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# Theoretical and Experimental Investigation of Effect of Water Emulsion on Pressure of Hydrodynamic Journal Bearing

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## ABSTRACT

Hydrodynamic journal bearing is a bearing operating with hydrodynamic lubrication, in which the bearing surface is separated from the journal surface by the lubricant film generated by the journal rotation. In this paper Pressure distribution on Journal Bearing is studied by considering Sommerfeld and Reynolds boundary conditions. Solution of one dimensional Reynolds equation is done using Finite difference method and graph is obtained with help of MATLAB. Experiment work is carried out for investigation of effect of water emulsion on pressure of journal bearing by considering different water ratio on Hydrodynamic Journal Bearing Apparatus. Experimental results are compared for effect of water emulsion on pressure for same speed and load condition.
**Keywords:** Journal Bearing, Pressure Distribution, Reynold Equation, Sommerfeld Boundry Condition.

## I. INTRODUCTION

Industrial machinery with high horsepower and high loads, such as steam turbines, centrifugal compressors, pumps and motors, utilize journal bearings as rotor supports. In hydrodynamic lubricated bearings, there is a thick film of lubricant between the journal and the bearing. When the bearing is supplied with sufficient lubricant, a pressure is build up in the clearance space when the journal is rotating about an axis that is eccentric with the bearing axis. The load can be supported by this fluid pressure without any actual contact between the journal and bearing. The load carrying ability of a hydrodynamic bearing arises simply because a viscous fluid resists being pushed around. Under the proper conditions, the resistance to motion will develop a pressure distribution in the lubricant film that can support a useful load. The load supporting pressure in hydrodynamic bearing arises from either the flow of a viscous fluid in a converging channel or the resistances of a viscous fluid to being squeezed out from between approaching surfaces. So many authors has tried to study the pressure distribution of journal bearing, some of the cases are discussed here. J.A.Cole and C.J. Hughest [1] have presented Pressure distribution of Journal bearing for different situation like half Sommerfeld condition, full Sommerfeld condition and Reynolds condition. Pressure plotting has been used by a number of investigators to determine the extent of the load-carrying film in complete bearings. A. Cameron and Mrs. W. L. Wood [2] have compared Pressure distribution for various boundary conditions with experimental result done by Nucker. D. M. Nuruzzaman, M. K. Khalil, M. A. Chowdhury, M. L. Rahaman [3] have presented variation of pressure with angular position by analytical and FEM method. The results showed that the hydrodynamic pressure profile increased steadily from zero and it changed very rapidly in the area of the smallest film thickness and reached to a maximum. In this region the film was convergent, the pressure then gradually dropped to zero. By D. W. Garside and S. Hother-Lushingtonj-[4] presented the main differences between water and oil which affect its use in plain bearings are:The lack of boundary lubrication properties and The viscosity of water is about $1/30^{th}$ of that of oil. This implies that only $1/30^{th}$ of the load can be carried when using water if the same minimum film thickness is to be maintained with the same size bearing.

## II. METHODS AND MATERIAL

### A. Theoretical Background

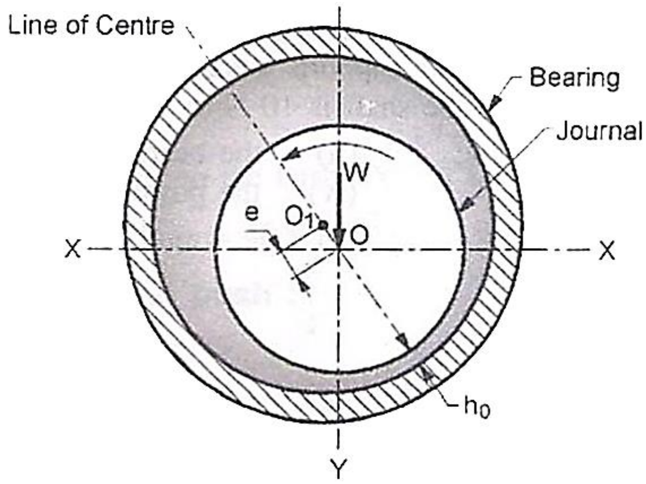


**Figure 1.** Geometry of Journal Bearing

Radial Clearance (C): It is the difference in the radii of bearing and journal. C = R – r

Where r = radius of the Journal R = radius of the bearing

Eccentricity (e): It is the distance between the centres of bearing and journal in operating condition.

Minimum Oil-Film Thickness (h0): It is the oil-film thickness along the line joining the centres of the journal and bearing.

Eccentricity Ratio (s): It is the ratio of eccentricity to radial clearance s = e / C

### B. Finite Difference Solution for 1D Reynolds Equation

Reynolds equation for one dimensional flow assuming constant viscosity is given by

$$\partial/\partial x(h^3\ \partial p/\partial x) = 6U\eta\ (dh/dx)$$

Where

$h = c(1 + \varepsilon\cos\theta)$

Converting above equation into non dimensional form

$x = r\ \theta, dx = r d\theta$

and $\quad p = 6U\eta rP/c^2$

on substituting above value in the equation

$$\partial/r\,\partial\theta[c^3(1 + \varepsilon\cos\theta)^3 * \partial/r\,\partial\theta(6U\eta rP/c^2)] = 6U\eta\ \partial/r\,\partial\theta(1 + \varepsilon\cos\theta)c$$

Cancelling $1/r$ & $c$ from both sides

$$\frac{\partial}{\partial\theta}\left[(1 + \varepsilon\cos\theta)^3 * \frac{\partial p}{\partial\theta}\right] = \frac{\partial}{\partial\theta}\ (1 + \varepsilon\cos\theta)$$

$$3(1 + \varepsilon\cos\theta)^2 * (-\varepsilon\sin\theta)\,\partial p/\partial\theta + \partial^2 p/\partial^2\theta\,(1 + \varepsilon\cos\theta)^3 = -\varepsilon\sin\theta$$

let $(1 + \varepsilon\cos\theta) = A$

$-3A^2\varepsilon\sin\theta\,\partial p/\partial\theta + \partial^2 p/\partial^2\theta\, A^3 + \varepsilon\sin\theta = 0$

Rearranging term,

$\partial^2 p/\partial^2\theta\, A^3 - 3A^2\varepsilon\sin\theta\,\partial p/\partial\theta + \varepsilon\sin\theta = 0$

This is non-dimensional formulation of 1D Reynolds equation.

Using FDM approach,

$$\partial^2 p/\partial^2\theta = [P_{i+1} - 2Pi + P_{i-1}]/h^2$$

$$\&\ \partial p/\partial\theta = [P_{i+1} - P_{i-1}]/2h$$

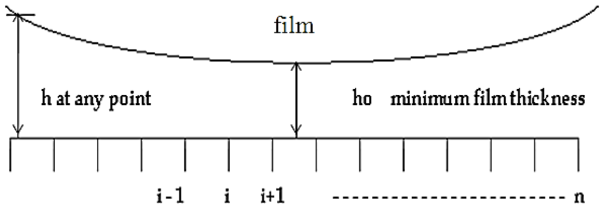


**Figure 2.** One Dimensional Grid

$$A^3\,\frac{(P_{i+1} - 2Pi + P_{i-1})}{h^2} - 3A^2\varepsilon\sin\theta\,\frac{(P_{i+1} - P_{i-1})}{2h} + \varepsilon\sin\theta = 0$$

$$(P_{i+1} - 2Pi + P_{i-1}) - 3h\,\frac{\varepsilon\, sin\theta}{2h}(P_{i+1} - P_{i-1}) + h^2\,\frac{\varepsilon\sin\theta}{A^3} = 0$$

$$\left(1 - 3h\,\frac{\varepsilon\, sin\theta}{2A}\right)P_{i+1} + \left(1 + 3h\,\frac{\varepsilon\, sin\theta}{2A}\right)P_{i-1} + h^2\,\frac{\varepsilon\sin\theta}{A^3} = 2Pi$$

$$\therefore Pi = \left(0.5 - 3h\,\frac{\varepsilon\, sin\theta}{4A}\right)P_{i+1} + \left(0.5 + 3h\,\frac{\varepsilon\, sin\theta}{4A}\right)P_{i-1} + h^2\,\frac{\varepsilon\sin\theta}{2A^3}$$

By this equation we can get non dimensional pressure at different point in 1-D domain. Although solution of this equation takes numbers of iterations, we have solved it using MATLAB. We can also compare this solution with analytical solution.Fig.3 shows non dimensional pressure using Sommerfeld condition where p=0 at 0 = 0 and 0 = n.Fig.4 shows Non dimensional pressure using Reynolds condition where p = 0 at 0 = 0 and 0 = n + a.

Here graph is studied for non-dimensional pressure distribution for different eccentricity ratio of 0.2, 0.4, 0.6 and 0.8.

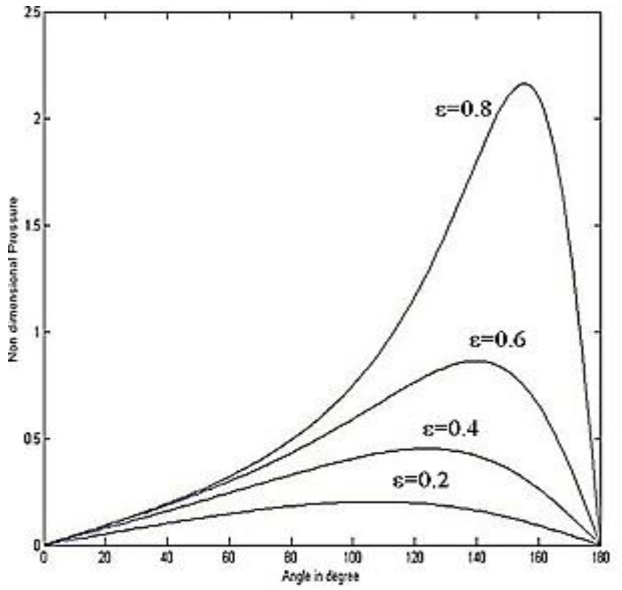


**Figure 3.** Pressure for Sommerfield Condition

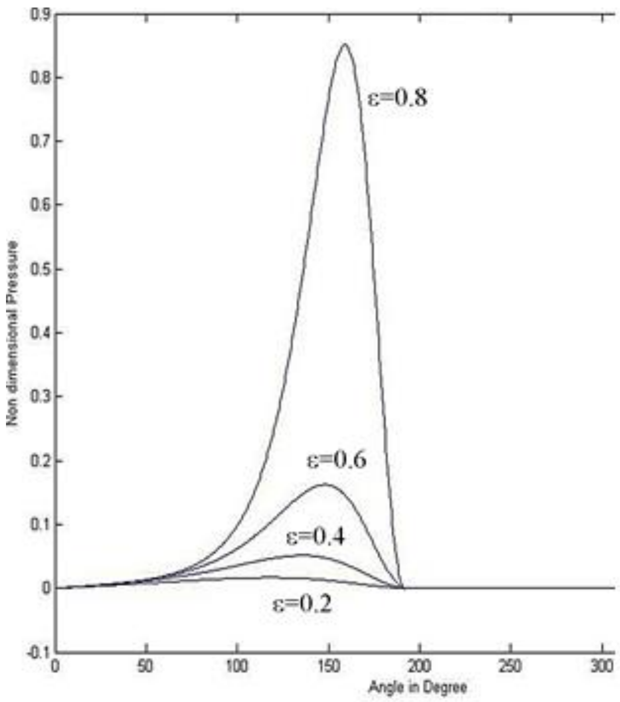


**Figure 4.** Pressure for Reynold Condition

## C. Experimental Investigation

Apparatus: The 'DYNAMIC' apparatus consists of a journal with brass bush pressed over outer diameter. Bearing caps are provided on both sides of bearing to which loading attachment is fixed. The journal is rotated by variablel speed D.C. motor. A torque arm with scale is fixed to bearing. This is used along with sliding weight to determine the friction torque. An oil corrector tray is provided for measurement of oil flow from bearing.

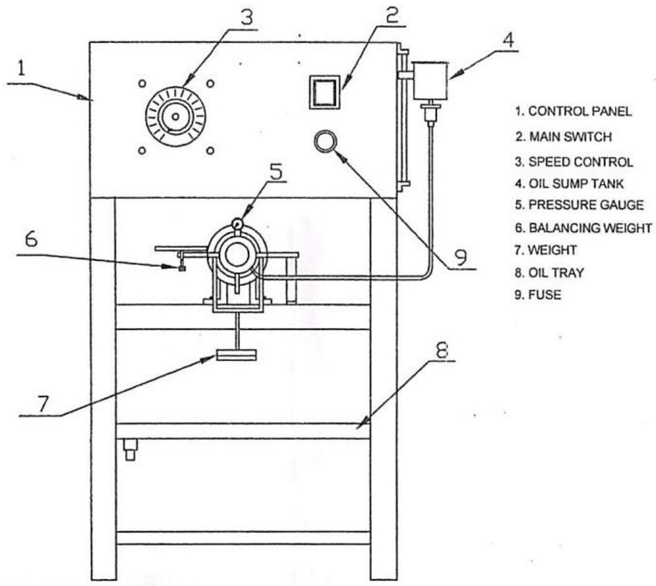


**Figure 5.** Line Diagram of Journal Bearing Apparatus

**Experimental Procedure:**

Fill up sufficient oil in the oil supply tank and open the bottom cock so that oil is let to the bearing. Adjust the pressure gauge at 0°. Adjust the pointer on torque arm to match with the zero on the scale fitted on the frame. Put 'On' the supply and start the motor at required speed. Pressure will start to develop. Put the required weight in the weight hanger. Put small weight in balancing hook & adjust the distance so that the pointer should again coincide with zero on the scale. Note down weight & its distance. Wait for some time for pressure to build up. When pressure remains steady, note down pressure. Insert measuring flask at flowing oil and measure the time required for 10ml. also, hold thermometer in dropping oil and note down oil temperature. Repeat the procedure for different speeds and loads, and complete the observation table.

Now, keeping one speed constant and varying different load, pressure are measured for pure oil, then 10% water in oil emulsion then similarly for 20% and 30%. Now speed is changed and similar procedure will give us reading for pressure.

# III. RESULTS AND DISCUSSION

Following table and graph shows decrease in pressure with increase of water percentage in oil for same speed and load conditions which ultimately reduce load carrying capacity of journal bearing and may result in frequent bearing failure. Here P0, P10, P20, P30 shows pressure of pure oil then 10%,20%,30% water in oil emulsion respectively. Here L1 to L5 are load according to serial no. in table

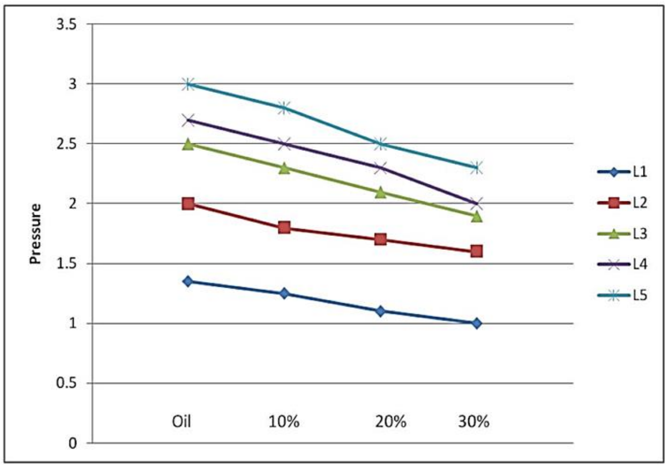


**Figure 6.** Graph of Pressure at 300 rpm

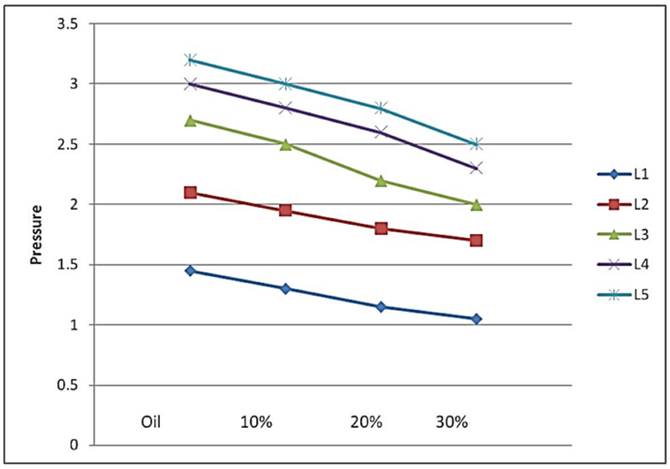


**Figure 7.** Graph of Pressure at 700 rpm

## IV. CONCLUSION

In hydrodynamic lubricated bearings, there is a thick film of lubricant between the journal and the bearing. When the bearing is supplied with sufficient lubricant, a pressure is building up that support the load. In the literature review Full Sommerfeld, Half Sommerfeld and Reynolds condition with curve represented by different author is studied. Solution of 1D Reynolds Equation is done with FDM method and same is used for Sommerfeld condition with help MATLAB and relevant pressure curve are presented. Experimental work is done on Journal Bearing Apparatus. Different combination of oil with water is taken and pressure is measured for same load and same speed for different water and oil combination. Observation table and related Graph are presented which clearly shows reduction in Pressure for same load and same speed with increase in water percentage which ultimately reduces load carrying capacity of Journal bearing.

## V. REFERENCES


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