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Development of Software for Design of Hydrodynamic Journal Bearing

Pratikkumar P. Patadia[1], Bhupesh Goyal[2] and Kinjal A. Suthar[3]
[1]*Mechanical Engineering Department, Babaria Institute of Technology, Vadodara, India*
[2]*Mechanical Engineering Department, Parul Institute of Technology, Vadodara, India*
[3]*Mechanical Engineering Department, Parul Institute of Technology, Vadodara, India*

***Abstract*- Hydrodynamic journal bearings are considered to be a vital component of all the rotating machinery. These are used to support radial loads under high speed operating conditions. Their design features vary widely according to their major operational specifications such as: Infinitely Short Journal Bearing, Square Journal Bearing and Infinitely Long Journal Bearing which creates complex design procedure of Hydrodynamic journal bearing and it is to be designed. Based on above discussion, Hydrodynamic journal bearing is a complex task for the designer. So in the present work software is developed to calculate the final dimensions of the Hydrodynamic journal bearing. User has to just give the required input and the software will give the required output immediately which improves the efficiency of designer.**

***Index Terms*- Hydrodynamic Journal Bearing, Infinitely Long Bearing, Infinitely Short Bearing, Square Bearing, Software Development.**

I. INTRODUCTION

Journal bearing design is complex. It involves optimizing clearances, bearing length, minimum film lubricant, viscosity, flow rate, and inlet slots. Design equations are available, but their solution is time consuming unless done on a computer. Types of Hydrodynamic Bearings based on L/D ratio. If the ratio of the length to the diameter of the journal (i.e. L/D) is less than 1, then the bearing is said to be short bearing. On the other hand, if L/D is greater than 1, then the bearing is known as long bearing. If L/D ratio is equal to 1 then it is known as Square Bearing. High pressures and temperatures generated in a hydrodynamic film should be considered when selecting bearing materials. Bearings subjected to cyclic stresses can fail by fatigue[1]. The bearing material should also be compatible with the journal material so when metal-to-metal contact occurs at starting and stopping, minimal surface damage occurs.

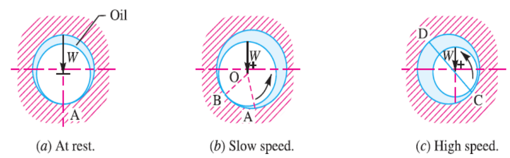

Fig.1 Wedge Film Journal Bearing[2]

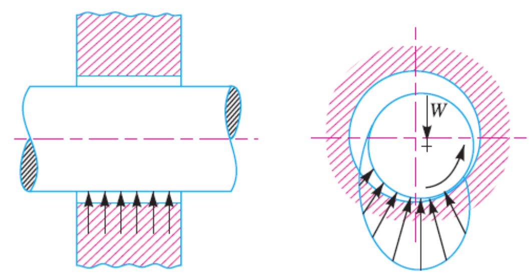

Fig.2 Pressure Distribution in Hydrodynamic Bearing[2]

II. DESIGN PROCEDURE FOR HYDRODYNAMIC JOURNAL BEARING

The following procedure may be adopted in designing journal bearings, when the bearing load, the diameter and the speed of the shaft are known.

1. Determine the bearing length by choosing a ratio of l / d from Table 1.

2. Check the bearing pressure, p = W / l.d from Table 1. for probable satisfactory value.

3. Assume a lubricant from Table 2. and its operating temperature (t0). This temperature should be between 26.5°C and 60°C with 82°C as a maximum for high temperature installations such as steam turbines.

4. Determine the operating value of ZN / p for the assumed bearing temperature and check this value with corresponding values in Table 1, to determine the possibility of maintaining fluid film operation.
5. Assume a clearance ratio c / d from Table 1.
6. Determine the coefficient of friction (μ) by using the relation.
7. Determine the heat generated by using the relation.
8. Determine the heat dissipated by using the relation.
9. Determine the thermal equilibrium to see that the heat dissipated becomes atleast equal to the heat generated. In case the heat generated is more than the heat dissipated then either the bearing is redesigned or it is artificially cooled by water.

Machinery	Bearing	Maximum bearing pressure (p) in N/mm^2	Operating values			
			Absolute Viscosity (Z) in kg/m-s	ZN/p Z in kg/m-s p in N/mm^2	$\frac{c}{d}$	$\frac{l}{d}$
Automobile and air-craft engines	Main	5.6 – 12	0.007	2.1	—	0.8 – 1.8
	Crank pin	10.5 – 24.5	0.008	1.4		0.7 – 1.4
	Wrist pin	16 – 35	0.008	1.12		1.5 – 2.2
Four stroke-Gas and oil engines	Main	5 – 8.5	0.02	2.8	0.001	0.6 – 2
	Crank pin	9.8 – 12.6	0.04	1.4		0.6 – 1.5
	Wrist pin	12.6 – 15.4	0.065	0.7		1.5 – 2
Two stroke-Gas and oil engines	Main	3.5 – 5.6	0.02	3.5	0.001	0.6 – 2
	Crank pin	7 – 10.5	0.04	1.8		0.6 – 1.5
	Wrist pin	8.4 – 12.6	0.065	1.4		1.5 – 2
Marine steam engines	Main	3.5	0.03	2.8	0.001	0.7 – 1.5
	Crank pin	4.2	0.04	2.1		0.7 – 1.2
	Wrist pin	10.5	0.05	1.4		1.2 – 1.7
Stationary, slow speed steam engines	Main	2.8	0.06	2.8	0.001	1 – 2
	Crank pin	10.5	0.08	0.84		0.9 – 1.3
	Wrist pin	12.6	0.06	0.7		1.2 – 1.5
Stationary, high speed steam engine	Main	1.75	0.015	3.5	0.001	1.5 – 3
	Crank pin	4.2	0.030	0.84		0.9 – 1.5
	Wrist pin	12.6	0.025	0.7		13 – 1.7
Reciprocating pumps and compressors	Main	1.75	0.03	4.2	0.001	1 – 2.2
	Crank pin	4.2	0.05	2.8		0.9 – 1.7
	Wrist pin	7.0	0.08	1.4		1.5 – 2.0
Steam locomotives	Driving axle	3.85	0.10	4.2	0.001	1.6 – 1.8
	Crank pin	14	0.04	0.7		0.7 – 1.1
	Wrist pin	28	0.03	0.7		0.8 – 1.3
Railway cars	Axle	3.5	0.1	7	0.001	1.8 – 2
Steam turbines	Main	0.7 – 2	0.002 – 0.016	14	0.001	1 – 2
Generators, motors, centrifugal pumps	Rotor	0.7 – 1.4	0.025	28	0.0013	1 – 2
Transmission shafts	Light, fixed	0.175	0.025-	7	0.001	2 – 3
	Self -aligning	1.05	0.060	2.1		2.5 – 4
	Heavy	1.05		2.1		2– 3
Machine tools	Main	2.1	0.04	0.14	0.001	1–4
Punching and shearing machines	Main	28	0.10	—	0.001	1–2
	Crank pin	56				
Rolling Mills	Main	21	0.05	1.4	0.0015	1–1.5

Table.1 Design values for journal bearing [2]

S. No.	Type of oil	Absolute viscosity in kg / m-s at temperature in °C											
		30	35	40	45	50	55	60	65	70	75	80	90
1.	SAE 10	0.05	0.036	0.027	0.0245	0.021	0.017	0.014	0.012	0.011	0.009	0.008	0.005
2.	SAE 20	0.069	0.055	0.042	0.034	0.027	0.023	0.020	0.017	0.014	0.011	0.010	0.0075
3.	SAE 30	0.13	0.10	0.078	0.057	0.048	0.040	0.034	0.027	0.022	0.019	0.016	0.010
4.	SAE 40	0.21	0.17	0.12	0.096	0.78	0.06	0.046	0.04	0.034	0.027	0.022	0.013
5.	SAE 50	0.30	0.25	0.20	0.17	0.12	0.09	0.076	0.06	0.05	0.038	0.034	0.020
6.	SAE 60	0.45	0.32	0.27	0.20	0.16	0.12	0.09	0.072	0.057	0.046	0.040	0.025
7.	SAE 70	1.0	0.69	0.45	0.31	0.21	0.165	0.12	0.087	0.067	0.052	0.043	0.033

Table.2 Absolute viscosity of commonly used lubricants [2]

III. CASE STUDY FOR SQUARE, INFINITELY SHORT AND LONG BEARINGS

Problem Definition for Square Bearing: [3]

A Hydrodynamic Journal Bearing has a journal diameter of 50 mm and a Eccentricity ratio is 0.6. The radial clearance between journal and bearing is 50 microns. The journal rotates at 1490 r.p.m. The viscosity of lubricating oil is 25cP.Radial load 3.2kN. Calculate

- Length of the bearing (mm)
- Minimum oil film thickness (mm)
- Flow rate of lubricant(mm3/s)
- Co-efficient of friction
- Rate of heat generation (kW)

Solution:

Radial Load (N)=3200N, l/d ratio = 1

- Journal speed = n_s = 1490/60 = 24.833 r.p.s
- Diameter of journal= 50 mm
- Eccentricity ratio= 0.6
- Viscosity of lubricatint =μ=25 cP =$25*10^{-3}$ Pa-s. =$25*10^{-9}$ N-s/mm^2
- Radial clearance=c= 0.05 mm

Length of bearing: l/d=1

L= l/d *d =50 mm

Eccentricity ratio (ε) : ε= 1-(ho/c), ε= 1-0.4= 0.6

Minimum oil film thickness (ho) : ho= c(1-ε)

ho= 0.05 (1-0.6)= 0.02mm

Flow rate of lubricant (Q): Q= 4.33*r*ns*c*l

=4.33*25*24.833*0.05*50 Q = 6720.52 mm^3/s

Co-efficient of friction (f): f= (3.22* 2 * c2) / d2

f=0.00644

Rate of heat generation or power lost in friction (Hg) : Hg= 2*л*ns*f*W*r/10^6

Hg= 0.0804 kW

Problem Definition for Infinitely Short Bearing: [3]

A Hydrodynamic Journal Bearing has a l/d ratio is 0.5, journal diameter of 80 mm and a ho/c ratio is 0.3. The radial clearance between journal and bearing is 50 microns. The journal rotates at 1800 r.p.m. The viscosity of lubricating oil is 30 mPa-s. Assuming the narrow approximation. Calculate

1) Length of bearing
2) Minimum oil film thickness
3) Eccentricity ratio
4) Flow rate of lubricant
5) Co-efficient of friction
6) Load carrying capacity
7) Pressure distribution

Solution:

Given data:

- l/d ratio = 0.5
- Journal speed = n_s = 1800/60 = 30 r.p.s
- Diameter of journal= 80 mm
- ho/c ratio= 0.3

- Viscosity of lubricatint =μ=30 mPa-s =30*10^{-3} Pa-s. =30*10^{-9} N-s/mm^2
- Radial clearance=c= 0.05 mm
- Length of bearing:

l/d=0.5

L= l/d *d =40 mm

- Minimum oil film thickness (ho) :
  ho= c(1-ε)= ho= 0.3*0.05= 0.015mm
- Eccentricity ratio (ε) : ε= 1-(ho/c)
- ε= 1-0.3= 0.7
- Flow rate of lubricant (Q) :
- Q= л*d*ns*c*ε*l
  =3.14*80*30*0.05*0.7*40

Q= 10555.75 mm^3/s

- Co-efficient of friction (f) :

f= (5.68 * 2 * c2) / d2, f=0.0071

- Load carrying capacity (W) :

$$W=\frac{л2\mu dnsl3\varepsilon\sqrt{((16/л2)-1)\varepsilon2+1}}{4c2(1-\varepsilon2)2}$$

W=13978.74 N

- Pressure distribution (p) :

$$p=\frac{3\mu лdns\varepsilon sin\theta(\frac{l2}{4}-z2)}{rc2(1+\varepsilon cos\theta)3}$$

At θ= 25

p=3*30*10^{-9} *3.14*80*30*sin25(40^2/4)/40*0.05^2*$(1+0.7\cos25)^3$

p=0.1839 N/mm^2

Similarly At θ=50, p=0.4775 N/mm^2

Similarly At θ=75, p=1.1137 N/mm^2

Similarly At θ=150, p=15.55 N/mm^2

Similarly At θ=200, p=5.97 N/mm^2

Problem Definition for Infinitely Long Bearing: [3]

A Hydrodynamic Journal Bearing has a l/d ratio is 2, journal diameter of 80 mm and a ho/c ratio is 0.3. The radial clearance between journal and bearing is 0.04 mm. The journal rotates at 1200 r.p.m. The viscosity of lubricating oil is 12 mPa-s. Assuming the narrow approximation. Calculate

- Length of bearing
- Minimum oil film thickness
- Eccentricity ratio
- Flow rate of lubricant
- Co-efficient of friction
- Load carrying capacity
- Pressure distribution

Solution:

Given data:

- l/d ratio = 2
- Journal speed = n_s = 1200/60 = 20 r.p.s
- Diameter of journal= 80 mm
- ho/c ratio= 0.3
- Viscosity of lubricatint =μ=12 mPa-s =12*10^{-3} Pa-s. =12*10^{-9} N-s/mm^2
- Radial clearance=c= 0.04 mm
- Length of bearing:

l/d=2, L= l/d *d =160 mm

- Minimum oil film thickness (ho) :
  ho= c(1-ε)= ho= 0.3*0.04= 0.012mm
- Eccentricity ratio (ε) :
  ε= 1-(ho/c), ε= 1-0.3= 0.7
- Flow rate of lubricant (Q) :
  Q= л*d*ns*c*ε*l
  =3.14*80*20*0.04*0.7*160
  Q= 22507.52 mm^3/s
- Co-efficient of friction (f) :
- f= (5.68 * 2 * c2) / d2
  f=0.00568
- Load carrying capacity (W) :

$$W=\frac{л2\mu dnsl3\varepsilon\sqrt{((16/л2)-1)\varepsilon2+1}}{4c2(1-\varepsilon2)2}$$

W=372766.65 N

- Pressure distribution (p) :

$$p=\frac{3\mu лdns\varepsilon sin\theta(\frac{l2}{4}-z2)}{rc2(1+\varepsilon cos\theta)3}$$

At θ= 25

p=3*12*10^{-9} *3.14*80*30*sin25(160^2/4)/40*0.04^2*$(1+0.7\cos25)^3$

p=2.9427 N/mm^2

Similarly At θ=50, p=0.4775 N/mm^2

Similarly At θ=75, p=1.1137 N/mm^2

Similarly At θ=150, p=15.55 N/mm^2

Similarly At θ=200, p=5.97 N/mm^2

IV. DEVELOPED SOFTWARE FOR DESIGN OF HYDRODYNAMIC JOURNAL BEARINGS

Feature of the Software:

There are number of feature of this software. The original manual calculation for the design of Bearings is very complex so with the help of the software it became a simple. With the help of the software we can obtain error less result & save the time. With the help of the software we can compare the design easily for different material & also for the different parameter while manual calculation is very complex and time consuming. The software provides flexibility to the users, easy to understand & user friendly. This software provides facility to check if the developed design is safe or not and if design is not safe so, according to we can also change material property and get the safe design.

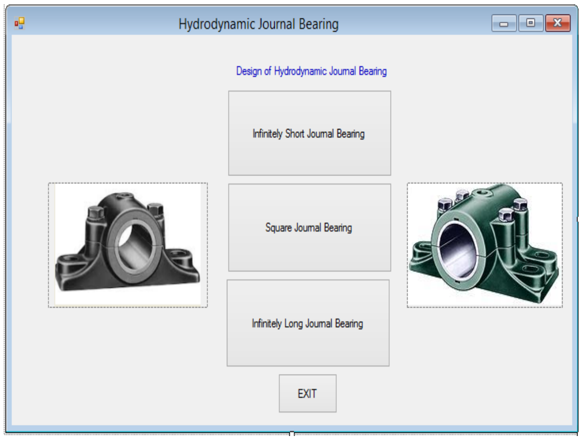

Fig.3 Design Form in VB Software For Hydrodynamic Bearings[4]

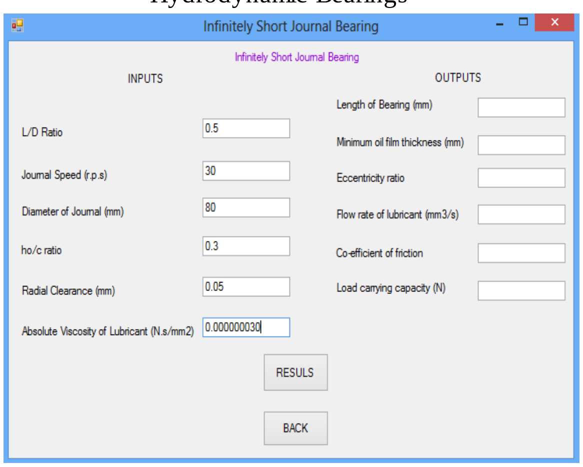

Fig.4 Inputs of Infinitely Short Journal Bearings

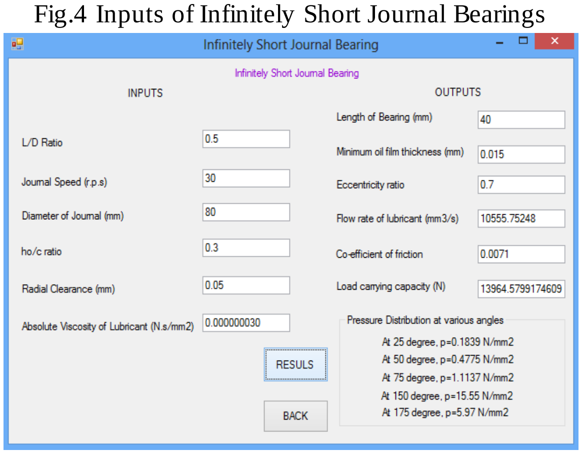

Fig.5 Outputs of Infinitely Short Journal Bearings

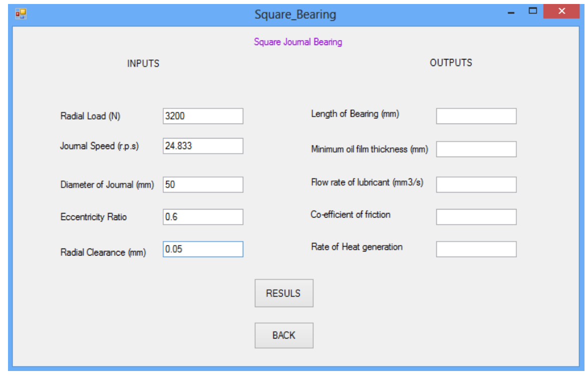

Fig.6 Inputs of Square Bearings

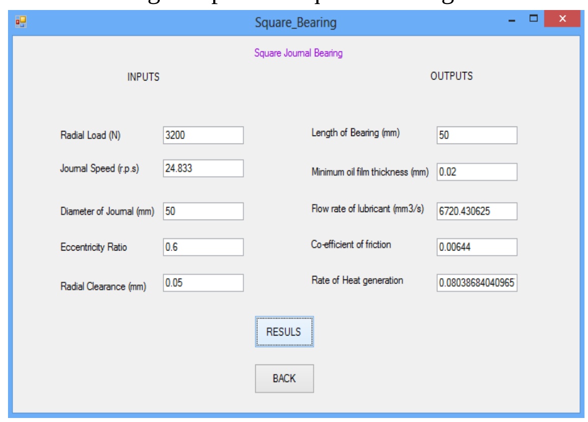

Fig.7 Outputs of Square Bearings

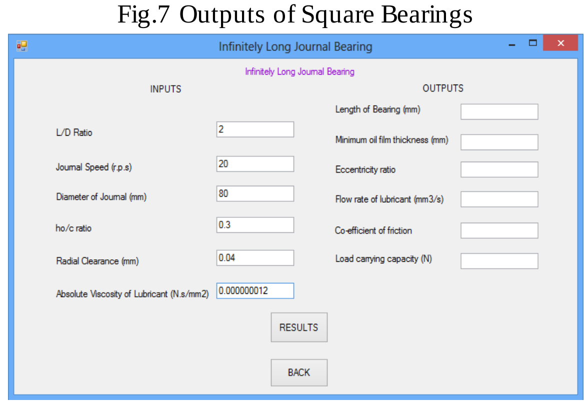

Fig.8 Inputs of Infinitely Long Journal Bearings

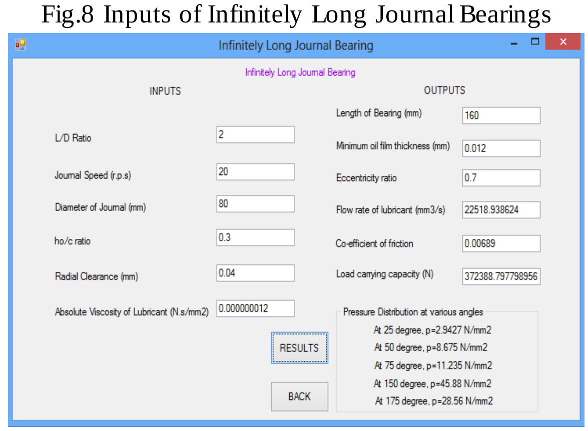

Fig.9 Outputs of Infinitely Long Journal Bearings

V. COMPARISON TABLE OF OUTPUTS OF MANUAL AND SOFTWARE

Type of Bearing	Design Considerations	Manual Output	Software Based output
Infinitely Short Journal Bearing	Length of bearing	40	40
	Minimum oil film thickness	0.015	0.015
	Eccentricity ratio	0.7	0.7
	Flow rate of lubricant	10555.75	10555.248
	Co-efficient of friction	0.0071	0.0071
	Load carrying capacity	13978.74	13964.58
Square Journal Bearing	Length of the bearing	50	50
	Minimum oil film thickness	0.02	0.02
	Flow rate of lubricant	6720.52	6720.43
	Co-efficient of friction	0.00644	0.00644
	Rate of heat generation	0.0804	0.0804
Infinitely Long Journal Bearing	Length of bearing	160	160
	Minimum oil film thickness	0.012	0.015
	Eccentricity ratio	0.7	0.7
	Flow rate of lubricant	22507.52	22518.94
	Co-efficient of friction	0.00568	0.00689
	Load carrying capacity	372766.65	372388.79

Table.3 Outputs of Hydrodynamic Journal Bearings

VI. CONCLUSION

- The original manual calculation for the design of Hydrodynamic bearings is very complex but if the Hydrodynamic bearing is designed with the help of this software lot of time can be saved and quick output can be obtained.
- Errorless result also is obtained with this software.
- While it is not possible to compare for different Material property if one is making calculations manually. But while running this software one can compare for different material properties easily.
- The software provides flexibility to the users.
- It is very user friendly and easy to understand.
- This software provides facility to check if the developed design is safe or not.

REFERENCES

[1] V.B.Bhandari, Machine Design elements.
[2] R.S.Khurmi and J.K.Gupta, Machine Design
[3] R.B.Patil,Industrial Tribology.
[4] Shyam N. Chawda, Microsoft Visual Basic.net