Design of Journal Bearing
Test Rig

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2012

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Abstract:
Our study deals with a design of suitable test rig, which can help in determining the load bearing capacity, pressure distribution of a journal bearing. Present project work is about designing a test rig, which can be further utilized to check on the behavior of different materials as may be proposed in the design of journal bearing. Therefore the study involves theoretical aspects on the working principle of a journal bearing, numerical calculation and finally a 3D model of the test rig. The sole purpose of designing a test rig is to make it an economical design and yet fulfilling its purpose for conducting experiments. Realization of the project is achieved through 3D modeling and 2D drawing using Autodesk inventor. Test rig will allow the end user to visualize the behavior of any bearing under different working conditions.

Keywords:
Journal bearing, Eccentricity, 3-D modeling, Pressure distribution
Acknowledgements

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Karlskrona

September 2012

Raajeshkrishna R.Govindaraj

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1 Notations

C Clearance of the bearing

e eccentricity of the bearing

ε eccentricity ratio

θ Angle

$P_{\text{max}}$ maximum pressure

R radius of the shaft

μ Viscosity of the lubricant

U velocity of the shaft
2 Introduction

Journal bearing is the most common type of plain bearing. It consists of a sleeve, with a shaft rotating in it and a thin film of lubricant, restricting the contact between them. The study on journal bearing comes under Engineering Tribology. As known, small improvements in the field of Tribology leads to better usage of energy [2]. Importance lies in testing newly found material such as the polymers, to see whether they are suitable for bearing application.

A test rig is an apparatus or equipment used for measuring the performance of any mechanical equipment. Test rig can be placed in laboratory for studying the pressure distribution of the journal bearing.

Journal bearings play an important role in almost every automobile application. The bearing guiding the shaft should have good thermal properties, strength and load bearing capacity. The friction between bearing and shaft should be low in order to get good power transmission. The direct contact between the shaft and the sleeve should be avoided, since it will damage both the sleeve and shaft. The lubricant will form a thin film between the moving surfaces. The pressure build-up varies according to the load in the bearing. Higher load in the bearing, results in direct contact with the shaft and the sleeve, which will damage both surfaces. The maximum pressure for every bearing should be determined so that it does not exceed the limits under any working condition, in order to avoid damage to the bearing.

In this present work, laboratory equipment was developed to determine the maximum pressure in the journal bearing, under certain load conditions. The set up has some design constraints like flexibility, so that it could be fixed in any laboratory, without disturbing the alignment of the shaft and motor. Also the rig should be mobile, so that it can be transported or moved to any location.

Initially an analytical calculation was carried out, in order to determine the pressure distribution with necessary assumptions. Then further on, the design of parts for the whole setup. While choosing some parts in the setup like plumber block, materials for bearings, shafts, tubes and the selection of motor for the desired RPM, standard dimensional parameters and standard equipments were considered for the setup.
2.1 Statement of the thesis work

The work involves developing laboratory equipment for the purpose of testing journal bearing materials. This equipment will be used at a laboratory to analyze different bearing material types that can be used for manufacturing bearings.

The work involves a coordinated approach between theoretical calculation and iterative steps to design and develop comprehensive and feasible setup for the purpose of testing journal bearing materials.

2.2 Specified aim and purpose of the work

The main aim of the thesis is to design test rig, journal bearing and shaft with certain clearance set up of the system provision for taking out line to measuring board. To know how pressure is developed at different points in the journal bearing. By applying loads the proportional pressure is also to analyse the design of compact and portable equipment is done using CAD modelling software such as Autodesk Inventor. Determine the cost of the product and study feasibility of the whole design.

2.3 Background

Numerous types of experiments have been conducted on bearings and the studies continue, with advancements in technology and materials, resulting in need for analysis of these new materials suitable for bearing application. Journal bearings test rig used for this educational purpose was built specifically to our laboratory. A 3D model is made using the software AUTODESK INVENTOR.
3 Theoretical Background

3.1 Basics of bearings

As known, bearings have played a vital role in engineering. The main purpose of a bearing is to support a rotating shaft or play as intermediate between a rotating part and a stationary part.

3.2 Classification of bearings

Bearings can be classified as hydrodynamic and hydrostatic bearings. In hydrodynamic bearings, the lubricant is absorbed or forced into the system by the rotation of the bearing. Whereas in a hydrostatic bearing system, an external source like a pump is required to force the lubricant into the system [16].

Journal bearings are mainly used for carrying axial loads or vertical loads. Journal bearing is a hydrodynamic bearing where, due to rotation of the journal in the bearing the lubricant is forced into the system. The bearing has a rotating shaft guided by a bearing, which is fixed. The friction between bearing and shaft is reduced by means of lubricants with high viscosity. The lubricant flows between the shaft and the stationary bearing. When the bearing is in running condition, there will be a pressure build up between the shaft and the bearing. The pressure should be tested for better performance and increased durability of the bearing.

3.3 Basic Principle of Journal Bearings

Journal bearing also called as plain bearings are widely used in automobile applications, not restricting the smooth movement of the parts. Journal bearings consist of two parts, the shaft transmitting the motion also known as the journal and the sleeve guiding the shaft. Both the parts are made of specific metal with good thermal properties and strength. The friction between two parts should be less in order to deliver the transmission with good efficiency. A thin film of lubricant is present between the two metal surfaces to prevent the direct contact between them also reducing friction.
The direct contact between metals may lead to damage of the shaft, or the sleeve leading to failure of the mechanism.

Load to the journal bearing can be of two types. Load applied on the shaft and load applied on the sleeve depending on the working conditions and type of applications used. In our case we are dealing with hydrodynamic bearing with load applied on the sleeve. Since the load is applied on the sleeve, the gap between the top layer of the shaft and the sleeve will be reduced forming a converging surface at the top, which on rotation of the shaft develops pressure inside the bearing. The aim of this project is to calculate the pressure inside the bearing [16].

3.4 Working Principle of Journal Bearing

Depending upon the type of application the two cases of journal bearing can be considered.

The journal shaft can be fixed and the sleeve can move perpendicular to the axis of the shaft. That is the sleeve can be self-positioning.

The sleeve can be fixed and the journal shaft can be self-positing depending upon the load type.

Irrespective of the type of application in a journal bearing, the position of the journal or the sleeve is directly related to the external load. When the bearing is sufficiently supplied with lubrication and under zero loads, the journal shaft or sleeve will rotate concentrically within the bearing. When a load is applied the journal or sleeve moves eccentric position forming a wedge shape of oil film, where the load supporting pressure is generated.

The clearance will be of the order of one thousandth of the diameter of journal. The figure below depicts the different parts and also the terms used in the journal bearing
Figure 3.1. Journal bearing.
4 Analytical Method

As any mechanical project starts with a mathematical calculation, in present project it is important to know the pressure distribution on the bearing surface. Pressure distribution and maximum pressure in bearings vary according to load on the bearing, speed of the shaft and materials used. Initially for mathematical calculations dimensions of the bearing, load, and velocity of the shaft are assumed for calculating the maximum pressure in the bearing.

4.1 Assumptions

The pressure and viscosity are both considered to be constant through the length of the bearing [2].

Derivative of velocity across the film thickness are far more important than any other velocity derivatives.

The flow is laminar

The lubricant is considered to be Newtonian

The lubricant adheres perfectly to the surfaces of the solids

End leakage is negligible.

4.3 Feasible model

Considering short bearing type of equation for this experiment; henceforth a bearing of diameter to length ration almost equivalent to 1 is chosen. Therefore 100 x 100 mm bearing is considered for this purpose. This size is good enough to manufacture and also for experimental purpose.

4.4 Determination of pressure distribution

**Eccentricity:** The distance between the center axis of the shaft and the sleeve.
**Eccentricity ratio:** It is the ratio of radius of shaft to clearance in the bearing.

The distance between the center part of the shaft and the center part of the sleeve is called the eccentricity. Eccentricity plays a key role in varying the pressure in the bearing. Varying pressure is directly proportional to varying eccentricity. The maximum possible eccentricity is the radial clearance of the bearing. So the ratio of eccentricity to the clearance gives the eccentricity ratio. Eccentricity ratio can vary from 0 to 1. If the ratio is zero, then the shaft is exactly in the center of the bearing sleeve. Also this indicates that there is no pressure and in the bearing. And if the eccentricity ratio is one, then the load on the bearing is maximum and there is contact between the shaft and the sleeve. By varied the eccentricity ratio from 0 to 1 for pressure calculation. So our pressure calculation is preceded with the Reynolds’s equation as its base [3], [4]. So the equation for calculating the maximum pressure is,

\[
P = \frac{\mu U r}{e^2} \left[ \frac{6e(s\sin\theta)(2+e\cos\theta)}{(2+e^2)(1+e\cos\theta)^2} \right]
\]

(4.1)

### 4.4.1 Assumptions

\(\mu=0.01\ \text{Ns/m}^2\), viscosity of the lubricant.

\(U=10\ \text{m/s}\), velocity of the shaft.

\(r=50\ \text{mm}\), radius of the shaft.

\(\Theta=0-180\ \degree\).

\(c=40\ \mu\text{m}\), clearance of the bearing for minimum tolerances.

\(c = 130\ \mu\text{m}\), clearance of the bearing for maximum tolerances.

\(e=\) eccentricity of the bearing.

\(\varepsilon=0.1\), eccentricity ratio.
Here a tolerance range of 40 to 130µm has been chosen, to get a pressure distribution in a range of 0.1 to 0.4 bars, which is equivalent to a weight of 5kgs to 20kgs. This weight range is ideal for laboratory usage.

Substituting the above mentioned assumptions in the Reynolds’s equation gives,

\[
Maximum \ pressure, P_{max} = 1.8480 \times 10^4 \ \text{N/m}^2
\]

### 4.5 Pressure distribution for varying angles

By varying the rollup angle from 0 to 180 and calculated the relative pressure in the bearing. The pressure distribution for maximum and minimum tolerance has been tabulated in the following table.
Table 4.1. Pressure distribution for with minimum and maximum tolerances varying roll-up angles.

<table>
<thead>
<tr>
<th>Angle, Degrees</th>
<th>Pressure, (10^3) N/m(^2) Maximum tolerance</th>
<th>Pressure, (10^4) N/m(^2) Minimum tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0.5980*10(^3)</td>
<td>0.6414*10(^4)</td>
</tr>
<tr>
<td>40</td>
<td>1.124*10(^3)</td>
<td>1.2058*10(^4)</td>
</tr>
<tr>
<td>60</td>
<td>1.5145*10(^3)</td>
<td>1.6247*10(^4)</td>
</tr>
<tr>
<td>80</td>
<td>1.7224*10(^3)</td>
<td>1.8478*10(^4)</td>
</tr>
<tr>
<td>100</td>
<td>1.7227*10(^3)</td>
<td>1.8480*10(^4)</td>
</tr>
<tr>
<td>120</td>
<td>1.5151*10(^3)</td>
<td>1.6253*10(^4)</td>
</tr>
<tr>
<td>140</td>
<td>1.1246*10(^3)</td>
<td>1.2065*10(^4)</td>
</tr>
<tr>
<td>160</td>
<td>0.5984*10(^3)</td>
<td>0.6420*10(^4)</td>
</tr>
</tbody>
</table>

Figure 4.2. Pressure Distribution for Maximum and minimum tolerances for different roll-up angles.
Figure 4.3. Pressure Distribution for Maximum and minimum tolerances for different roll-up angles with eccentricity ratio 0.5.

From above graphs it is clear that, for minimum tolerance, higher pressure values are obtained compared to maximum tolerances.
5 Product Development

Product development as described by Broman G, should be a coordinated approach [1]. Starting with some assumptions and taking all constrains into consideration, a theoretical modeling is developed. Upon further investigation and simulation the model is optimized and final product developed.

5.1 Design Approach

The aim is to design a test-rig to study the characteristics of the journal bearing. The setup requires parts like shaft, sleeve and frame to be designed and demands parts like motor of 1500 RPM with 0.5-1.5 Hp, plumber block (2 Numbers) and plastic tubes to be procured from manufacturing companies. These parts should be put together in an assembly for the rig. The justification for the design of the parts and their assemblies are explained in three different phases.

5.1.1 Phase 1

Initially the shaft and sleeve should be designed and the shaft is placed inside the sleeve. The sleeve in the bearing is provide with holes on the surface to allow the flow of lubricant through them due to the pressure created in the bearing under running condition. The power to the shaft is transferred from the motor. The shaft of the motor and the shaft of the bearing are connected using flange coupling transmitting motion. From the sleeve a weight hanger should be attached to apply load in the bearing.

5.1.2 Phase 2

The whole setup in phase 1 should be mounted on a flat surface a steel plate of 7mm thick so there won’t be any miss alignment in the shaft and sleeve. A weight hanger is attached to the sleeve. A frame is made so that this flat surface can be mounted upon the frame. The frame should be rigid so that it doesn’t deform when the load is applied. Also the top surface of the frame where the bearing and motor setup is mounted should be flat with slightly
high tolerance. This flatness allows the narrow alignment of the bearing shaft and the motor shaft. The Frame will have an extension on one side in order to mount the oil tank.

5.1.3 Phase 3

An oil tank is placed above the frame extension to supply lubricant to the journal bearing. The tube from oil tank supplying lubricant is inserted in a hole drilled in the sleeve especially for this purpose. The tank is placed above certain height to the bearing, allowing constant flow of lubricant into the bearing and providing sufficient inlet pressure in the bearing. Plastic tubes of cylindrical cross section approximately 10 mm diameter and of length approximate to the height of the wall are inserted into holes in the sleeve and mounted straight along the height of the wall. When the bearing is in running condition, due to the application of load by adding weight to the holder, pressure develops in the bearing. The pressure in the bearing forces the lubricant out of the sleeve holes and through the tubes attached to them. Due to variations of pressure in the bearing, tubes in holes along the surface of the sleeve will have different heights of lubricant level, portraying the pressure distribution in the bearing.

5.2 Manufacturing parts

The manufacturing components are frame, shaft, weight holder, measuring panel, base plate, adjustable pads. These parts are mostly manufactured by mild steel except the sleeve, since sleeve should be made out of higher strength material.

5.3 Parts to be procured

While building any equipment as known some parts have to be manufactured and other parts can be procured, finally all the parts are assembled together to form the equipment. Here in this section a list of all the part required for this setup is made in two categories namely procurement parts and the manufacturing parts.
## 5.3.1 Procurement parts

*Table 5.1. Parts to be procured.*

<table>
<thead>
<tr>
<th>Parts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Motor:</strong> To drive the shaft at a uniform speed. Importance should be given to torque requirement.</td>
<td></td>
</tr>
<tr>
<td>2. <strong>Coupling:</strong> To connect the shaft and the motor, a slight miss alignment should be composited by the coupling.</td>
<td></td>
</tr>
<tr>
<td>3. <strong>Plumber block:</strong> To hold the shaft at the two ends, alignment of the shaft is of high importance.</td>
<td></td>
</tr>
<tr>
<td>4. <strong>Pipes:</strong> For the easy flow of the lubricant from the tank to the bearing and also from bearing to the measuring panel.</td>
<td></td>
</tr>
<tr>
<td>5. <strong>Weights:</strong> To be used to develop pressure in the bearing.</td>
<td></td>
</tr>
<tr>
<td>6. <strong>Oil tank:</strong> To store lubricant and supply and for the continuous supply of lubricant.</td>
<td></td>
</tr>
<tr>
<td>7. <strong>Bolts and Nuts:</strong> Are used to fasten the some manufacturing parts and also secure the bearing units.</td>
<td></td>
</tr>
</tbody>
</table>
6 Design of individual parts

6.1 Bearing

6.1.1 Design need

The sleeve or bearing is an important part of journal bearing. The bearing allows the rotation of shaft along a fixed axis without affecting the efficiency of the transmission. This can be achieved by using lubricants between the shaft and the sleeve. In our design the load in the bearing which is a single piece component, is applied perpendicular to the rotating axis. In this design, according to the requirement, the sleeve should be capable of allowing the lubricant in continuously and pumping them out when there is a pressure build up. The inner surface of the bearing should be smooth without any deflection in the roundness, since uneven surface may damage the shaft and the sleeve while applying load. The sleeve should also hold the weight hanger where the load in the bearing is applied.

6.1.2 Dimension and specification

Table 6.1. Dimension and Specification for bearing.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mild steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the bearing</td>
<td>100 mm</td>
</tr>
<tr>
<td>Inner diameter</td>
<td>100 mm</td>
</tr>
<tr>
<td>Outer diameter</td>
<td>122 mm</td>
</tr>
<tr>
<td>Number of holes</td>
<td>30</td>
</tr>
<tr>
<td>Holes outer diameter</td>
<td>9 mm</td>
</tr>
<tr>
<td>Holes inner diameter</td>
<td>1 mm</td>
</tr>
<tr>
<td>Bolt groove diameter</td>
<td>6 mm</td>
</tr>
<tr>
<td>Distance between grooves</td>
<td>60 mm</td>
</tr>
</tbody>
</table>
6.1.3 Design motivation

The sleeve is strong enough to withstand load and should not deflect or deform while applying the load. So the bearing is made of mild steel. The inner surface of the bearing is well polished and the tolerance is very high so that the shaft and sleeve won’t get damaged while applying load. This also prevents the uneven distribution of pressure inside the bearing. The fluid should flow out of the bearing to the pipes to depict the distribution of pressure inside the bearing, so holes are drilled on even intervals to allow the flow of lubricant outside the bearing. There are totally thirty holes drilled throughout the bearing surface. The pressure will be high on the top of the bearing, since the load is applied downwards. On the top layer of the bearing there are twenty five holes drilled with five rows and five columns and five rows with one column on the bottom surface. The plastic tubes which allow the lubricant to pass through from the bearing are not directly fixed to the bearing. Instead they are attached to small copper tubes fixed to the bearing so that the tubes can easily be inserted and removed when necessary. The weight hanger is attached to the bearing to apply load. The weight hanger is therefore fastened to the bottom surface of the bearing.

Figure 6.1. Bearing.
6.2 Journal shaft

6.2.1 Design need

Shafts are a mode of power transmission in any automobile application. The shaft generally connects the engine and the drive. The shaft should be made of strong materials so that it won’t deform under heavy loads and high pressure. The shaft transmits power only in desired direction without deviating from its path and it should be placed in between bearing sleeve. The surface of the shaft should be very smooth because uneven surface leads to irregular distribution of pressure and also leads to misalignment of the shaft to that of the motor. The shaft should be connected to the motor shaft using coupling. The coupling should be flexible so that slight difference in shafts linearity can be adjusted. Key slot should be provided in the shaft for coupling. Also the bearing shaft end and motor shaft end should be of same diameter. Slots should be provided to constrain the axial motion of shaft allowing it to have only single degree of freedom.

6.2.2 Dimension and specification

Table 6.2. Shaft Dimension and Specification.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mild steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the Shaft</td>
<td>285 mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>100 mm</td>
</tr>
</tbody>
</table>

6.2.3 Design motivation

The material used for making the shaft should be very hard and it should not deform under heavy loads and high pressure, so mild steel is used for making the shaft. The surface of the shaft is polished and is machined with very high tolerance so that there won’t be any damage to the sleeve and shaft also preventing the uneven distribution of pressure inside the bearing.
Circularity and roundedness are also very important while machining the shaft. The shaft is held by plumber blocks on each side. The diameter of the shaft held inside the plumber block is small to restrict the movement of the shaft axially, so that the shaft rotates in a confined path. At one end of the shaft is provided with a sir clip to hold the shaft inside the plumber block from moving out. The rear end of the shaft connecting the motor is still reduced in diameter to match the coupling diameter, which connects with the motor. A keyway is provided at the end of the shaft to connect with the coupling. The coupling used for connecting the journal shaft and the motor shaft is Oldham coupling since it is flexible and slight misalignment in the linearity of both the shafts can be adjusted.

![Figure 6.2. Journal Shaft.](image)

### 6.3 Base plate

#### 6.3.1 Design need

The base plate is placed above the table frame where the journal bearing setup and motor are fixed. The base plate is rigid enough so that it won’t undergo any deflection while applying the load. Since the motor and bearing are mounted on the same surface, the surface flatness of the plate is very high preventing any misalignment between the bearing shaft and the
motor shaft. The base should also provide certain space for the weight hanger to hang down freely.

6.3.2 Dimension and specification

Table 6.3. Base plate dimension and specification.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>800 mm</td>
</tr>
<tr>
<td><strong>Breadth</strong></td>
<td>300 mm</td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td>7 mm</td>
</tr>
<tr>
<td><strong>Bolt groove diameter</strong></td>
<td>M16</td>
</tr>
<tr>
<td><strong>Length (hollow section)</strong></td>
<td>150 mm</td>
</tr>
<tr>
<td><strong>Breadth (hollow section)</strong></td>
<td>120 mm</td>
</tr>
<tr>
<td><strong>Material used</strong></td>
<td>mild steel</td>
</tr>
<tr>
<td><strong>Section</strong></td>
<td>solid</td>
</tr>
</tbody>
</table>

6.3.3 Design motivation

The base plate is made of mild steel for good tensile strength and rigidity. The suitable thickness of the base plate for maintaining good strength is 7 mm, which will provide a rigid platform for the motor and bearing setup won’t deform under high loads. The plate is attached to the table frame using bolts so that the whole experimental setup can be easily dismantled and assembled. The plate should be flat in order to prevent misalignment of the shafts. So the tolerance in flatness is set to 0.01-0.00 which is very suitable for the type of flatness expected. The bearing and shaft are held by two plumber blocks, which are fastened to the base plate using bolts. The bolt grooves to fix the plumber block are extended horizontally on the top
and vertically at the bottom to adjust the journal bearing’s linearity with respect to the axis of shaft and motor. In between the two plumber blocks a hollow section is made to allow the weight hanger, which is attached to the bearing sleeve to hang down freely. The base plate is cut into a hollow section at a distance of 200 mm from the plate’s end.

Figure 6.3. Base plate.

6.4 Frame

6.4.1 Design need

The basic need of the design is to hold the whole bearing setup providing a rigid platform. The table is made compact and portable so that it can be easily transported and installed in laboratories. The table is sturdy enough in order to absorb vibrations of motor and bearing in running condition. The table is rigid so that it will not deform in shape during application of load in the bearing. This is a main factor to be considered because deformation in the table leads to misalignment and linearity between the bearing shaft and motor shaft leading to damage of the journal bearing. The table should be designed also to hold the oil tank at certain height above the bearing setup for providing continuous lubrication to the bearing.
6.4.2 Dimension and specification

*Table 6.4. Frame Dimension and Specification.*

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>800 mm</td>
</tr>
<tr>
<td><strong>Breadth</strong></td>
<td>600 mm</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>500 mm till the base plate</td>
</tr>
<tr>
<td></td>
<td>300 mm above base plate to hold the oil tank</td>
</tr>
<tr>
<td><strong>Material used</strong></td>
<td>Mild steel</td>
</tr>
<tr>
<td><strong>Section</strong></td>
<td>Square hollow section of side</td>
</tr>
<tr>
<td></td>
<td>40*40 mm and 2 mm thickness</td>
</tr>
</tbody>
</table>

6.4.3 Design motivation

The material used for manufacturing the table is mild steel since it will be strong and provide a rigid platform that won’t deform under heavy loads. A solid section of mild steel throughout the table will make the table too heavy which affects the mobility of the table. This can be overcome by using hollow sections of mild steel throughout the frame. This makes the frame strong and less weight comparatively. The oil tank in this setup will be helpful if it is placed somewhere closer to the table. So we planned for the oil tank holder fixed to the table. So from the one side of the table an extension of the frame is designed above to hold the oil tank. All the joints in the frame are welded. The legs of the table are provided with leveling pads in order to ensure that the table on uneven surface is balanced. Also these pads will prevent the surface under the table from damaging.
Figure 1.4. Frame.

Figure 6.5. Leveling pads.
6.5 Weight holder

6.5.1 Design need

The purpose of this component is to hold the weights added to the bearing to create the necessary pressure in the bearing. The holder is fastened with the help of bolts to the bottom surface of the bearing sleeve. The holder should be designed with less weight material so that its load impact on the bearing will be negligible. A projection is made in the base plate to allow the weight holder hang freely downwards without any hindrances. Also the weights can be easily added and removed from the holder.

![Figure 6.6. Weight holder.](image)

6.6 Copper tubes

6.6.1 Design need

When the bearing is in running condition there will be flow of lubricant outside the holes in the bearing sleeve. This lubricant is collected in a tube and mounted on the wall. The tube is not directly connected to the bearing. These tubes can’t firmly fix to be bearing since the depth of the hole is very less. Instead we can fix a copper tube of the same diameter of the bearing holes to the sleeve and in turn the tubes collecting lubricant can be fixed to them so that they can be held firmly while the fluid is pumped out. For this design we can procure a long copper tube of required diameter and thickness and can be cut into small pieces.
6.6.2 Dimension and specification

Table 6.5. Copper tube Dimension and Specification.

<table>
<thead>
<tr>
<th>Material</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>30 mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>9 mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

Figure 6.7. Copper tube.

6.7 Oil tank

This component is not necessarily to be manufactured. A readily available plastic tank can also be sued for the purpose. The main function is to hold the oil and give a continuous supply of the lubricant while testing.
7 Assembly process

The assembly of the whole setup is described by the assembly diagram drawn in Auto-CAD and a stepwise assembly diagram using Photoshop.

*Figure 7.1. Assembly 1.*

*Figure 7.2. Assembly 2.*
Figure 7.3. Assembly steps.
7.1 Assembly chart

FRAME FIXED WITH LEVELING PADS AT THE BOTTOM

BASE PLATE SHOULD BE PLACED ABOVE THE FRAME

BASE PLATE IS FASTENED TO THE FRAME USING BOLTS

PLUMBER BLOCK 1 IS FIXED TO THE BASE PLATE USING SUPPORT BLOCK

SHAFT INSIDE THE BEARING, ATTACHED WITH WEIGHT HANGER IS PLACED INSIDE PLUMBER BLOCK 1

PLUMBER BLOCK 2 IS PLACED ON THE OTHER SIDE OF THE BEARING AND FASTENED TO THE BASE PLATE ARRESTING THE BEARING HUS

SHAFT IS CONNECTED TO THE COUPLING

OTHER END OF THE COUPLING IS CONNECTED TO THE MOTOR SHAFT

MOTOR IS FASTENED TO THE BASE PLATE USING BOLTS

OIL TANK IS PLACED ABOVE THE FRAME

TUBES MOUNTED ON THE WALL CONNECTED TO THE BEARING SLEEVE

OIL COLLECTING PAN SHOULD BE PLACED BELOW THE BEARING HUS TO COLLECT THE LEAKING OIL

PHASE 1  PHASE 2  PHASE 3  PHASE 4
7.2 Assembly Steps

- Frame connected to leveling pads are placed first.
- Base plate should be placed on the frame.
- Plumber block 1 fastened to the base plate.
- Bearing sleeve with shaft is connected to the plumber block 1.
- Plumber block 2 is fastened to the base plate holding the bearing and shaft.
- Weight holder is connected to the bearing sleeve.
- Coupling is made between bearing shaft and motor shaft.
- Motor is fastened to the base plate.
- Oil tank is placed above the frame.
- Copper tubes are connected to the bearing sleeve.
- Tubes for collecting oil are connected to the copper tubes.
- Oil collecting pan is placed below the bearing setup.
8 Experimental approach

Figure 8.1. Experimental approach flow chart.

8.1 Working principle

- Oil tank at certain height creates a pressure head, which helps in easy moment of lubricant into the bearings.
- Due to rotation of the shaft and load on the sleeve, a load bearing pressure is created.
- In the region of load bearing pressure, the lubricant is pumped out through the holes provided on the sleeve.
- The oil from these holes is made to pass through tubes to the measuring panel.
- The difference in height of the inlet and outlet pressure heads helps us in calculating the pressure at the specific point on the sleeve.
• The obtained pressure values are tabulated to get the pressure distribution in the journal bearings

### 8.2 Calculation of pressure head

Pressure head at inlet and outlet can be calculated using the following formulas.

**Inlet pressure**

\[ P_i = -\gamma \cdot H_1 \]  \hspace{1cm} (8.1)

**Specific weight**

\[ \gamma = \rho \cdot g \]  \hspace{1cm} (8.2)

**Outlet pressure**

\[ P_o = P_i - \gamma \cdot (H_2 - H_1) \]  \hspace{1cm} (8.3)
9 Cost Estimation

Costing is the initial approximation of the budget requirements to manufacture the product. It plays an important role in decision making. The costing of the present product was done based on the current market prices of the material and a rough estimate of the total cost is made, taking into consideration, both the material as well as labor cost.

The costing model was arrived at after a good study of different suppliers, manufactures for each product and a visit to a small scale industry in Karlskrona. Discussion with people from this industry helped us in understanding the different aspect involved such as machining time and labor requirement for producing some of the parts. The table below lists out the cost required for each item available in market.

*Table 8.1. Estimated Cost of the whole Setup.*

<table>
<thead>
<tr>
<th>Item</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Motor</td>
<td>To drive the journal and create the required torque to build up the pressure.</td>
</tr>
<tr>
<td>2 Bearing</td>
<td>Used to support the journal shaft at the ends.</td>
</tr>
<tr>
<td>3 Frame</td>
<td>Made of hollow mild steel tubes to support the whole equipment.</td>
</tr>
<tr>
<td>4 Steel plate</td>
<td>To form a base on the frame to support the motor and journal bearing assemble.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Functionality</th>
<th>Quantity</th>
<th>Price per unit</th>
<th>Total price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>To drive the journal and create the required torque to build up the pressure.</td>
<td>1</td>
<td>1594</td>
<td>1594</td>
</tr>
<tr>
<td>Bearing unit</td>
<td>Used to support the journal shaft at the ends.</td>
<td>2</td>
<td>225</td>
<td>450</td>
</tr>
<tr>
<td>Frame</td>
<td>Made of hollow mild steel tubes to support the whole equipment.</td>
<td>1.5*20ft</td>
<td>249 for 4 meters</td>
<td>1245</td>
</tr>
<tr>
<td>Steel plate</td>
<td>To form a base on the frame to support the motor and journal bearing assemble.</td>
<td>1/4&quot; 2<em>2 ft &amp; 3/8&quot; 1</em>2</td>
<td>581</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Part Description</td>
<td>Application</td>
<td>Specifications</td>
<td>Quantity</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>5</td>
<td>Steel support block</td>
<td>To form a base on the steel plate and to support the plumber block.</td>
<td>0.105&quot; 2*2 ft</td>
<td>217</td>
</tr>
<tr>
<td>6</td>
<td>Adjustable pads</td>
<td>To be fixed at the bottom of the frame to act as anti-vibrant</td>
<td>4</td>
<td>26.5</td>
</tr>
<tr>
<td>7</td>
<td>Hydraulic hose</td>
<td>For the oil to flow form bearing to measuring panel.</td>
<td>9mm thick 50metes</td>
<td>3174</td>
</tr>
<tr>
<td>8</td>
<td>Coupling</td>
<td>To connect with shaft and motor, also to the care of any misalignment</td>
<td>1</td>
<td>505</td>
</tr>
<tr>
<td>9</td>
<td>Copper tubes</td>
<td>To fix the tubes to the bearing</td>
<td>3ft</td>
<td>44.73</td>
</tr>
</tbody>
</table>

Based on feedback received from the industry and study of cost form different supplier, a final estimate of the test rig has been made. As estimated a total of 20000kr would be required to produce this equipment including material, machine time and labor cost.
10 Conclusion

This thesaurus mainly concentrates on design of a test rig, which will help in study of the characteristics of journal bearing including load bearing capacity, maximum pressure and material selection. The whole setup is designed using AutoCAD inventor. Simulations were done in the same software for checking the maximum stress and the design was altered in order to prevent deformation while applying the load. The design is made as compact as possible after a lot of brainstorming and design motivations for every part are mentioned in the present report. An approximate cost of producing the whole setup after consulting a manufacturing company in Karlskrona has been made. The cost of the components that are to be manufactured and the cost of the components to be procured are tabulated. Initially analytical results are calculated for pressure distribution with necessary assumptions regarding dimensions and load. Once the setup is manufactured and in running condition, the pressure distribution of the bearing should be experimentally calculated and compared with the analytical results. This design will help the reader to visualize the behavior of the journal bearing under varying loads.
11 Future work

The behavior of this design is not visualized by the present work and the experimental results were not calculated since the product is not manufactured yet. After the test rig is manufactured, an experiment should be conducted and its characteristics should be studied. If there is any drawback in the present design that is noticed while the bearing is in running condition, those things need to be altered. Once the experimental results are obtained it should be compared with the analytical results and a motivation of the results should be portrayed.
12 References


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10. Qiang LI, Shu-Lian, Xio-Hong, Shui-Ying, (2011), A new method for studying the 3D transient flow of misaligned journal bearing in fixed rotor bearing system, ISSN 1673-565X.


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Appendix

Bearing
Shaft
Weight holder
Support block