STABILITY CHARACTERISTICS
OF
FLOATING BUSH BEARINGS

BY

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CERTIFICATE

We are satisfied that the thesis entitled STABILITY CHARACTERISTICS OF FLOATING BUSH BEARINGS presented by Mr. K. Athre is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision and that the results contained in it have not been submitted in part or full to any other university or institute for award of any degree/diploma.

We certify that he has pursued the prescribed course of research.

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ABSTRACT

Stability is known to be an important criterion in the design of high speed, oil lubricated bearings. Efforts to increase the stability range of such bearings are being made by such methods as design improvements and modifications of bearing arrangements. An impetus to this effort was given by the introduction of floating bush bearings for high speed applications including gas turbines and turbosuperchargers. The present work on stability of floating bush bearings sprang from R and D work on turbo-superchargers for Diesel Engines at the institute.

The study was carried out for two arrangements, the 'Single Floating Bush Bearing' and the 'Double Floating Bush Bearing'.

The first design studied was the single floating bush bearing. The analysis was conducted for short bearing, infinite bearing and the finite bearing analysis was tried. The stability of the rotor-bearing system was studied by applying Routh-Hurwitz criterion for which the characteristic determinant was obtained from the equations of equilibrium. From the characteristic determinant the coefficients of the characteristic equation were obtained through a computer

package developed for the purpose. The program developed was general and worked even when each element of the characteristic determinant, which may be of order $m \times n$ was a polynomial of an arbitrary order n. Noiterative procedures were involved and hence the values obtained were exact. Using the same computer package the points of instability were obtained by applying the Routh-Hurwitz criterion to the characteristic polynomial. The program could be used for different types of bearings such as the ordinary journal bearing, the single floating bush bearing and the double floating bush bearing.

The stability curves for flexible bearings were obtained through the rigid bearing analysis. This involved finding the roots of the charactrristic equation. The known existing methods for finding the roots of a polynomial were found to be unreliable. Considerable amount of effort was therefore spent on developing a computer program for this purpose. The finally developed program generated the initial values from the coefficients of the polynomial.

For the finite bearing analysis the Reynolds partial differential equation was solved by a modified finite difference approach. This new approach used the concept of 'Reynolds Moving Boundary Condition', satisfying the Reynolds boundary condition $p = \frac{\partial p}{\partial \theta} = 0$ at $\theta = \pi + \alpha$ in toto, unlike the commonly used iterative technique where the only condition satisfied being, p, the pressure should never be negative.

The second design studied was the unequal length single floating bush bearing and finally the analysis of double floating bush bearing was conducted and stability charts drawn.

Originally it was planned to carry out experiments to validate the theoretical work. However subsequently it was felt that the magnitude of theoretical work was rather large and it was considered better to concentrate on the theoretical work and to take it to a conclusive stage sacrificing the experimental validation part.

Certain differences were found in the coefficients evaluated by the numerical method presented in the thesis and those previously obtained analytically by Tanaka and

Hori in 1972. The stability charts for single floating bush bearings using short bearing approximation were replotted and compared with the results obtained through infinite bearing approximation; the latter in general gives a lower value for the onset of instability, though the profile of curves is nearly the same by both the methods. It was noted that the more rigid the bearing is the better is its stability. Further improvement of stability of the bearing could be obtained by increasing the ratio of outer clearance to inner clearance and at this ratio of more than 2.4 the profile of the curves was found to be smoother indicating stable operation.

Results for finite bearings could not be obtained because of convergence problem. Though the Reynolds equation for the inner film could be easily solved, solving the Reynolds equation for the outer flim under the balance of torques and forces was unsuccessful though several methods were tried. Solving the Reynolds equation by taking care of the moving boundary condition improved the accuracy of the results and indicated that the final Reynolds boundary condition was satisfied far earlier than suggested by the iterative technique.

Results of calculation for unequal length bearings showed that the idea of 'unequal length' floating bush bearing could be used to advantage. In general, decreasing the ratio of the outer bearing length to the inner bearing length for a floating bush improves the stability characteristics. The improvement was found to be particularly remarkable for rigid bearings.

The double bush results show an impressive improvement in the stability of the rotor-bearing system, for certain combinations of clearance ratios. For a double bush two clearance ratios are defined. The one is called OUTERMOST clearance ratio and the other OUTER clearance ratio. In general increasing the outermost clearance ratio and the outer clearance ratio improves the stability of the rotor-bearing system. Also for a particular outer clearance ratio increasing the outer most clearance ratio increases the stability range. Thus with a proper choice of these clearance ratios a double floating bush will be much more stable than a single floating bush bearing.

C O N T E N T S