SOLUTION PROCEDURE

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Chapter 4

SOLUTION PROCEDURE

4.1 GENERAL

The solution procedure to be adopted for determining the static and dynamic performance characteristics of elastohydrodynamic circular and noncircular bearing problems with Newtonian and micropolar lubricants is presented in the chapter. The procedure comprises the coupled solution of

1) The two dimensional modified Reynold's equation
2) The three dimensional elasticity equation to obtain the displacement field.

The simultaneous solutions of all these equations have to be obtained by using finite element method and a direct iterative procedure. Additional iterations are required to establish the Reynold's boundary conditions at the trailing edge of fluid film in circular bearing and each lobe of the non-circular bearing and to establish the equilibrium journal centre for the vertical load support in the case of non circular bearings.

4.2 SOLUTION SCHEME

The solution scheme used for solving elastohydrodynamic lubrication involves the determination of various quantities. The flow charts for determining these quantities with various iterative segments and convergence criteria are presented here.

4.2.1 Solution of Nodal Pressures

The Reynold's equation representing the flow field in the clearance space of the journal bearing is solved to obtain the pressure and velocity components in the flow field.

After discretizing the flow field as explained in Chapter 2 the element fluidity matrix is formed for each element. The boundary conditions are applied at the element equation stage and the element fluidity matrices are assembled to form the global fluidity matrix. The global system of equations (2.33) thus formed are solved to get nodal pressure components. The flow chart of the scheme for obtaining nodal pressures is given in Fig 4.1.

4.2.2 Computation of Reynold's Boundary

Reynold's boundary condition is established based on that the pressure gradient $\frac{\partial p}{\partial \theta} = 0$ at the boundary ($\theta = \theta_r$) of positive pressure fluid film.

Initially a value of θ_r is assumed for the film extent. The pressure gradient $\left(\frac{\partial p}{\partial \theta}\right)$ at its trailing edge is computed and depending on whether the pressure gradient is negative or positive, a respectively positive or negative correction on the first trial value of θ_r is made. The pressure gradient at the trailing edge is calculated again for the modified value of the film extent. In subsequent iterations, the new trial value θ_r is selected by linear interpolation or extrapolation using the two closest values from the previous iterations. The iteration is terminated when the magnitude of the pressure gradient becomes smaller than an arbitrarily assigned small value, 0.01.

In noncircular bearings, for a given journal centre position (ε, ϕ), each lobe has its own positive pressure fluid film, the extent of which has to be determined. For circular and noncircular flexible bearings, the film extent of deformable bearing at any eccentricity ratio, is obtained using the same iterative procedure starting with the value of θ_r for the corresponding rigid bearing, as the first trial value. The flow diagram for determining Reynold's boundary is shown in Fig. 4.2.

4.2.3 Determination of Attitude Angle for Non-Circular Bearings

In the case of non circular bearings, the direction of load when specified with reference to the lobe geometry, requires a unique unknown attitude angle. The attitude angle for a given operating eccentricity is determined by using the iteration scheme described below.

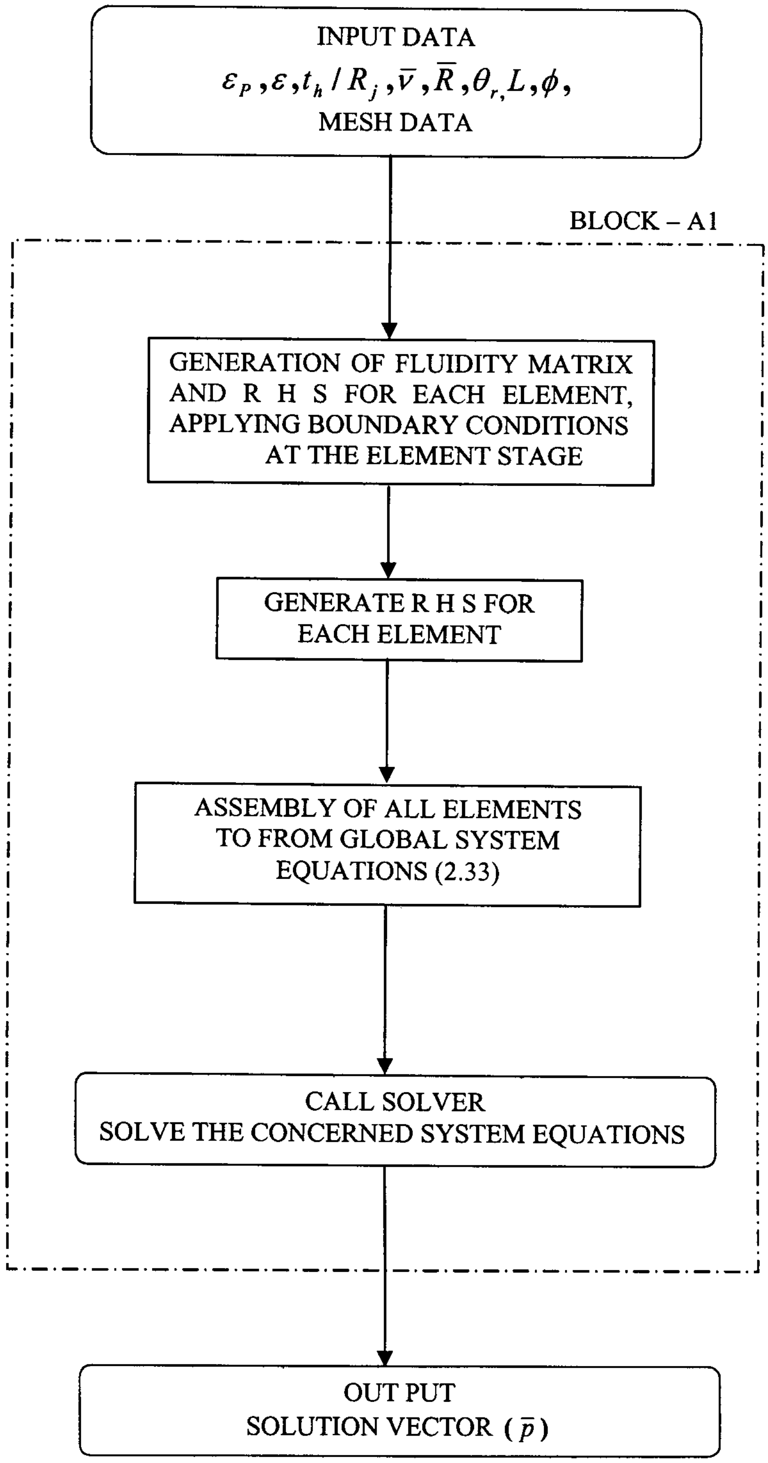

Fig. 4.1 Flow Diagram for Determining Nodal Pressure

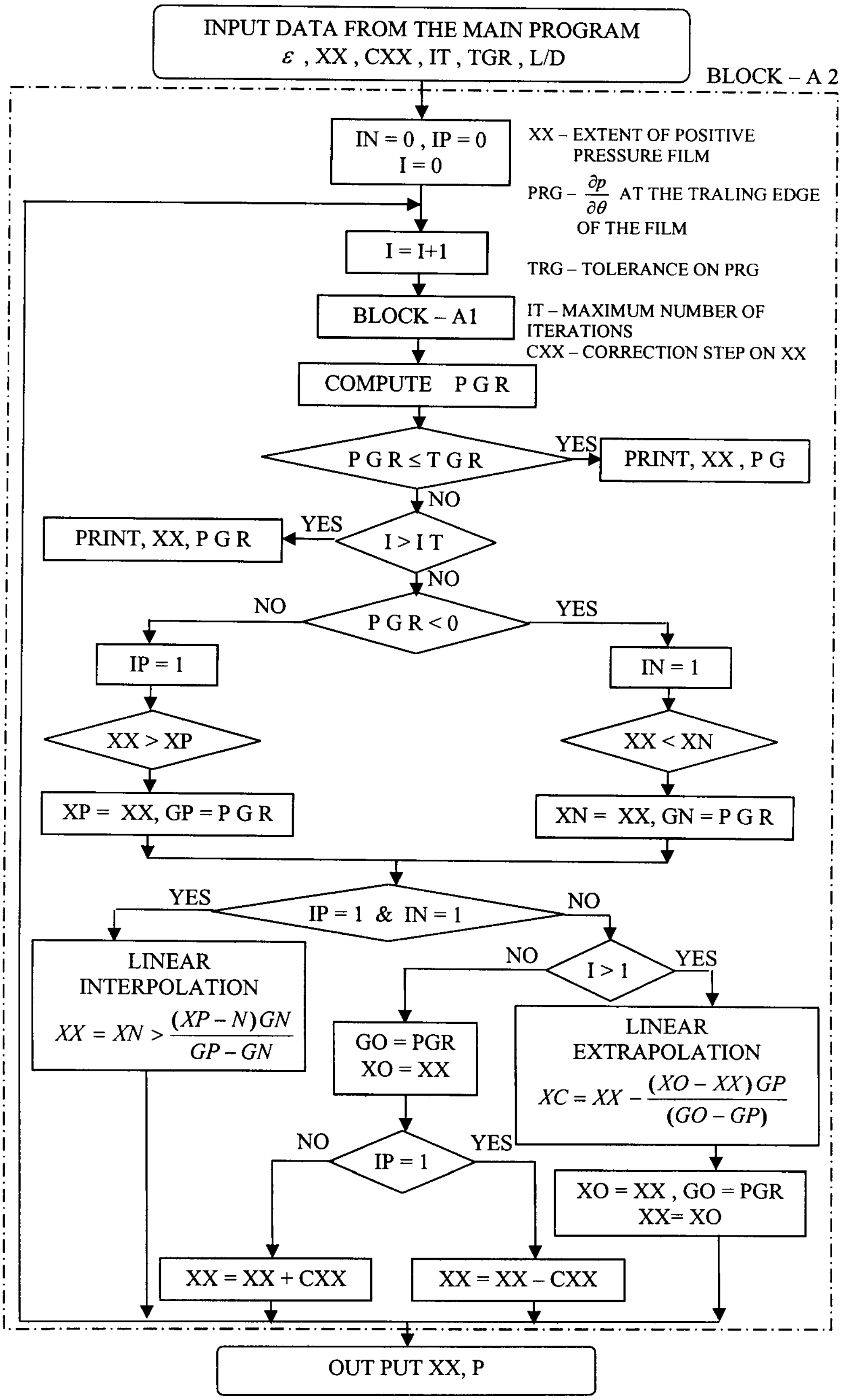

Fig. 4.2 Flow Diagram for Reynolds Boundary

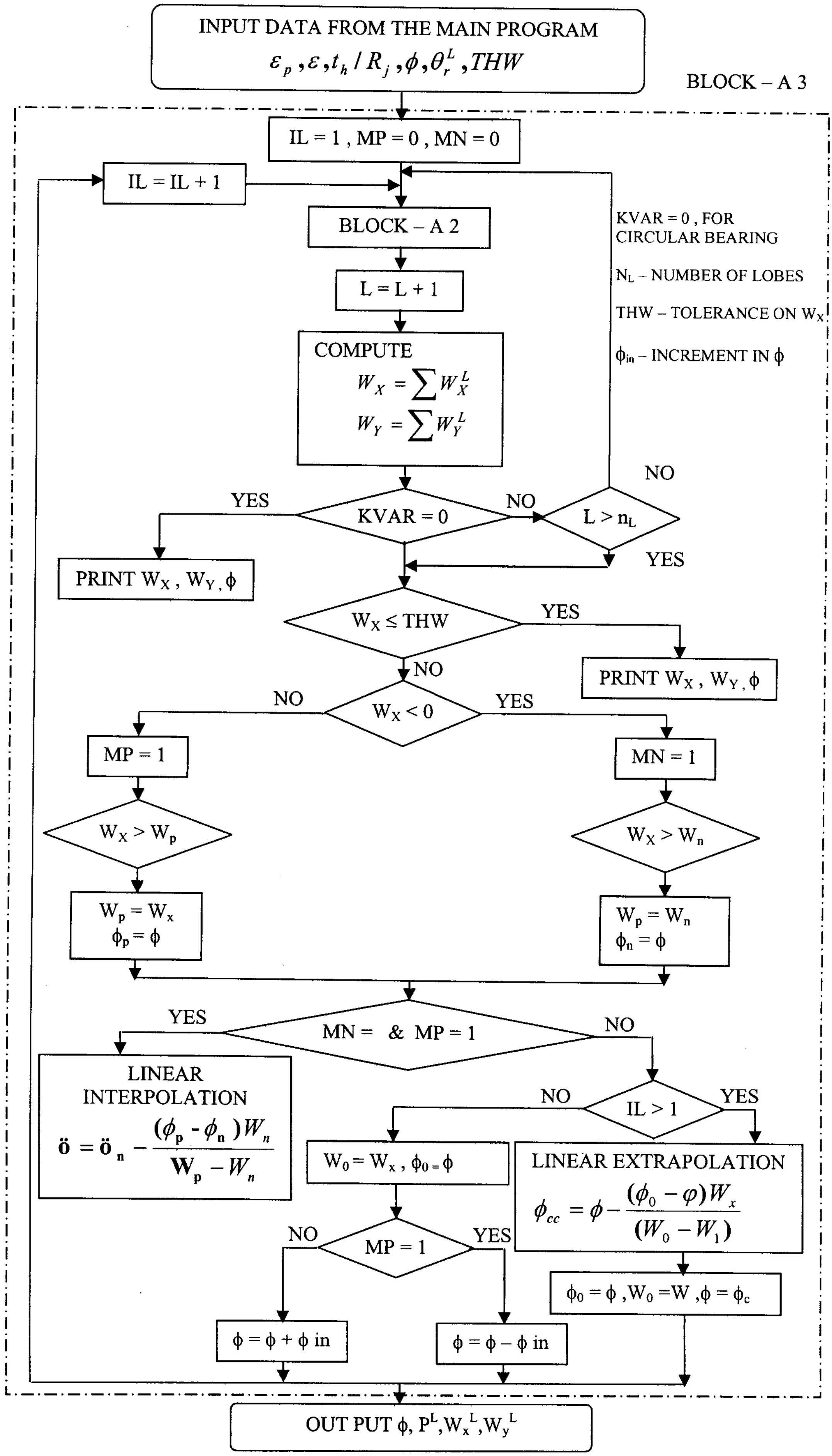

Fig.4.3 Flow Diagram for Attitude Angle for Non-Circular Bearings

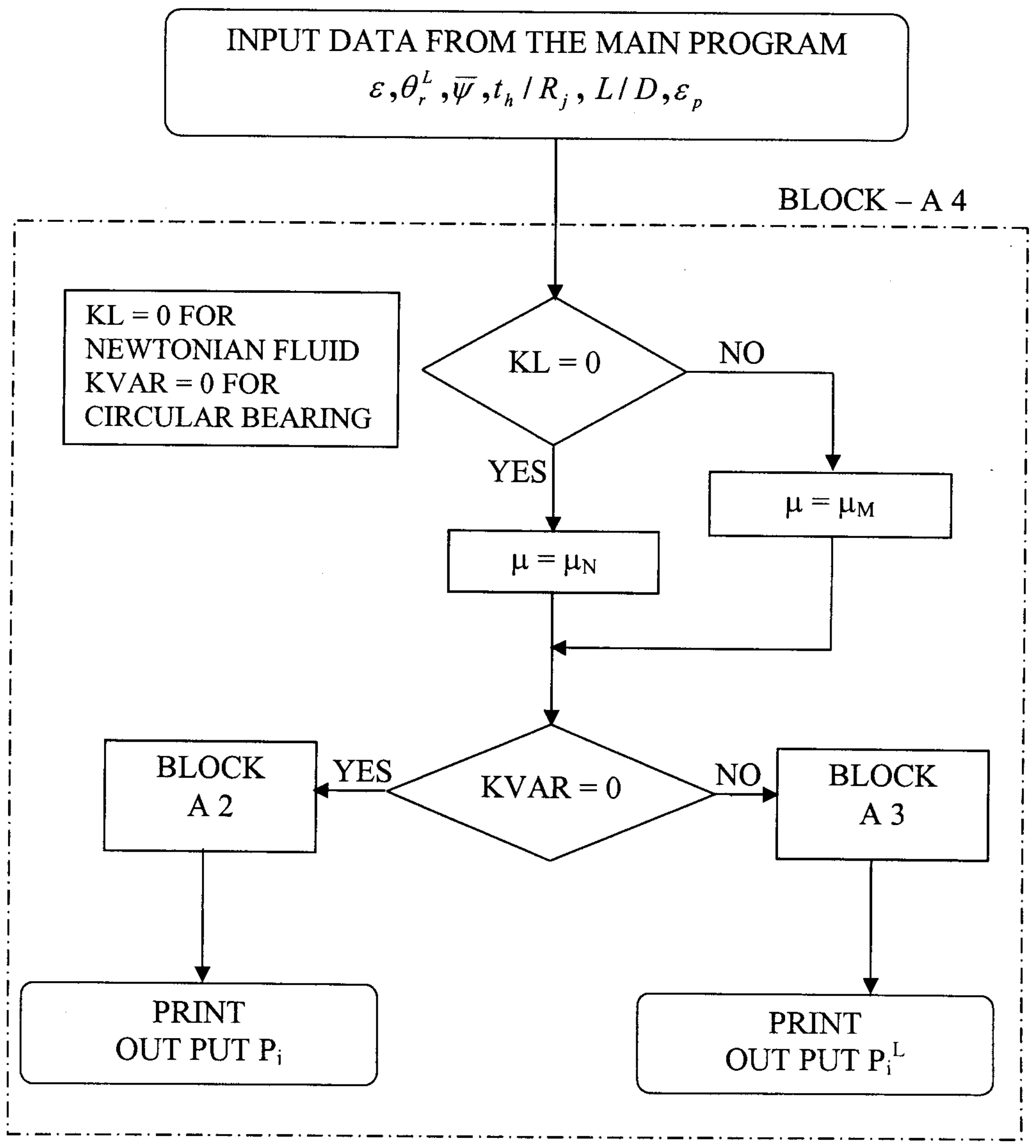

Fig. 4.4 Flow Diagram for Determining Nodal Pressure for Circular and Noncircular Bearing with Newtonian and Micropolar Lubricants

First a trial value of ϕ is chosen for which the horizontal component of load capacity is obtained from Eq. (3.5) for each lobe of a bearing with given eccentricity ratio ε. Depending on whether the horizontal component of the load capacity is positive or negative, a respective positive or negative correction is made in the first trial value of ϕ. For the corrected value of ϕ, the component of load is again calculated. The next value of ϕ is obtained using linear interpolation or extrapolation considering the two closest values of ϕ obtained from the previous iterations. These iteration are terminated when the horizontal component of the load carrying capacity achieves a value less than a pre assigned arbitrarily small value (0.01).

For flexible noncircular bearings, the attitude angle is computed using the procedure explained above after modifying the film thickness by taking into account the elastic deformation of the bearing liner in the radial direction. The flow diagram for determining attitude angle is given in Fig 4.3.

4.2.4 Computation of Nodal Pressures for Circular and non Circular Bearings with Newtonian and Micropolar Lubricants

The flow diagram for calculating the nodal pressures for circular and noncircular bearing with Newtonian and micropolar lubricants is given in Fig 4.4. The viscosity for micropolar fluid is determined from Eq. (1.1) in the case of computing nodal pressures for bearing with micropolar fluids.

4.2.5 Computation of Nodal Displacements

For computing nodal displacements, the stiffness matrix for each element is generated by the Subroutine STIFF, using Eq. (2.41). The right hand side of Eq. (2.40) is formed in the subroutine LOAD for each element using the nodal pressures obtained from the solution of lubricant flow-field. The global system equations are then obtained by assembling the stiffness matrices and RHS (Subroutine FRONT). The global stiffness matrix and column vector of the nodal forces are also modified by the subroutine FRONT, for the specified boundary conditions and the global system equations are solved to obtain nodal

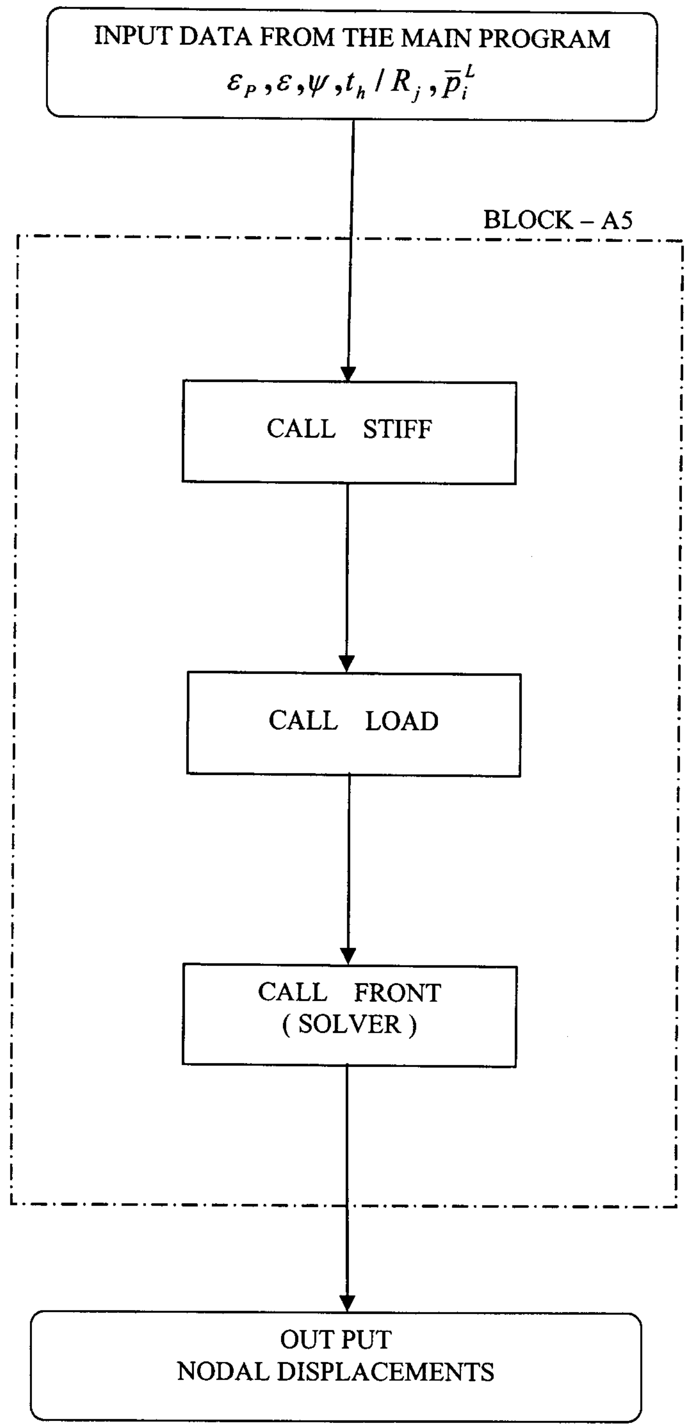

Fig. 4.5 Flow Diagram for Determination of Nodal Displacements

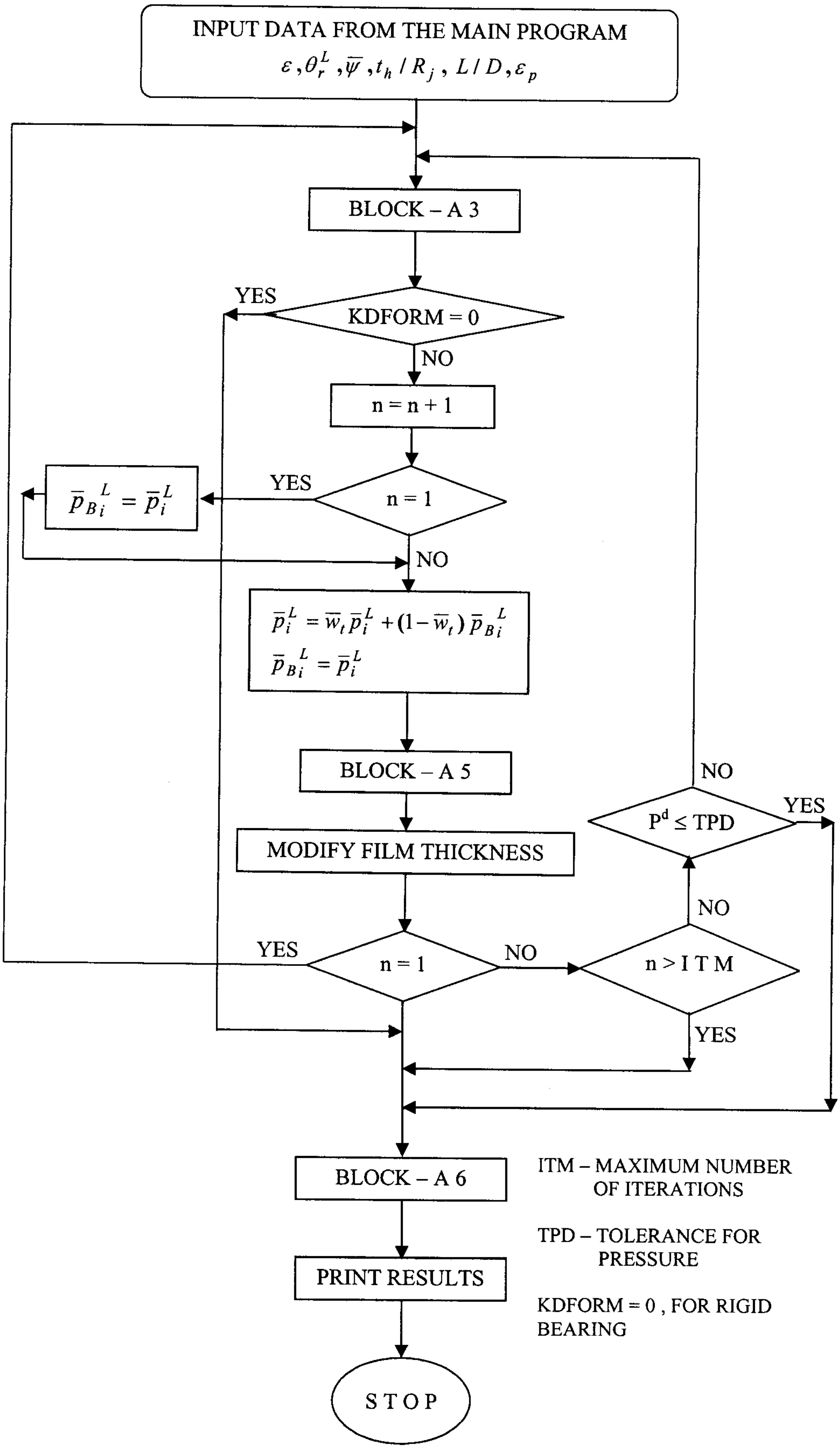

Fig. 4.6 Solution Scheme for Journal Bearings with Newtonian and Micropolar Lubricants

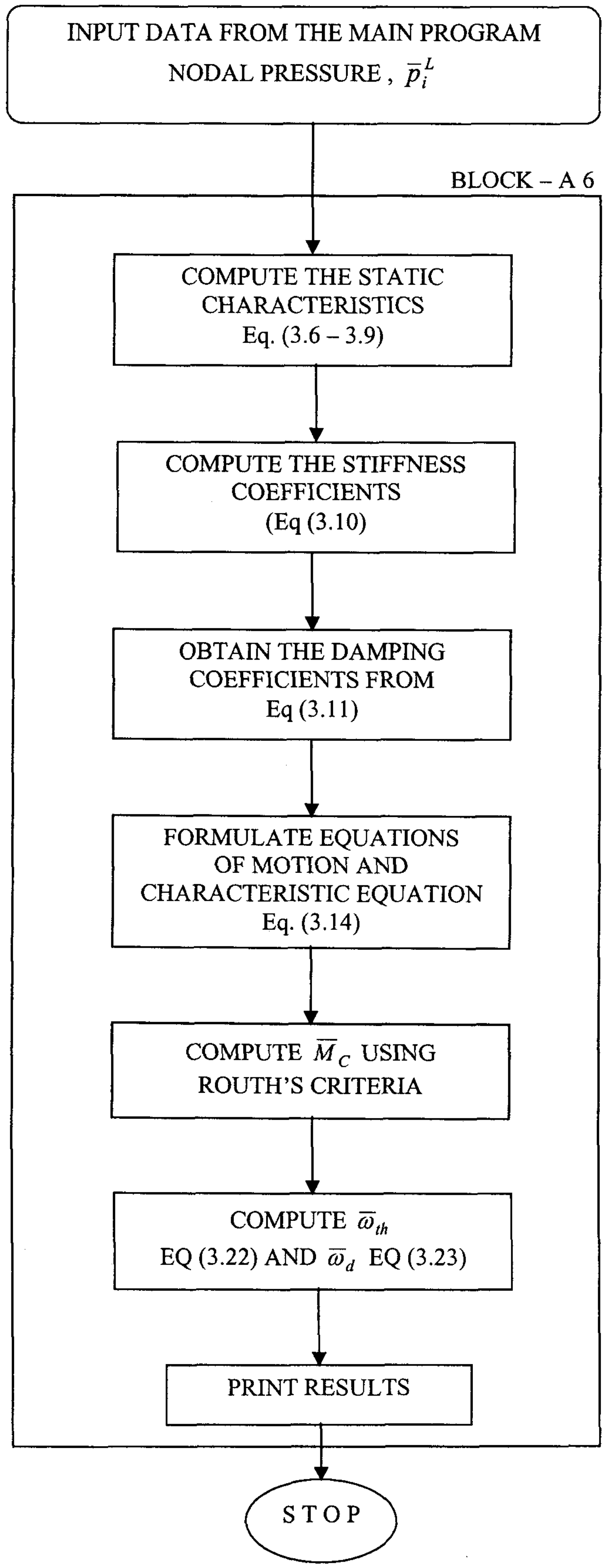

Fig. 4.7 Flow Diagram for Computing the Journal Performance Characteristics

displacements ($\bar{v}_\theta, \bar{v}_r$ and $\bar{v}_z$) by the same subroutine. The flow diagram for determination of nodal displacements is given in Fig. 4.5.

4.2.6 Results for Journal Bearings with Newtonian and Micropolar Lubricants

Fig 4.6 shows the solution scheme for obtaining the results of circular and noncircular journal bearings taking the bearing liner deformation in to account. The iterative scheme for EHD analysis of flexible circular and noncircular bearings involve the following steps, (i) assuming the bearing to be rigid, the film extent in the circular bearing or in each lobe of the non circular bearing and the nodal pressures are computed as the first trail value for EHD iteration, and (ii) considering the bearing liner to be flexible with a deformation coefficient, $\bar{\psi}$, and using the nodal pressures calculated in step (i), the nodal displacements are determined. Using these nodal displacements, the film thickness is modified. The pressure distribution is then recomputed for the modified film geometry. Iterations are repeated by solving the governing equations of flow and elastic fields till convergence is satisfied.

4.2.7 Performance Characteristics

The performance characteristics of the bearing are calculated from the computed pressures. The static characteristics in terms of load capacity, attitude angle, end leakage and frictional force are obtained from equations given in Chapter 3.

The stiffness coefficients are determined using Eq. (3.10). A linear perturbation method considering the perturbations of the journal centre in the radial and circumferential directions are considered to evaluate the stiffness coefficients.

For determining the damping coefficients using Eq. (3.11), the fluid force components in ξ and η directions are calculated separately for the cases $\dot{\xi} = 0, \dot{\eta} = 0$ by giving values of $\dot{\xi}$ and $\dot{\eta}$.

Threshold speed and damped frequency of whirl are obtained, using the stiffness and the damping coefficients and Routh's criteria from expressions given in Chapter 3. The flow chart for computing the bearing performance characteristics is given in Fig 4.7.

4.3 REMARKS

A large number of iterations were required to obtain the pressure and elastic fields at higher eccentricity ratios and large values of deformation coefficients. The iterations required for the solution were considerably reduced when the weighted averages of nodal pressures were used to calculate the effective nodal pressures.