NON LINEAR DYNAMICS OF A FLEXIBLE ROTOR SUPPORTED BY TURBULENT FLUID FILM JOURNAL BEARING WITH MICRO POLAR STRESS FLUID

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ABSTRACT

The examination displays a powerful investigation of an adaptable rotor bolstered by tempestuous diary holding on for couple pressure liquid as grease. The dynamic conditions are shaped for the investigation of rotor focus and bearing focus is assessed. The summed up type of the Reynolds condition is explained under the short bearing suspicion to get the bearing powers. The rotor is bolstered evenly on two adaptable heading which are displayed as nonlinear springs. The dynamic investigation of rotor and the bearing focus has been completed utilizing the conditions of movement which are fathomed by the ODE45 routine of the MatLab programming. The conditions of movement are utilized to get the direction plots of the rotor and the bearing focus over a wide scope of non dimensional speed. The outcomes acquired by shifting the fundamental framework parameter of given adaptable rotor bolstered on violent holding on for couple pressure liquid. It is discovered that couple pressure liquid improves the steadiness of the rotor bearing framework in any event, when the stream is fierce.

Keyword: - *Non Linear Dynamics, Turbulant flow, micro polar stress, and Flexible Rotar etc….*

INTRODUCTION

Turbo-machines, one of the most significant classes of hardware, are broadly utilized all through the industrialized world. These utilized in the cutting edge ventures normally work at high rotational speed which causes scouring between the rotor and the stator. The persistent scouring between the rotor and the stator may bring about the perpetual shutdown of the rotor-bearing framework. Consequently it is fundamental to break down the dynamic conduct of the rotor-bearing framework to improve the dependability and proficiency of the rotor-bearing framework. Grating, which present between moving component causes wear of the machine component and continue towards the lasting shutdown of machine because of disappointment of machine component. Oil is marvel by which a slender layer of liquid known as oil is given between the reaching surface which not on decreases the erosion and subsequently wear, additionally it goes about as a mechanism for cooling of the surfaces by moving warmth created between the surfaces. Greases, which are commonly Newtonian and non-Newtonian, show an indispensable impact on the presentation of bearing. The oils utilized could possibly contain added substance. An oil without added substance, Newtonian may not play out its capacity agreeably well under the different working conditions. Thus a few added substances are constantly included alongside ointments so as to expand its ideal attributes. The utilization of non-Newtonian liquid oils expands the heap conveying limit and furthermore improves the warmth move rate. Specialists currently drawing closer towards the use of these oil containing added substances. Newton [1] put a hypothesis with respect to the power required to beat the thick obstruction offered by liquid when oppressed between two bodies having relative movement among them. N. Petroff [2] completed examinations of liquid film oil framework. He considered the impact of thick power that exists because of gooey opposition. O. Reynolds [4] expressed that hydrodynamic activity assumes fundamental job for oil of orientation. Weight gets developed so as to help the applied bearing burden. The idea of turbulent disturbance was absolute originally presented by EI Naschie[1] who broke down an exceptional type of confusion that can be found in the confined clasping of shells. Gardner and Ulschmid [2] researched on the tilting cushion and a sleeve diary bearing found that when the stream system changes from laminar to violent, there is decrease of the greatest temperature and an expansion in power misfortunes. A miniaturized scale continuum hypothesis was proposed by Stokes [11], utilized for couple pressure liquid and had the option to clarify the molecule size impact on the different rotor-bearing framework parameters and its presentation attributes. Lin [12, 13] broke down the feeds miniaturized scale continuum hypothesis to explore the crush film attributes of long halfway diary holding on for couple pressure liquid as ointment and clarified the dynamic conduct of the short diary holding on for couple pressure liquid as grease and brought about increment in unique firmness and better damping qualities and consequently diminish the siphoning power with lessening of the stream rate. A numerical plan was proposed by Abdallah [15] et al. which was exceptionally productive in taking care of the issue for diary bearing greased up with couple pressure liquid utilizing changed Reynolds condition, the film thickness condition and the limit conditions for the weight field. Hsu et al. [16] broke down the joined impact of couple stresses and the surface unpleasantness on the oil of short diary bearing and found that consolidated impact can bring about improving burden conveying limit and diminishes the height edge and rubbing parameters. Lahmer[17] explored ,when the Elasto-hydrodynamic examination of the twofold layer diary holding on for couple pressure liquid as oil broke down with smaller scale continuum hypothesis and discovered increment in load conveying limit and soundness of the rotor bearing framework and diminishing in rubbing element and height point.

MATERIALS AND METHODS

The present research considers an adaptable rotor bolstered by two couple pressure liquid film diary direction with establishment which carries on as nonlinear springs exposed to an intermittent outside excitation is contemplated utilizing ODE45 routine of MatLab. Fig. 1 shows an adaptable rotor bolstered on a level plane by two indistinguishable couple pressure liquid film diary orientation with nonlinear springs. O_mIs the focal point of rotor gravity, O_1 is the geometric focus of the bearing, O_2 is the geometric focal point of the rotor, O_3 and is the geometric focal point of the diary. Fig. 2 shows the cross segment of the liquid film diary bearing where (X,Y) is the fixed arrange and (e,u) is the pivoted facilitate, e being the counterbalanced of the diary focus and u being the disposition point of the X-coordinate.

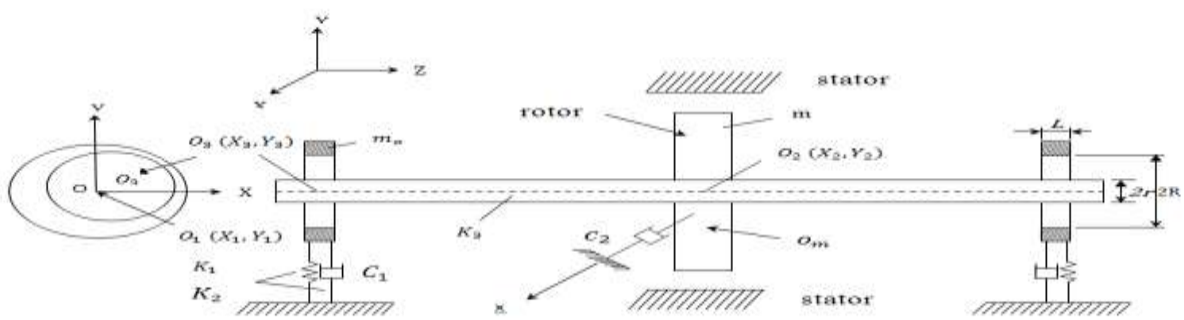

Fig. 1 Model of a flexible rotor supported on two non-linear suspensions

From the equilibrium of force, the forces applied to the journal center O_3 and the equations of motion of O_3 in Cartesian coordinates and the equations of motion of the bearing center could be written as:

$$F_x = f_e cos\varphi + f_\varphi sin\varphi = k_p(X_2 - X_3)/2 \quad (1)$$

$$F_y = f_e sin\varphi - f_\varphi cos\varphi = k_p(Y_2 - Y_3)/2 \quad (2)$$

$$m\ddot{X}_2 + c_2\dot{X}_2 + k_s(X_2 - X_3) = m\rho\omega^2 cos\phi \quad (3)$$

$$m\ddot{Y}_2 + c_2\dot{Y}_2 + k_s(Y_2 - Y_3) = m\rho\omega^2 sin\phi - mg \quad (4)$$

$$m_0\ddot{X}_1 + c_1\dot{X}_1 + k_1X_1 + k_2X_1^3 = F_x \quad (5)$$

$$m_0\ddot{Y}_1 + c_1\dot{Y}_1 + k_1Y_1 + k_2Y_1^3 = -m_0 g + F_y \quad (6)$$

where f_e and f_φ are the resulting viscous damping forces in the radial and tangential directions, g is the acceleration due to gravity, F_x and F_y are the components of the couple stress fluid film forces.

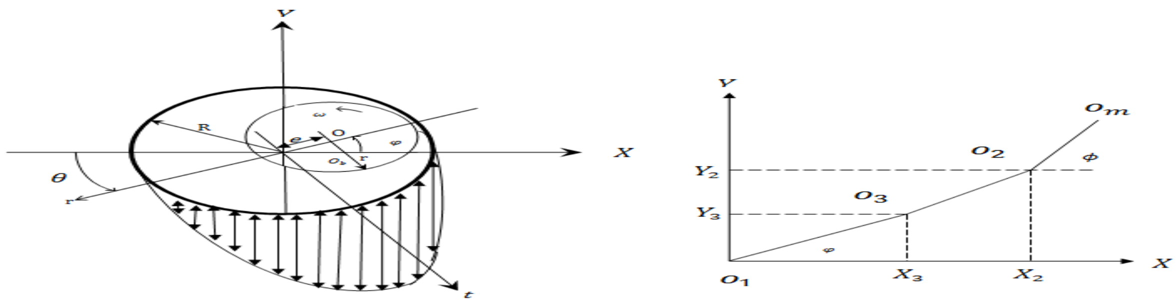

Fig .2.Cross section of a fluid film journal bearing.

Based on the assumption of turbulent flow and couple stress fluid lubricant, Modified Reynolds's equation can be formed as:

$$\frac{1}{R^2}\frac{\partial}{\partial\theta}\left(\xi(h,l)G_\theta\frac{\partial p}{\partial\theta}\right)+\frac{\partial}{\partial z}\left(\xi(h,l)G_z\frac{\partial p}{\partial z}\right)=\frac{U}{2R}\frac{\partial h}{\partial\theta}+\frac{\partial h}{\partial t} \quad (7)$$

Where, $\xi(h,l)=h^3-12l^2h+24l^3\tanh\left(\frac{h}{2l}\right)$,

l is the characterstics length of the additives $\left(l=\left(\frac{\eta}{\mu}\right)^{1/2}\right)$, η is the material constant responsible for the couple stress property.

$\frac{\partial h}{\partial x}=-\frac{c\varepsilon}{R}sin\theta,$

$h=c\left(1+\varepsilon cos\left(\gamma-\varphi(t)\right)\right)=c(1+\varepsilon cos\theta),\frac{1}{G_\theta}=12+0.0260(Re^*)^{0.8265},\frac{1}{G_z}=12+0.0198(Re^*)^{0.741}$

$U=R\omega,\varepsilon=\frac{e}{c},\frac{\partial h}{\partial t}=c\dot{\varepsilon}cos\theta+c\varepsilon\dot{\varphi}sin\theta,$

$x=R\theta,\ Re^*$ Is local Reynolds number($Re^*=\rho Uh/\mu$). Thus the Reynolds's equation can be written as

$$\frac{1}{R^2}\frac{\partial}{\partial\theta}\left(\xi(h,l)G_\theta\frac{\partial p}{\partial\theta}\right)+\frac{\partial}{\partial z}\left(\xi(h,l)G_z\frac{\partial p}{\partial z}\right)=-6\omega c\varepsilon sin\theta+12(c\dot{\varepsilon}cos\theta+c\varepsilon\dot{\varphi}sin\theta) \quad (8)$$

Using the ''short bearing approximation'' $\left(\frac{L}{D}<0.25,\frac{\partial p}{\partial\theta}\ll\frac{\partial p}{\partial z}\right)$ we can set $\frac{\partial p}{\partial z}=0$.

Then the pressure distribution in the circumferential direction could be neglected.

$$\frac{\partial}{\partial z}\left(\frac{h^3}{\mu}\xi(h,l)G_z\frac{\partial p}{\partial z}\right)=-6\omega c\varepsilon sin\theta+12(c\dot{\varepsilon}cos\theta+c\varepsilon\dot{\varphi}sin\theta) \quad (9)$$

Within the boundary conditions $\begin{cases}\frac{\partial p}{\partial z}=0,z=0\\ p=0,z=\pm L/2\end{cases}$

The pressure distribution is introduced.

$$p=\frac{-3\mu\omega\varepsilon sin\theta+6\mu(\dot{\varepsilon}\cos\theta+\varepsilon\dot{\varphi}sin\theta)}{c^2(1+\varepsilon cos\theta)^3\xi(h,l)G_z}\left(z^2-\frac{L^2}{4}\right) \quad (10)$$

The resulting forces in the radial and tangential direction could be formulated as

$$f_e=\frac{\mu RL^3}{2c^2}\int_0^\pi\frac{[\varepsilon(\omega-2\dot{\varphi})\sin\theta-2\varepsilon\dot{\cos\theta}]}{(1+\varepsilon\cos\theta)^3\xi(h,l)G_z}\cos\theta d\theta \quad (11)$$

$$f_\varphi=\frac{\mu RL^3}{2c^2}\int_0^\pi\frac{[\varepsilon(\omega-2\dot{\varphi})\sin\theta-2\varepsilon\dot{\cos\theta}]}{(1+\varepsilon\cos\theta)^3\xi(h,l)G_z}\sin\theta d\theta \quad (12)$$

$$F_x=f_ecos\varphi-f_\varphi sin\varphi=\frac{K_p(X_2-X_3)}{2} \quad (13)$$

$$F_y=f_esin\varphi-f_\varphi cos\varphi=\frac{K_p(Y_2-Y_3)}{2} \quad (14)$$

Let $\alpha=-\frac{\mu RL^3}{4c^2}$ $\beta=\int_0^\pi\frac{\sin\theta\cos\theta}{(1+\varepsilon\cos\theta)^3\xi(h,l)G_Z}d\theta$, $\gamma=\int_0^\pi\frac{cos^2\theta}{(1+\varepsilon\cos\theta)^3\xi(h,l)G_Z}d\theta$ $\delta=\int_0^\pi\frac{cos^2\theta}{(1+\varepsilon\cos\theta)^3\xi(h,l)G_Z}d\theta$

Therefore

$$\boldsymbol{\varepsilon}' = \frac{\begin{matrix}\beta c K_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi] \\ -\delta c K_p[(y_2-y_1-\varepsilon\cos\varphi)\cos\varphi-(x_2-x_1-\varepsilon\sin\varphi)\sin\varphi]\end{matrix}}{4\alpha\omega(-\gamma\delta+\beta^2)} \quad (15)$$

$$\varphi' = \frac{\omega}{2} - \frac{cK_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi]}{4\alpha\delta\omega\varepsilon} - \frac{\begin{matrix}\beta^2 cK_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi] \\ -\beta\delta cK_s[(y_2-y_1-\varepsilon\cos\varphi)\cos\varphi-(x_2-x_1-\varepsilon\sin\varphi)\sin\varphi]\end{matrix}}{4\alpha\varepsilon\delta(-\gamma\delta+\beta^2)} \quad (16)$$

The non-dimensional parameters are introduced as below.

$x_1 = \frac{X_1}{c}, y_1 = \frac{Y_1}{c}, x_2 = \frac{X_2}{c}, y_2 = \frac{Y_2}{c}, \frac{d}{dt} = \omega\frac{d}{d\phi},\ s^2 = \frac{\omega^2}{\omega_n^2}, \omega_n^2 = \frac{K_p}{m}\beta = \frac{\rho}{c}, f = \frac{mg}{cK_p}, \xi_1 = \frac{c_1}{2\sqrt{k_1 m_0}}, \xi_2 = \frac{c_2}{2\sqrt{K_p m}},$
$C_{om} = \frac{m_0}{m},\ C_{p_1} = \frac{K_p}{k_1},\ s_1^2 = C_{om}C_{p_1}s^2,\ \alpha = \frac{k_2c^2}{K_pC_{om}}$

Then Equation (1) to (6) become

$$\boldsymbol{\varepsilon}' = \frac{\begin{matrix}\beta c K_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi] \\ -\delta c K_p[(y_2-y_1-\varepsilon\cos\varphi)\cos\varphi-(x_2-x_1-\varepsilon\sin\varphi)\sin\varphi]\end{matrix}}{4\alpha\omega(-\gamma\delta+\beta^2)} \quad (17)$$

$$\varphi' = \frac{1}{2} - \frac{cK_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi]}{4\alpha\delta\omega\varepsilon} - \frac{\begin{matrix}\beta^2 cK_p[(y_2-y_1-\varepsilon\sin\varphi)\cos\varphi-(x_2-x_1-\varepsilon\cos\varphi)\sin\varphi] \\ -\beta\delta cK_s[(y_2-y_1-\varepsilon\cos\varphi)\cos\varphi-(x_2-x_1-\varepsilon\sin\varphi)\sin\varphi]\end{matrix}}{4\alpha\omega\varepsilon\delta(-\gamma\delta+\beta^2)} \quad (18)$$

$$x_1'' + \frac{2G_1}{s_1}x_1' + \frac{1}{s_1^2}x_1 + \frac{\alpha}{s^2}x_1^3 + \frac{1}{2C_{om}s^2}(x_2-x_1-\varepsilon\cos\varphi) = 0 \quad (19)$$

$$y_1'' + \frac{2G_1}{s_1}y_1' + \frac{1}{s_1^2}y_1 + \frac{\alpha}{s^2}y_1^3 + \frac{1}{2C_{om}s^2}(y_2-y_1-\varepsilon\sin\varphi) + \frac{f}{s^2} = 0 \quad (20)$$

$$x_2'' + \frac{2G_2}{s}x_2' + \frac{1}{s^2}(x_2-x_1-\varepsilon\cos\varphi) = \beta\cos\varphi \quad (21)$$

$$y_2'' + \frac{2G_2}{s}y_2' + \frac{1}{s^2}(y_2-y_1-\varepsilon\cos\varphi) = \beta\cos\varphi - \frac{f}{s^2} \quad (22)$$

These are the coupled Non-linear differential equations which represents a Non-linear dynamic system. The solution of these coupled nonlinear differential equations can be obtained by MatLab Routine ODE45.

RESULTS AND DISCUSSION

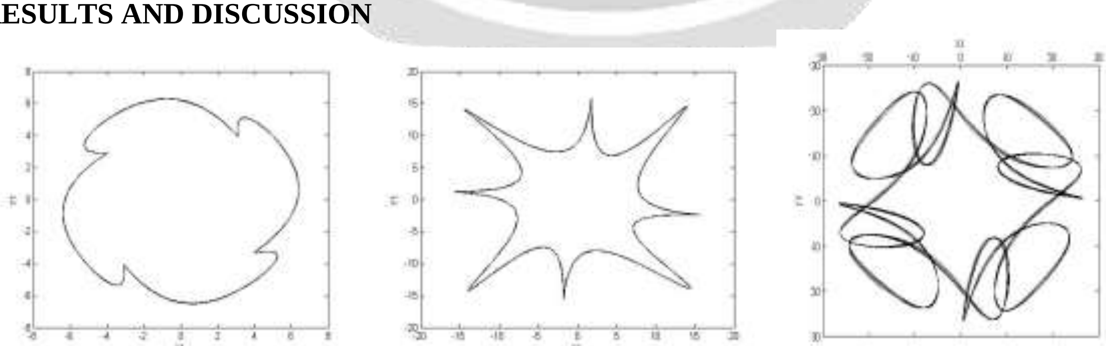

Fig.3. Trajectory maps of rotor centre for l=0.1 at speed ratio (s) = 1.5, 3.5, 7.0

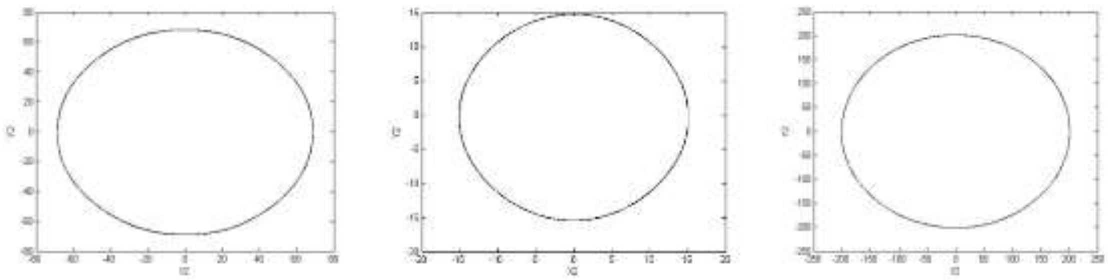

Fig.4. Trajectory maps of rotor centre for l=0.1 at speed ratio (s) = 1.5, 3.5, 7.0

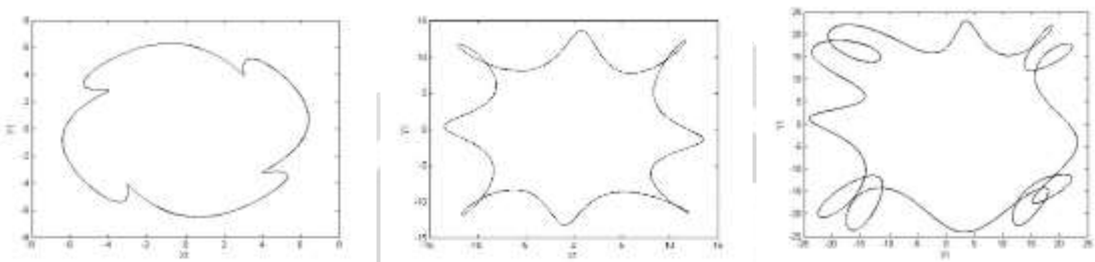

Fig.5. Trajectory maps of rotor centre for l=0.15 at speed ratio (s) = 1.5, 3.0, 7.0

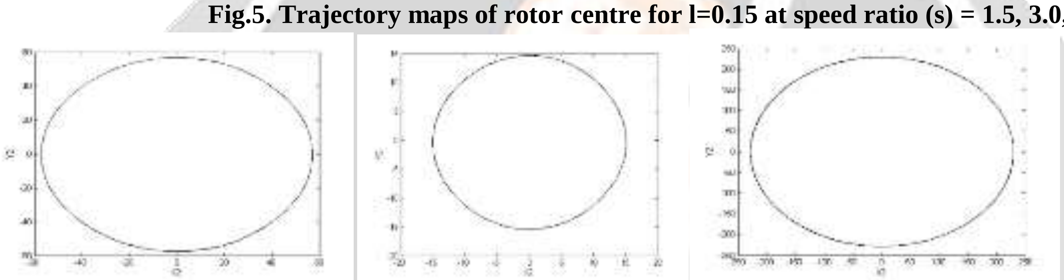

Fig.6. Trajectory maps of rotor centre for n-0.3 at speed ratio (s) = 1.5, 3.0, 7.0

It is found that the stability of the rotor bearing center increases for the non-dimensional speed ratios even when the flow is turbulent. For the higher speed ratios the stability of system increases as compared with considering couple stress fluid in place of Newtonian fluid.

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