Journal of Tribology

Discussion

A Global Approach of Thermal Effects Including Pad Deformations in Tilting-Pad Journal Bearings Submitted to Unbalance Load[1]

R. S. Paranjpe.[2] The authors are to be congratulated on a very interesting and useful piece of work. The authors have compared the relative importance of including different effects viz. thermal effect (effective oil viscosity), thermal expansion of bearing elements, elastic deformation of bearing pads. This is potentially useful information in deciding which analysis to perform for a given application, provided, the application is similar to the one considered by the authors.

It appears from Fig. 7 and Table 3, that inclusion of the thermal effect (effective viscosity) gives the greatest improvement over a conventional rigid, isothermal analysis. Our (Paranjpe and Han, 1994, Paranjpe, 1995) experience in this regard also has been that any thermal analysis, even a fairly simplified one, is generally a significant improvement over an isothermal analysis.

Could the authors explain how they arrived at Eq. (12) to estimate the maximum temperature?

References

Paranjpe, R. S., and Han, T. Y., 1994, "A Study of the Thermohydrodynamic Performance of Steadily Loaded Journal Bearings," *STLE Tribology Transactions,* Vol. 37, pp. 679–690.

Paranjpe, R. S., 1995, "A Study of Dynamically Loaded Engine Bearings Using a Transient Thermohydrodynamic Analysis," Accepted for publication in *STLE Tribology Transactions.*

A. Palazzolo.[3] The authors present a very interesting method for simulating the response of tilt pad journal bearings to static and imbalance loads. Could you please clarify the following points:

(1) Is the $\frac{3}{2}$ factor used in Eq. (12) selected empirically or by theory? If empirically, why not adjust it to "fit" the test data in Table 3 more closely. If by theory, could the authors discuss it more thoroughly?

(2) A finite element model of the pad is reduced to a super-element consisting of nodes only on the surface facing the shaft, and the pivot and constraint nodes. A boundary element model could be condensed in the same manner by converting it to an equivalent stiffness matrix.

A boundary element approach requires triangularization of a full matrix whereas the FE treats a banded matrix.

A back substitution is required in either approach at each time step.

Considering these points, could the authors identify how significant is the CPU time savings using BE instead of FE for pad flexibility modeling?

(3) Figure 5 shows large variations in temperature for unbalance loading. The authors state that this shows that although Gadangi and Palazzolo's (1994) temperature variations are small, large (25°C) variations could exist. Does this not also raise the question of how accurate is the effective temperature method versus the less approximate local method of Gadangi and Palazzolo? Could the authors address this concern?

Hiromu Hashimoto.[4] The authors presented an interesting analysis on the dynamic behavior of tilting-pad journal bearings. In this paper, the effects of elastic pad deformations and thermal expansion of pad on the transient motion of bearings are examined by applying a simple global energy balance on each pad.

I would like to ask the following questions:

(1) According to your numerical results, as far as the journal trajectory is concerned, the isothermal theory gives better solutions than the theory considering the thermal effects only. Is it possible to estimate approximately the journal trajectory by applying the isothermal theory?

(2) Could you show the criterion of dynamic load under which the elastic pad deformations are not negligible?

(3) Could you show the CPU time to obtain the typical journal trajectory for four cases (case 1–case 4)?

Authors' Closure

The authors are grateful for the discussion of Rohit S. Paranjpe. The coefficient $\frac{3}{2}$ in Eq. (12), which permits determining the maximum temperature, is usually used in our numerical programs including a global energy balance relating to both journal and thrust bearings. This value is empirical and based on many comparisons between theory and experiments, but we do not try to adjust it in this study.

We would like to thank Dr. Alan Palazzolo for his interest in this work and for his questions.

The first point is discussed above. Concerning the second question, a comparison has been made to analyze the CPU time when elastic pad deformations are obtained using either boundary element approach or finite element model. For the finite element model, isoparametric elements with eight nodes are used. For a grid size of 7 × 21 nodes respectively in r and θ directions, the CPU time (HP 9000 computer) is reported in

[1] By M. Fillon et al., published in the January 1996 issue of the JOURNAL OF TRIBOLOGY, Vol. 118, pp. 169–174.

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