The Numerical Solution of the Reynold's Partial Differential Equation Applied to the Air Lubrication of Circularly Curved Surfaces

SUMMARY

In this study, a slider bearing pitched at various angles is placed above a surface moving at a fixed velocity. The problem is to determine the variation of the load due to the existing air pad between the slider bearing and the moving surface as the minimum bearing to surface distance changes.

The analysis of load variation with bearing to surface spacing in which the center of pressure was located at a fixed point was carried out by obtaining numerical solutions to the difference equation which approximates the Reynold's partial differential equation in two dimensions. The computations of this solution were carried out on the IBM 704 and 7090 Data Processing Systems.

The Reynold's Equation is:

$$\frac{\partial}{\partial x}\left(\frac{h^3\rho}{\mu}\frac{\partial \rho}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{h^3\rho}{\mu}\frac{\partial \rho}{\partial y}\right)=6U\frac{\partial}{\partial x}(\rho h)$$

which is solved under the boundary conditions:

$$p(0, y) = p(B, y) = p(x, 0) = p(x, L) = p_0$$

where B and L are the length and width of the slider bearing.

By making first order central difference approximations to derivatives in the above equation a difference equation in the form of a quadratic is obtained.

The rectangular region over which the pressure distribution is defined is transformed to a square region by the introduction of suitable scaling factors.

The pressure distribution is obtained in the following manner. First by inserting the boundary values into the difference equation the pressure at the center of the square region is obtained. In the computation, the value of the mesh spacing is equal to one-half the side of the region. Then by using this central value with the boundary values the interior points of a 5x5 mesh are obtained. This mesh is then improved by successively computing each point in it. Improvement is considered to be satisfactory when the difference between the present value of each point and the previously obtained value of that point is less than a predetermined accuracy limit. The mesh spacing used in this mesh is one-half the spacing defined previously.

This procedure is then repeated by halving the mesh spacing thus obtaining a 9x9 mesh. Then, if necessary, a 17x17 mesh can be obtained by again cutting the spacing in half and proceeding in the same manner.

When the mesh is computed, it is desired to evaluate the centroid and load of this pressure distribution. These two quantities are computed by using standard formulas. The integrands in these formulas are approximated by 7x7 polynomial surface fits. The centroid and the load are then easily obtained by performing the integrations over the region defined by the square mesh.

The program to compute the centroid and load was written using the 7090 FORTRAN Programming System. The program was set up to obtain the variation in the values of load vs. minimum surface spacing for a specified center of pressure. In order to accomplish this an iterative procedure was used. This procedure consisted of holding the initial bearing to surface spacing fixed over a range of specified values. The pitch of the bearing with respect to the moving surface was varied until the pressure distribution which had the required value of the centroid (within specified tolerances) was obtained.

It was found that the accuracy of the computations was not great enough using normal programming methods. It was then necessary to evaluate many of the critical equations using double precision.

The solutions to this problem were obtained for slider bearings having curvature in both one and two dimensions. The results of the study showed that the plane approximation to the cylindrical slider bearing yield results which were quite different from the results using the cylindrical slider bearing.

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By:

Mr. V. A. Ciminera - Systems Computational Analysis

Mr. R. V. Wadding - Engineering Computational Analysis

Dr. W. C. Orthwein - Analysis and Computation Center

IBM Space Guidance Center - Owego, New York