A Study of Thermo - Mechanical Interactions of Journal - Bearing Systems

[1]G.Srikanth, [2]Dr. C.Janardhan Rao
[1]Dept. of Mech., AITAM, Tekkali, Srikakulam, AP, India
[2]HOD, Dept. of Mech., AITAM, Tekkali, Srikakulam, AP, India

Abstract
Operating clearance is one of the important variables in the performance of journal bearing. The difference of clearance with time is of significant practical interest particularly for situations where large frictional heat is formed as a result of dry contact. The deformation connected with expansion of the rotating shaft relative to that of the stationary bearing may be quite large to the point that a absolute loss of clearance may take place with a catastrophic seizure. This seizure occurrence normally occurs through the startup process when shaft is in direct contact with bush. Particularly vulnerable to seizure are bearings that have not been used for a comparatively long period of time or when the lubricant provide to the bearing is blocked thus during the startup process the shaft and the bush are in direct contact with a connected high friction coefficient. Under these circumstances one would like to be able to calculate how long it takes before the seizure may set in. The objective of this work is to carry out a comprehensive study of seizure in bearings during start up and when a transient flow disturbance is occurred and alive at seizure time which is a function of various parameters. The study assumes that the contact pressure is uniform in axial direction and that no crowning or misalignment is present in the system.

Keywords
Journal-Bearning Systems, Thermo-Mechanical Interactions, Seizure, TIS

I. Introduction

Thermal effects in hydrodynamic lubrication are significant due to the strong dependence of viscosity on temperature. Most modern automotive lubricants are multi grade oils containing polymeric additives at treat rates of up to 20% and making lubricants gently viscoelastic and somewhat cut off thinning. Therefore a combination of thermal and non-Newtonian effects plays a major role in the analysis of dynamically loaded journal bearings in mixed lubrication. A 2-D static contact study is to be performed to establish the contact forces and the contact angle. A transient heat transfer analysis is to be performed to model thermal effects of dry frictional heating on the journal and the bearing. A transient thermo-elastic study is to be performed to learn the interactions of the journal-bearing pair through bearing start-up. The variation of radial clearance, contact forces and ovalization of the bearing are to be studied in this analysis. The minimum nominal film thickness in dynamically loaded journal bearings such as crankshaft bearings is in the same order of scale as the surface roughness causing mixed lubrication to happen. The power dissipation connected with friction is apparent in the form of heat generation at the contacting surfaces and results in an augment in temperature of sliding bodies. Many widely used mechanical components such as bearings, seals, brakes and clutches are vulnerable to frictional heating.

II. Related Work

Thermally induced seizure is not a occurrence restricted to bearings operating under dry or boundary lubricated conditions. It can also occur in bearings running in fully lubricated condition. This phenomenon was discussed by Pascovici, Khonsari and Jang and an analytical model was formulated for this transient analysis. A limited temperature is taken as the condition for onset of seizure and this limiting temperature is when the approval between the journal and the bearing is completely lost. A "no-seizure" condition is also derived based on the limiting temperature. Thermally induced Seizure (TIS) can also occur in circumstances where there is a disturbance in the steady-state operation of the journal bearing. The aircraft engine bearings are not only required to survive these operating conditions but also to resume normal operation once the lubricant flow is re-established.

III. Literature Review

Wang performed a review of published results on TIS in conformal contacts. The stoppage of motion and welds of contacting surfaces recognize seizure the causes of the failure and the mechanisms of the onset of seizure may differ in agreement with material combinations, contact and lubrication states, and operating conditions. Other types of journal bearing failures such as scuffing and adhesion are also presented in his paper most of which were observed by stopping the bearing operation at early stages of seizure transitions before the catastrophe occurred and failures will eventually develop into seizure. The major causes of seizure of journal bearings are loss of clearance due to differential thermal expansions of the journal and bearing, loss of clearance due to build-up of wear debris, Intimate metal-metal contacts, and variation of surface geometry and material properties owing to interfacial tribochemical activities. Courses of seizure for non-conformal contacts are mainly lubrication breakdown, local welds at high temperatures, and deformation and shear. Thermally induced Seizure (TIS) can also occur in conditions where there is a disturbance in the steady-state operation of the journal bearing.

IV. Exisiting Method

The previous experimental set-up is used to study thermo hydrodynamic (THD) seizure in an unloaded bearing that is operating in completely lubricated conditions. The journal was made of polyamide and the bearing was made of glass-reinforced epoxy resin. The seizure time was resolute when the driving torque necessity exceeded a certain range. A theoretical THD analysis was done to determine the thermal answer of the lubricating oil. The viscous dissipation caused the oil temperature to rise. The thermal expansion of the shaft and its violation into the bushing was determined using a standard 2-D heat conduction equation. The boundary conditions at the boundary of the shaft and the fluid film were determined from the THD analysis.

A. Disadvantages

There is loss of clearance because of differential thermal expansions of the journal and bearing and loss of clearance due to build-up of wear debris. Intimate metal-metal contacts and Variation of surface geometry and material properties owing to interfacial tribochemical activities.

V. Proposed Method

To study the thermo-mechanical interactions of journal-bearing

systems subjected to dissimilar types of boundary conditions like unlubricated bearing start-up, a fully-lubricated bearing undergoing a trouble in the lubricant oil supply and a journal and bearing subject to oscillating heating. The finite element study is a easy and handy tool that is used with good accuracy in engineering. The commercial FEM software package was used to execute a detailed analysis of the thermo-elastic interactions of journal and bearing. Heat conduction analysis must be performed to conclude the material temperatures and the heat flow rates. The temperature distribution is also needed in order to execute analysis of the thermally induced stresses. Fortunately it is probable to work out a single mesh layout for the both problems. A computer program can read a single data file calculates the temperatures at the nodes then these temperatures are used in a thermo-mechanical analysis to compute the displacement, stresses etc.

A. Advantages

It deals with the incidence of seizure during start up period followed by an investigation of Thermally Induced Seizure (TIS) due to the transient flow disturbance. A widespread set of parametric simulations covering load, speed, shaft radius, operating clearance, bearing length, friction coefficient and thermal expansion coefficients are studied to give insight into the occurrence of TIS which assist to plan instrumentation systems and warning devices to take necessary precautions.

B. Journal Bearing Configuration

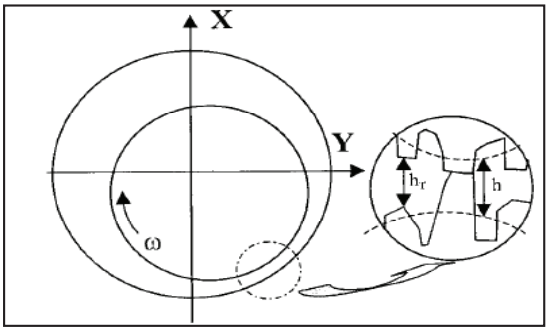

Fig. 1:

1. TIS in Journal Bearings During Start Up

Thermally induced seizure (TIS) in journal bearings is a mode of failure that can occur quite suddenly and end up with a catastrophic damage to the system. Although TIS can take place in lubricated bearings it is predominant when a hydrodynamic bearing happens to operate in the boundary or mixed lubrication regimes. These conditions occur during start-up or in the event of lubricant supply blockage.

2. Finite Element Modeling Procedure

The finite element model employs a finer mesh than the mesh used by Hazlett and Khonsari to estimate the contact forces with more accuracy. A simplified 2-dimensional analysis is performed. The analysis assumes that the contact pressure is consistent in the axial direction and no crowning or misalignment is present in the system. The effect of bearing length is analyzed in the 2-D analysis by taking into account the change in the contact width and change in the heat flux generated with change in bearing length.

3. 2-D Static Contact Analysis

This analysis uses one-half symmetry neglects conduction in the axial direction of the shaft. The solid element PLANE42 is used to model the journal and the bush. This element is a 2D bilinear element with the displacements in the X and Y directions as the degrees of freedom. The radial clearance between the journal and the bush is representation using two-noded contact elements namely CONTACT12. Contact elements are used to model the gap and they come into result only when the two nodes of the elements come into contact. The element properties include a normal stiffness value that rules the resistance to normal load. The finite element programmer assigns the stiffness value for the contact element.

4. Transient Thermal Finite Element Analysis

The thermal analysis is finished to conclude the temperature distribution in the journal-bushing pair. The journal and bushing are modelled as 4-noded solid thermal elements viz. PLANE55. The PLANE55 element has a single degree of freedom namely temperature at each node. It is noted that the elements at the centre of the shaft degenerates to triangles. This element is well-matched with the 4-noded structural solid element used in the thermo-mechanical analysis. The results of the thermal analysis can be productively exported to execute the thermo-elastic analysis.

5. Non-Linear Transient Elastic Finite Element Analysis

Two types of elements are used in the non-linear elastic model. The shaft and bush uses two dimensional isoperimetric plane stress solid element designated by PLANE42. The element is defined by four nodal points having two degrees of freedom at each node, translation in the nodal X and Y directions. The theory for the element is based on the formulation which includes customized extra displacement shapes.

6. Seizure Criterion

Frictional torque is the torque resisting the driving torque exerted by the motor. When the frictional torque increases beyond the extent of the driving torque capability it can be finished that the journal has seized in the bearing. The present model assumes that TIS is complete when the frictional torque reaches at least 50 times the driving torque.

Flowchart of Numerical Calculation

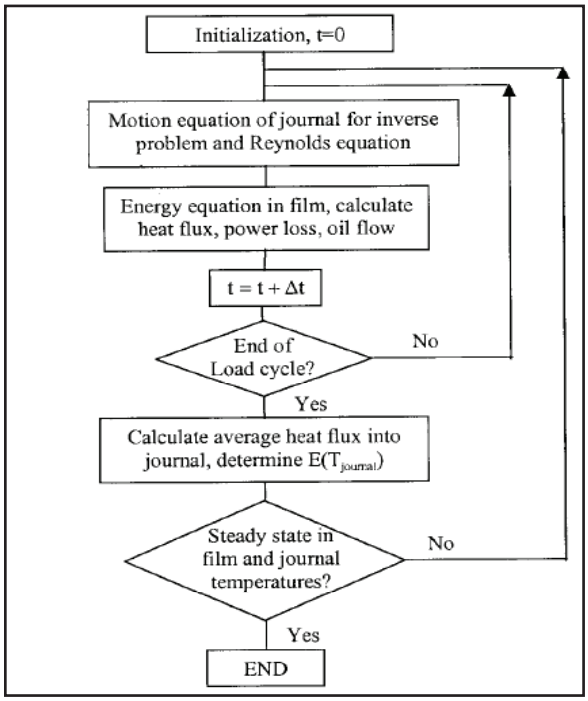

Fig. 2:

VI. Experiment Results

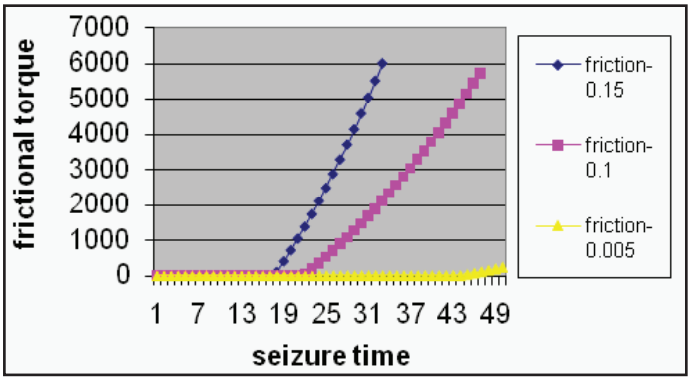

Fig. 3:

The journal bearing seizure analysis has been performed assuming that dry sliding occurs between the shaft and bushing. In a typical fluid film bearing the surface of the shaft and bushing are completely separated by Film of oil. The major effect of the lubricant is to provide a low friction coefficient and increased internal cooling. The friction coefficient for a lubricated contact is around 0.005 as compared to the value of 0.15 used for the dry sliding case. The heat generated at the rubbing surfaces is directly proportional to the frictional coefficient. Therefore, when the contact is lubricated, the magnitude of the clearance loss would be much less than the dry friction case. In addition, lubricant normally provides some internal cooling. A plot of the frictional torque versus time is shown in fig. 3 for the different frictional coefficient values.

VII. Conclusion

The combined effects of thermal, roughness, and non- Newtonian rheology are closely tied with roughness texture and structure, power law index, relaxation time, journal mass, features of nominal geometry, and operation condition. The fluid elasticity dramatically reduces oscillations of the film pressure but unaffects the minimum nominal film thickness, cycle averaged leaking flow, and power loss. Its effect on the load carrying capacity is dependent on the operating condition. A transient non-Newtonian THD theory of dynamically loaded journal bearings in mixed lubrication is presented. A mass conserving cavitation is included and shear thinning and viscoelasticity are characterized by the power law and the upper convected Maxwell models, respectively.

References

[1] Ai, Xiaolan, Cheng, H. S., Hua Dongyun, Moteki, K., Aoyama, S.,"A Finite Analysis of Dynamically Loaded Journal Bearings in Mixed Lubrication", STLE Tribology Transactions, Vol. 44, No. 2, pp. 273–281, 1998

[2] Boedo, S., Booker, J. F.,"Body Force and Roughness Effects in Mass-Conserving Model Based Elastohydrodynamic Lubrication Model", Proc. of the International Tribology Conference, Yokohama, pp. 1061–1066, 1995.

[3] Christensen, H.,"Stochastic Models for Hydro-dynamic Lubrication of Rough Surfaces", Proc. Instn. Mech. Engrs., Vol. 184, Part 1, No. 55, pp. 1013–1026, 1969–1970.

[4] Dowson, D.,"A Generalized Reynolds Equation for Fluid Film Lubrication", Int'l. Jour. Mech. Sci., Pergamon Press, 4, pp. 159–70, 1962.

[5] Ezzat, H., Rhode, S.,"A Study of the Thermohydrodynamic Performance of Finite Slider Bearings", ASME JOURNAL OF LUBRICATION TECHNOLOGY, Vol. 95, pp. 298–307, 1973.

[6] Lee, S. C., Ren, N.,"Behavior of Elastic-Plastic Rough Surface Contacts as Affected by the Surface Topography, Load and Materials", STLE Tribology Transaction, Vol. 39, pp. 67–74, 1996.

[7] Paranjpe, R. S.,"Analysis of Non-Newtonian Effects in Dynamically Loaded Finite Journal Bearings Including Mass Conserving Cavitation", ASME JOURNAL OF TRIBOLOGY, Vol. 114, pp. 736–746, 1992.

[8] Paranjpe, R. S., Han, T. Y.,"A Transient Thermohydrodynamic Analysis Including Mass Conserving Cavitation for Dynamically Loaded Journal Bearings", ASME JOURNAL OF TRIBOLOGY, 117, pp. 369–378, 1995.

[9] Richtmyer, R. D.,"Difference Methods for Initial Value Problems, Interscience Publishers, New York, pp. 101, 1957.

[10] Rastogi, A., Gupta, R. K.,"Lubricant Elasticity and the Performance of Dynamically Loaded Short Journal Bearings", Journal of Rheology, Vol. 34, pp. 1337–1356, 1990.

[11] Rastogi, A., Gupta, R. K.,"Accounting for Lubricant Shear Thinning in the Design of Short Journal Bearings", Journal of Rheology, Vol. 35, pp. 589–603, 1991.

[12] Wang, X., Wen, S., Gui, C.,"An Analysis of the Thermohydrodynamic Performance of Dynamically Loaded Bearings", Prof. of The First Asia International Conference on Tribology, Beijing, 1998, pp. 25–29, 1998.

Mr.G.Srikanth is a student of Aditya institute of technology and management, Tekkali, Srikakulam dist. Presently, he is pursuing his M.Tech [thermal Engineering] from this college and he received his B.Tech from Sri Raja Rajeswari Engineering college, affiliated to JNT University, Hyderabad in the year 2010. His area of interest includes Power Plants Technology and Renewable Sources, Thermal Engineering, all current trends and techniques in Mechanical engineering.

Dr.C.Janardhana Rao, well known excellent professor received M.E from M.S.U. of Baroda is working as professor and HOD, department of mech, AITAM, Tekkali. He is controller of examinations AITAM. And he awarded Ph.D (mech.eng) from A.U. Visakhapatnam in 2012. He has 14 years teaching experience in various engineering colleges. To his credit couple of publications both national and international conference journals. His area of interest includes Production technology, Machine tools, Unconventional machining processes, Metrology and Modern manufacturing methods in Mechanical engineering.