segment. Furthermore, it violates intuition by implying that good bearing operation requires large, not small, attitude \( \theta \).

Because of the assumptions (primarily constant film viscosity, the boundary conditions on the partial film, and the constancy of end-leakage factors), Fig. 10 must be considered only approximate. At best it will serve as a general guide. If we assume that the stability of actual bearings can be represented by a chart of similar form to that of Fig. 10, certain significant qualitative conclusions may be drawn. For example, increasing the load \( W \) by means of the so-called “oil dam” as proposed by Newkirk is an effective way to decrease both \( \Omega \) and \( S' \). It will achieve bearing stability only if the change in \( W \) is great enough to cause operation to shift from the unstable to the stable region.

It would appear that specifying a large \( C \) for a machine certain to operate at an \( \Omega \) ever, say, 0.4 would greatly help to reduce \( S' \) with only slight expense. This is true, provided the increased clearances do not result in appreciably cooler, and therefore more viscous, lubricant, or that the rotor dynamics situation is not otherwise affected adversely. There is evidence to suggest that large clearances are detrimental to smooth running particularly with overhung-mass rotors.

One of the most effective ways of reducing \( S' \) would seem to be the use of grooving (principally circumferential grooves), which reduces \( \mu' \) through reduction of \( \mu'_{cv} \). The desirability of low \( S' \) will direct the designer’s attention to low-viscosity lubricants. Grooving would receive increasing influence, In Part 2 of this paper the gas-film bearing will be shown to provide interesting stability characteristics as well as low viscosity.

A direct application of full-film-bearing stability theory is the rotating-cylinder or rotating-tapered-plug viscometer in which an attempt is made to measure fluid viscosity at high shear rates in the ostensibly uniform thin film between a rotating “self-centering” inner plug and a fixed outer wall. We see from stability theory that the inner plug cannot be expected to center itself and that the measurements will therefore not be reliable.

A general comment may be made on the turbine-vibration problem. There is little doubt that bearing design for stability must become an important concern for the turbomachine designer. Almost no information is yet available on the influence of bearings on the motion of a typical multilias flexible-shaft rotor. The study of even the most elementary systems looking toward the solution of this problem must probably include the treatment of a finite mass located at each bearing.

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References


DISCUSSION

Herbert S. Y. Cheng

The authors are to be complimented on their careful approach to this problem of stability of high-speed journal bearings. In particular, their discovery of the orbital motion for full film bearings and the separation of orbital motion from film failure is definitely a step forward in this field. The following points in their paper are of interest.

1. The trajectories of the journal center seem to indicate that the amplitudes of the orbital motion are reduced considerably as the value of \( \theta \) is decreased from 0.8 to 0.33. The normalized angular speed parameter seems to have little effect on the size of the orbit. If one takes a journal bearing of a particular geometry and considers the same steady load, the variation of the parameters with respect to the increase of the speed is shown to follow a certain curve in Fig. 8. A bearing would start off with vibrations of large amplitudes at low speeds and as the speed increases the amplitudes would diminish until the speed crosses over the threshold curve into the region of failure. This condition seems to confirm some of the previous experimental investigations on light rigid rotors [9]. Further experiments in the light of the results in this paper should be fruitful.

2. The writer wishes to know whether any attempts have been made to obtain a computer solution of the governing equations for the 180-deg film bearing. A solution of these equations should reveal whether there exist orbital motions of the journal center in the unstable zone.

Additional Reference


Clarence J. Maday

The authors are to be congratulated for the material presented in their paper and, in particular, for the numerical results of the stability analysis of the full journal bearing for the case of large displacements. This work again emphasizes that a designer must consider the system, which consists of the bearings and the rotor, rather than the bearings alone in order to achieve a successful design. The paper also demonstrates that the small displacement approximation (which predicts instability for the full journal bearing) may not always yield sufficient information to the designer who may consider the journal motion represented by Run B-2, for example, to be acceptable for practical purposes. It is interesting to note, however, that the results of the numerical studies confirmed those of the small displacement analysis which showed that the equilibrium position of the full journal bearing is unstable.

Fig. 8, which shows the dependence of orbital motion on the Sommerfeld number and the angular speed, is particularly interesting. It would be instructive if a similar curve were obtained for the 180-deg offset bearing and then shown on Fig. 10. Such a curve would be of use to a designer concerned with heavily loaded bearings for which orbital motion would be considered acceptable. Perhaps the authors plan to include such data in a forthcoming paper.

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It might be well to note that there are indications that the region of stability for the 180-deg bearing is reduced when flexible rotors are considered. A small displacement analysis of this problem was treated in a recent paper by Hori, whose work was previously referenced by the authors of this paper.

Authors' Closure
The comments of both discussers are welcomed. The suggestion to study the range of orbital solutions for the 180-deg film bearing is a good one. It would appear, however, that the major effort in high-speed bearing research, particularly from the designer's viewpoint, should perhaps be directed toward the study of bearings which have better stability characteristics. We believe that the simple journal bearing, even if operated with a partial film, is almost certainly not optimum for high-speed use.