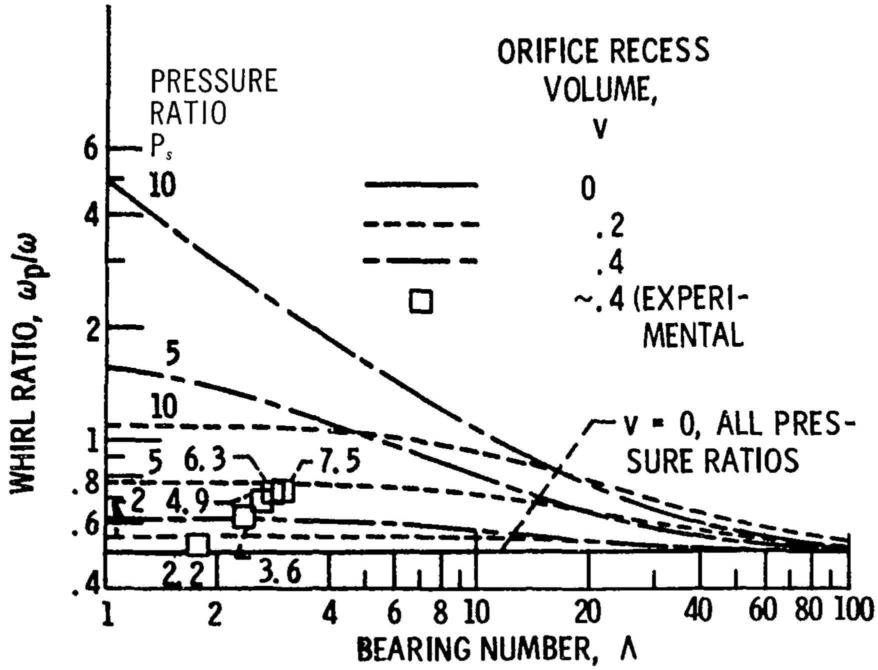


Fig. 7 Frequency of instability; $L/D = 1.5$; $L_1/D = 0.75$; $\delta = 0.447$; $\Lambda_t = 5$

5 When the orifice recess volume is zero, the dimensionless mass $\bar{M}_{2n}$ does not vary with bearing number Λ.

6 Steady-state attitude angles are sometimes larger than those in plain (unpressurized) bearings.

7 The whirl ratio at the threshold of instability is always 0.5 when the recess volume is zero. Whirl ratio increases with increasing recess volume, but approaches 0.5 asymptotically at large bearing numbers.

8 Preliminary experimental data are in fair agreement with the analytical results.

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# DISCUSSION

## F. A. Shen[2]

The authors are to be commended for a well presented analysis of rotating, externally pressurized gas bearings operating with small eccentricity ratios.

With reference to the author's stability results, particularly the relation between attitude angle and stability, the discusser would like to offer these comments. The popular concept of using attitude angle as an indicator of the bearing stability is primarily for hydrodynamic fluid-film bearings. The attitude angle is to specify the relative magnitude between tangential and radial load carrying component when the whirl velocity equals to zero. Should the tangential component of the bearing force exceed the applied tangential load, such as the case of a vertical shaft-bearing arrangement, the journal would initiate a whirl motion. In the process of whirl motion, both the radial and tangential component of the bearing force decrease with whirl velocity while the centrifugal force from the journal mass increases with the whirl velocity. When the centrifugal load becomes higher than the radial bearing (restoring) force, the bearing would become unstable.

In the case of externally pressurized bearings such as that described in the paper there is a substantial radial bearing force due to pressurized component in addition to that from the hydrodynamic bearing action. The magnitude of pressurized radial bearing force, contrary to the hydrodynamic component, is less affected by the journal whirl motion. This is the reason that instability criterion for an externally pressurized bearing with hydrodynamic action cannot be based solely on the steady-state bearing attitude angle. The actual stability determination, as the authors have shown in their paper, should always be based on the balance between the radial bearing (restoring) force and the inertia forces including the centrifugal component, of the journal and rotor unit.

[2] Power Systems Division (A Division of North American Rockwell Corp.), Canoga Park, Calif. Mem. ASME.



  

## Authors' Closure

The authors thank Dr. Shen for his discussion. Investigators long ago discarded the idea of simply adding together "hydrostatic" and "hydrodynamic" load components to obtain the *load capacity* of a rotating externally pressurized bearing. However, this concept appears to be remarkably accurate when applied to the *stability* problem, as long as there are no orifice recesses. The neutral stability condition occurs when the bearing whirls at half the rotational speed. The tangential load component is then zero, as it is when the bearing is stationary. The radial load component also assumes its zero-speed value. Thus, the "hydrodynamic" contribution to the load has disappeared entirely, and only the "hydrostatic" portion remains to be used in the stability calculation.

Orifice recesses change this simple picture. In this case, the radial load component at the critical whirl frequency drops below its zero-speed value, and stability is correspondingly reduced.