DYNAMIC CHARACTERISTICS OF NON-CIRCULAR TAPERED ANNULAR SEALS CONSIDERING FLUID INERTIA EFFECTS IN TURBULENT FLOW

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ABSTRACT

This paper presents an investigation of the rotordynamic behavior of a non-circular seal in the turbulent regime considering the effect of fluid inertia. Rotordynamic coefficients i.e., stiffness and damping coefficients have been evaluated for various seal configurations for water as the working fluid. Seal geometry characterized by offset factor has significant influence on the rotor dynamic coefficients of non-circular tapered seals. The Reynolds equation developed by Lund and Reinhardt [13] for laminar flow has been modified for case of turbulent regime and perturbed for the calculation of rotor dynamic coefficients for non-circular tapered seal using small amplitude linear vibration theory. The Reynolds equation is discretized using finite difference method and compilation of the program is done using FORTRAN language. The calculation of all the rotor dynamic coefficients for tapered non-circular seals have been done for a seal of diameter, D= 79.8mm, exit clearance, C_e=0.0002967 m, L/D=1.5 and for concentric operation. The lubricant used in the analysis is water having a density of 1000 Kg/m^3 and absolute viscosity of 0.001245 Pa-s. The pressure drop due to fluid inertia at the entrance edge effect has not been considered explicitly.

It is seen that direct stiffness increases with increase in offset factor (δ). Direct stiffness increases with increase in speed in the speed range of 5000-25000 rpm in case of non-circular seal for $\delta>1.0$, whereas it decreases marginally at $\delta<1.0$. Significant influence is observed for direct stiffness in the speed range of 15000- 25000 rpm. Cross stiffness decreases with increase in speed in the speed range of 5000-20000 rpm and thereafter it increases significantly for $\delta=1.5$. However variation of cross stiffness is marginal with increase in speed for all offset factors considered.

Both the direct and cross damping decrease with an increase in speed. It is seen that direct damping marginally increases with increase in offset factor. However cross damping shows negligible variation with increase in offset factors.

The effect of taper ratio vs. speed on rotor dynamic coefficients for a particular value of δ, L/D ratio, supply pressure and zero eccentricity has been calculated. It is seen that with the increase in taper ratio, the direct stiffness decreases. Cross stiffness also decreases with increase in taper ratio and it shows the minimum values at a speed of 20000 rpm for taper ratio equals 1.5. However, taper ratio does not effect the direct and cross damping coefficients significantly.

Whirl frequency ratio 'f' and Critical mass 'M_{cr}' against speed for non-circular bearing for zero eccentricity with certain value of L/D ratio and supply pressures has been calculated to look into the stability of the seal. Whirl frequency ratio decreases with increase in offset factor, $\delta>1.0$ and it increases for $\delta=0.75$. However, it is seen that the 'f' remains too below 0.5 for all the offset

factors considered. Critical mass 'M_{cr}' decreases for δ=1.0 and δ<1.0 whereas it increases for δ>1.0. Critical mass varies steadily up to speed of 15000 rpm for all offset factors considered. However, it increases suddenly in the speed range of 15000-25000 rpm for δ=1.5. Hence, from the stability point of view, the non-circular seal of offset factor equal to 1.5 is more stable. Flow reduces as the offset factors increases with an increase in speed.

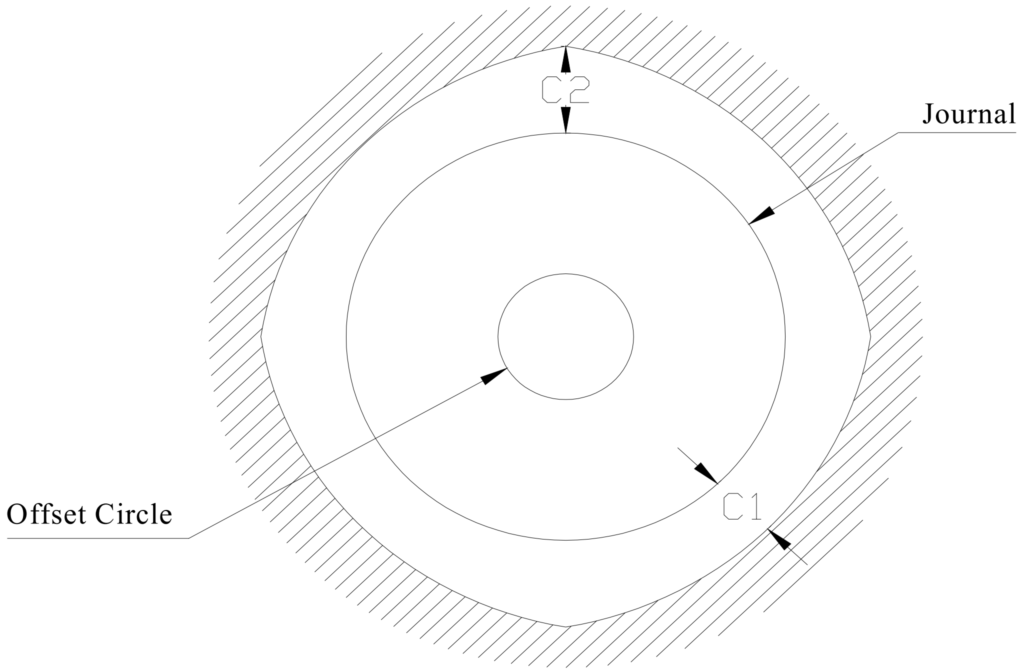

Fig. 1 Four Lobe Seal Geometry (δ< 1)

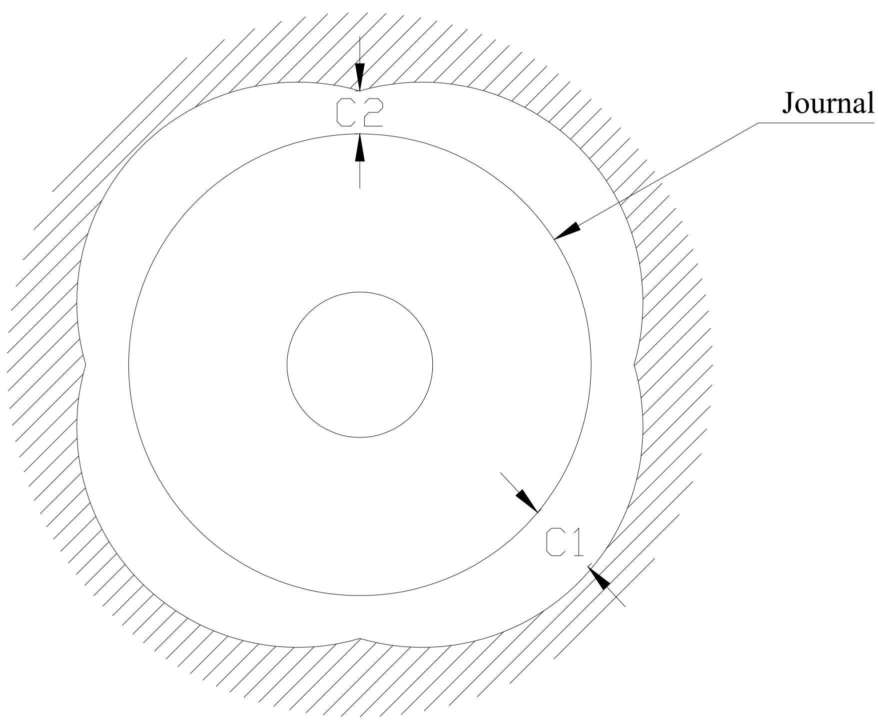

Fig. 2 Four Lobe Seal Geometry (δ> 1)