Study on Effect of Surface Texture on the Performance of Hydrodynamic Journal Bearing

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Abstract- The present study examines effect of surface texture on hydrodynamic journal bearing performance. The work is divided into two steps: 1. Mechanical indentation texturing technique used to incorporate the micro-dimples on bearing surface. 2. Experimentation on smooth and textured journal bearing with two oil inlet holes located at ± 90° to load line, to examine the effect of surface texture. A series of experimental results are presented, the effect of micro-dimples on pressure distribution on center plane of smooth and textured journal bearing at different loads and speeds. The Experimental results show that the pressure increases when surface texture (micro-dimples) is added on bearing surface. It is observed that with the increase of loads (200N to 800N) at constant speed and constant oil supply pressure, the percentage increase of maximum pressure (% Pmax) is more in textured journal bearing w.r.t smooth journal bearing and with the increase of speeds (1000 rpm to 3000 rpm) at constant load and constant oil supply pressure, percentage increase of maximum pressure (% Pmax) is more in textured journal bearing w.r.t smooth journal bearing.

Keywords- Journal bearing, surface texture, bearing performance, pressure distribution in journal bearing

I. INTRODUCTION

Surface texturing technology has been newly explored technique in the tribology community is a method of improving the friction and lubrication performance of various mechanical components.

The several researches and investigations on surface texture presents the potential benefits of modifying the surface topography such as reduce coefficient of friction and leakage problems in mechanical seals, improve load carrying capacity of journal and thrust pad bearing, as well as reduces the metal to metal contact and decreased surface damage. The presence of surface textures may also benefit because it works as a lubricant reservoir and storing and supplying the lubricant directly to the contact zone and reduce friction and wear problems. Sinanoglu [1] investigated the effects of shaft surface texture on journal bearing pressure distribution. Here experimental and neural network applications were employed for analyzing pressure variations on bearing system. Tala-ighil et al. [2] used a finite-difference numerical model to study the effect of surface textures on the lubrication of a journal bearing system under steady state condition. Cupillard et al. [3] studied the effect of surface texture on bearing friction and load carrying capacity using computational fluid dynamics.

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Cupillard [4] described surface texture is distinguished from roughness in that it is defined by a repetition of well-defined identical shapes along the surface whereas roughness is not well characterized and is considered random. The pattern formed composes the texture. Surface texture is well defined micro-dimples or cross crosshatches pattern on the tribological components have potential to improve the performance of several mechanical components [5]. Various shapes of feature such as circles, rectangles, squares, triangles, pentagons, hexagons, array of straight lines, curve lines and crosshatches pattern are being applied as texture. The difference in design as well as direction of surface texture can change the performance of tribological components. The main challenge is to determine the optimum value of critical dimensional between various geometrical parameters of tribological components. These geometrical parameters are length; width and depth of the texture, the distance between texture such as pitch, array, and angle as well as density and orientation of surface textures. Various techniques can be employed for surface texturing are Photolithography techniques [5], Laser surface texturing [6-9], Etching (wet and dry etching) [10-12], Mechanical indentation [13], Abrasive jet machining [14], Novel dressing technique [15, 16], Vibromechanical texturing [17, 18]. In this paper, we focus our attention to influence of surface textures (micro-dimples) on the performance of hydrodynamic journal bearings. In this current research mechanical indentation texturing technique was adopted for texturing the inner surface of bearing. Results are provided with different loads, speeds, and constant oil inlet pressure on smooth and textured journal bearing.

II. TEST BEARING

A. Material Selection

Material selected for research work is Phosphor-bronze, because of their good mechanical and physical properties they can be used as bearing materials. Phosphor bronze is an alloy of copper with 3.5 to 10% of tin, 9 to 10% lead, and a significant phosphorus content of up to 1%. The phosphorus is added as deoxidizing agent during melting. These alloys are notable for their toughness, strength, low coefficient of friction, and fine grain. It has hardness up to 75-100 BHN at room temperature, load carrying capacity is more than 27.6 MPa, tensile strength is 241.5 MPa and maximum operating temperature is 260°C moreover it has excellent fatigue strength rating 1.

B. Design and Fabrication of test bearing

Design of test bearing has been completed in Computer Aided Design softwares (Pro-E). The 3-dimensional model of test bearing is schematically presented in Fig. 1. Here inner diameter (ID) of test bearing is 65 mm, outer diameter (OD) is 85 mm and length of test bearing is 65 mm. On the middle circumference of the test bearing 10 holes are provided at 30 deg to each other for measuring circumferential temperature and pressure along with two inlet holes, the two inlet holes are for supplying oil at high discharge rate on to journal bearing. Fabrication of test bearing was got done competed with the help of an external vendor (Chavla Machining Works, Ghaziabad), though some work was completed in the Institute workshop. Experimentation test bearing after machining given in Figure. 2.

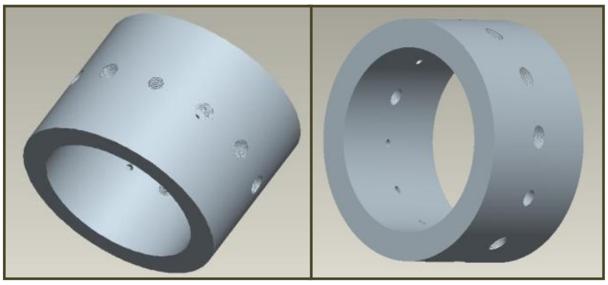

Figure 1: 3-D model of test bearing

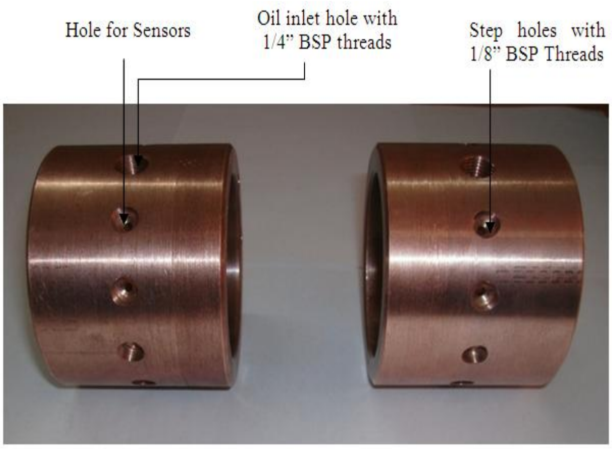

Figure 2: Test Bearing

III. INCORPORATION OF SURFACE TEXTURE

Mechanical Indentation texturing technique performed on specially designed fixture where pipe-vises are used. A pipe vise is an apparatus which enables a pipe to be held tightly or permit the strongest jaw-to-jaw gripping of pipe for high-torque applications like threading. Apparatus consists of two pipe-vises and one mild-steel rod is placed between two pipe-vises. This rod is welded with steels balls for incorporation of micro-cavities (dimples). The diameter and hardness of steel ball is 12 mm and 30 BHN. To incorporate micro-dimples on the experimentation test bearing, texturing apparatus is tightly bolted with table or base plate. The jaws are opened by turning the T-handles while the bearing is placed on wooden block to maintain proper height between pipe vises. Mild steel rod is positioned between jaws and bearing. Once the bearing and rod is properly positioned then both the jaws are closed by turning the T-handles. Due to clockwise rotation of jaws in downward direction some force is applied and the rod is pushed in downward direction. This process applies some force on the inner surface of bearing and micro-dimples are formed of particular depth on bearing surface. The details of textured bearing are illustrated in Table 1. The surface textures (micro-dimples) are located where maximum pressure is generated i.e. in converging zone of bearing.

Table 1: Surface texturing details

Bearing	Ball (Indenter) diameter (mm)	Dimple diameter (mm)	Dimple depth (μm)	No. of dimples (Nos.)
Phosphor Bronze Bearing	12	4	200	16

IV. EXPERIMENTAL SETUP

A schematic diagram of the journal bearing test rig used for experimental studies is shown in Figure 3. It is a sturdy versatile apparatus, easy to operate with provision to measure temperature and pressure on at every 30 degree angular position on the middle circumferential of bearing (bush). The journal is made of C-45 steel material and is mounted horizontally on two pedestal bearings. The journal is rotated by a motor through belt and pulley arrangement, 1:2 ratio pulleys is provided, to attain speed up to 5000 rpm. A sleeve fits over journal and radial load is applied on bearing by 1:1 lever mechanism, through pneumatic loading arrangement. Here lever are connected with pneumatic loading device in which cylinder and piston arrangement given, which is governed by compressed air. The motor speed is varied by a frequency drive; the driver frequency changed by a potentiometer knob provided on controlled front panel. A proximity sensors fixed on the journal senses its speed. The test rig is designed to apply a maximum radial load up to 2000 N.

Lubrication unit is made of a metallic tank with a motor and pump, by pass valve, control valve, pressure gauges, flow meter, and inlet and delivery pipe. An oil sump is provided beneath the bearing for collecting the used oil and it flows into metallic tank for recirculation. For pressure measurement on the middle circumference of bearing 10 pressure gauges are provided which are mounted on wooden box and connected with journal bearing test rig through tubes. Radial load and journal speed can be varied to suit the test conditions. Viscosity of the lubricating oil is determined by using FUNGILAB digital Readout Viscometer Model "VISCOBASIC L" Measuring range of viscosity of this model is 6 cP to 2x106 cP and rotational speed varies from 0.3 rpm to 100 rpm.

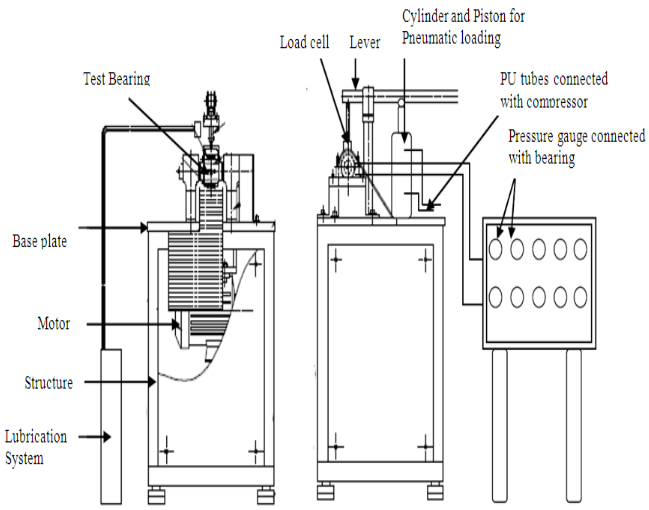

Figure 3: Schematic diagram of journal bearing test rig

V. EXPERIMENTAL PROGRAMME

A smooth and textured circular bearing(shown in Fig. 4(a and b)) was tested for pressure distribution in journal bearing using commercial grade of oil namely Hydrol 68 at load varying from 100 N to 800 N and speeds of 1000, 2000 and 3000 rpm respectively at constant oil supply pressure of 0.05 MPa. For each speed, the load on the bearing has been increased in steps of 200 N i.e. readings have been taken for loads 200, 400, 600 and 800 N. The oil was supplied through two oil holes at 90° to the vertical loading line. For each set of reading during experimentation, the stabilization time comes out to be nearly 1.5 hrs. Figure 5 shows the location of pressure gauges connection (1-10) for pressure measurement.

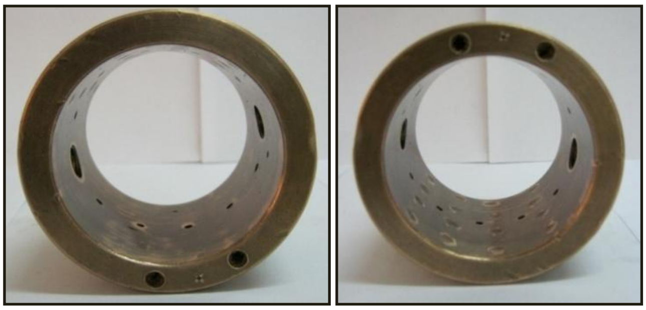

Figure 4: (a) Smooth bearing, (b) Textured bearing

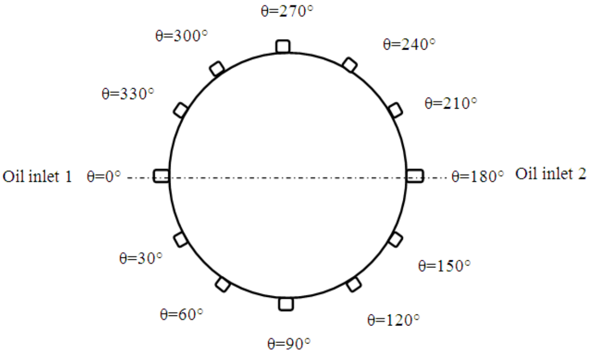

Figure 5: Diagram showing the location of pressure gauges connection (1-10) for pressure measurement.

VI. RESULTS AND DISCUSSION

Experiments have been carried out both on smooth and textured journal bearing at various speeds and loads for pressure distribution. The smooth and textured journal bearing are shown in Fig. 6 (a) and (b). Input parameters, various operating conditions and properties of oil under study are given in Table 2, Table 3 and Table 4.

Table 2: Input Parameters

Outer diameter of the bearing, OD	85 mm
Inner diameter of bearing, ID	65 mm
Length of bearing, L	65 mm
Radial Clearance, C	100μm
Average roughness in bearing, Ra	2μm

Table 3: Test operating conditions

Lubricants	Hydrol 68
Rotation speeds, N	1000,2000 and 3000 rpm
Load, W	200, 400, 600 and 800 N
Oil inlet pressure	0.05 MPa

Table 4: Properties of oil under study

Lubricant	Hydrol 68
Viscosity,μ(at oil temperature,33°C)	0.075 Pas
Oil density, ρ	880 Kg/m3
Thermal Conductivity, Koil	0.126 W/mK

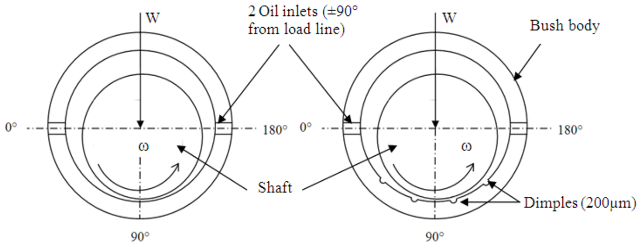

Figure 6: Bearing geometry (a) Smooth bearing and (b) Textured bearing

Figures 7 (a, b, c and d) 8 (a, b, c and d) and 9 (a, b, c and d) presents the pressure distribution on a center plane of smooth journal bearing for speeds = 1000, 2000, 3000 rpm, constant oil supply pressure 0.05 MPa and at varying loads from 200 N to 800 N. Figures also show that effect of surface texture (micro-dimples) on pressure distribution of journal bearing.

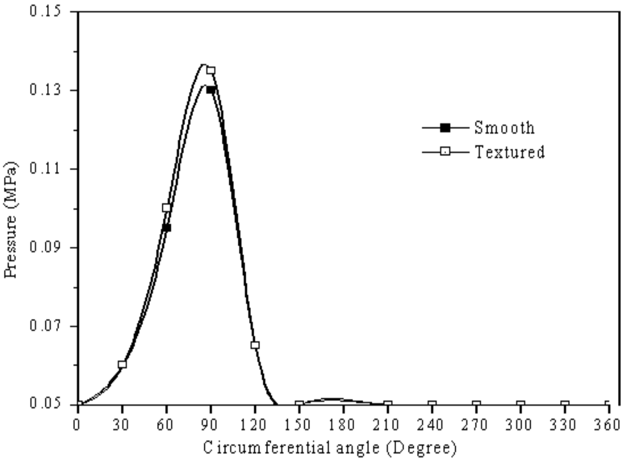

Figure 7 (a): Pressure distribution in the center plane of smooth and textured journal bearing at W= 200 N, N=1000 rpm and Ps = 0.05 MPa

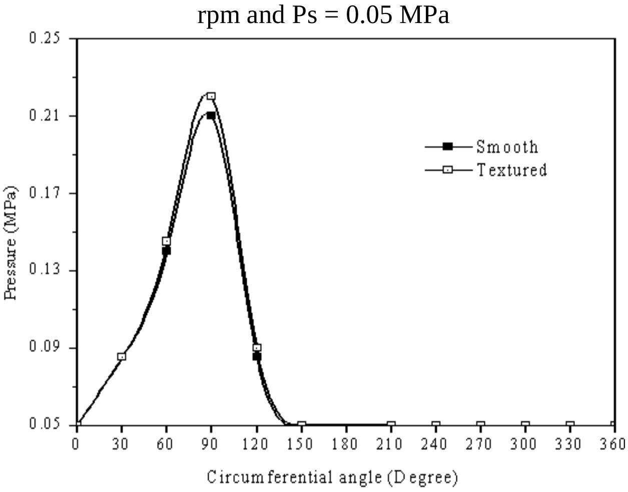

Figure 7 (b): Pressure distribution in the center plane of smooth and textured journal bearing at W= 400 N, N=1000 rpm and Ps = 0.05 MPa.

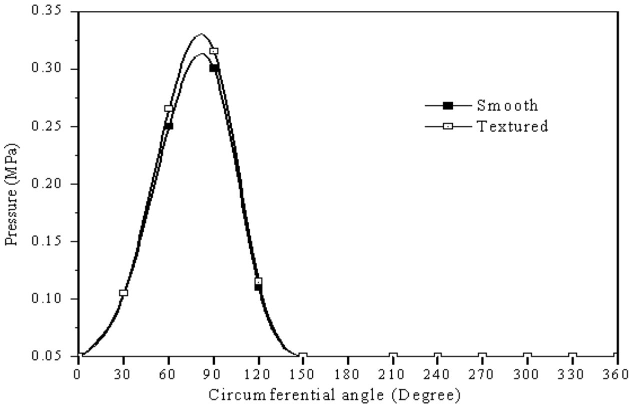

Figure 7 (c): Pressure distribution in the center plane of smooth and textured journal bearing at W= 600 N, N=1000 rpm and Ps = 0.05 MPa.

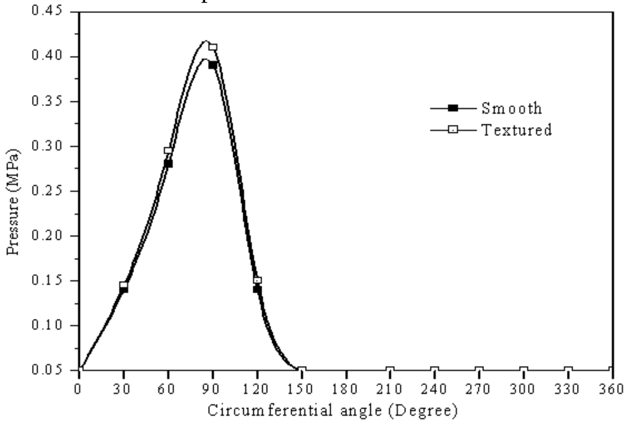

Figure 7 (d): Pressure distribution in the center plane of smooth and textured journal bearing at W= 800 N, N=1000 rpm and Ps = 0.05 MPa.

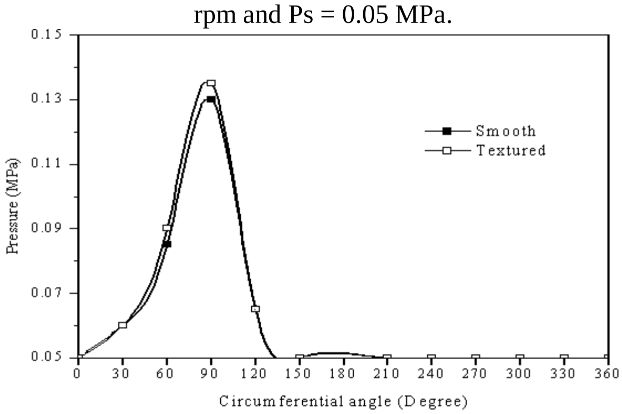

Figure 8 (a): Pressure distribution in the center plane of smooth and textured journal bearing at W= 200 N, N=2000 rpm and Ps = 0.05 MPa.

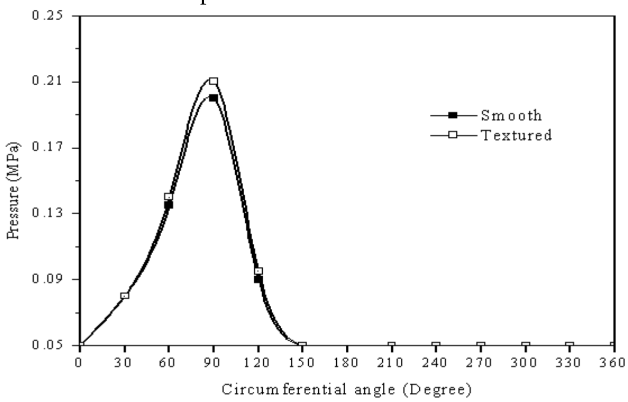

Figure 8 (b): Pressure distribution in the center plane of smooth and textured journal bearing at W= 400 N, N=2000 rpm and Ps = 0.05 MPa.

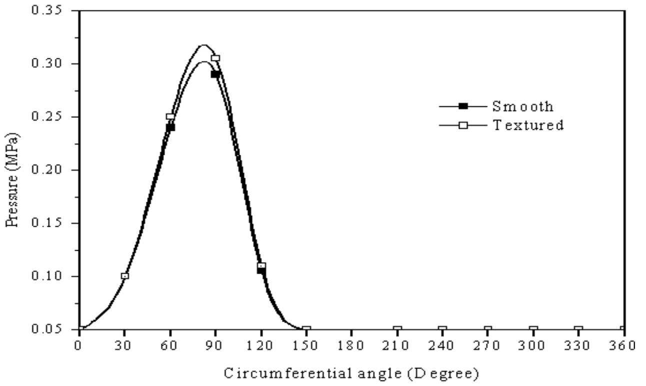

Figure 8 (c): Pressure distribution in the center plane of smooth and textured journal bearing at W= 600 N, N=2000 rpm and Ps = 0.05 MPa

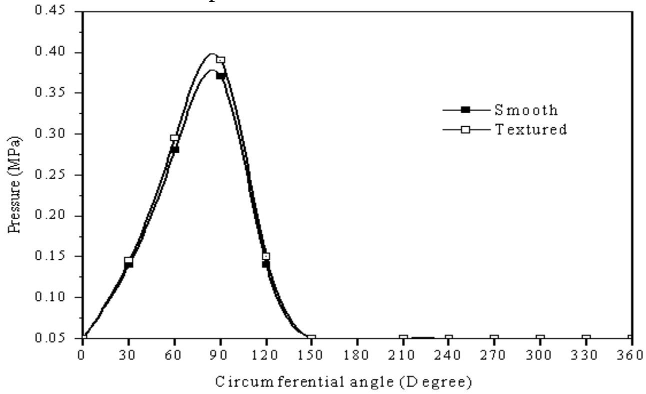

Figure 8 (d): Pressure distribution in the center plane of smooth and textured journal bearing at W= 800 N, N=2000 rpm and Ps = 0.05 MPa.

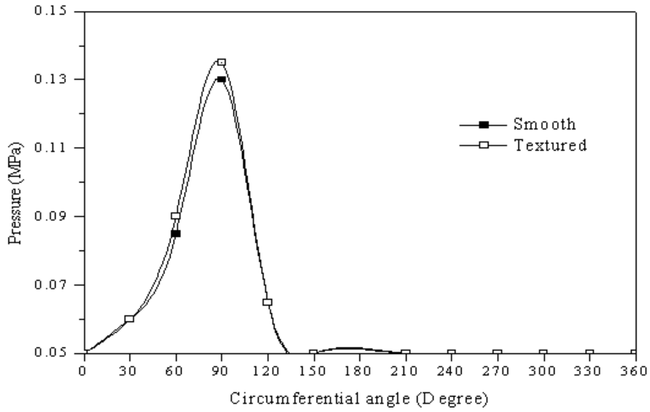

Figure 9 (a): Pressure distribution in the center plane of smooth and textured journal bearing at W= 200 N, N=3000 rpm and Ps = 0.05 MPa.

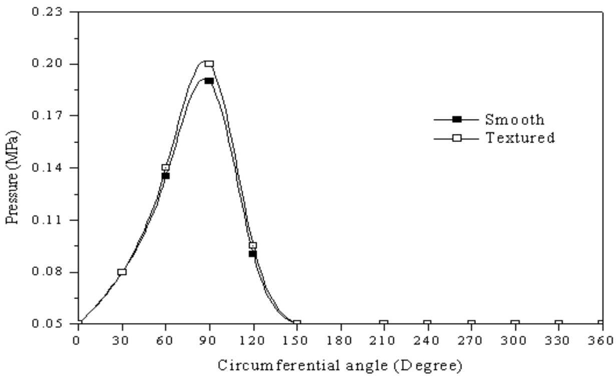

Figure 9 (b): Pressure distribution in the center plane of smooth and textured journal bearing at W= 400 N, N=3000 rpm and Ps = 0.05 MPa.

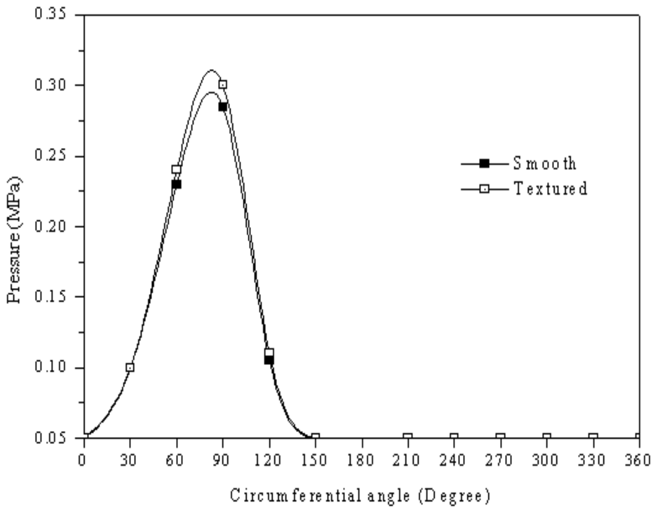

Figure 9 (c): Pressure distribution in the center plane of smooth and textured journal bearing at W= 600 N, N=3000 rpm and Ps = 0.05 MPa.

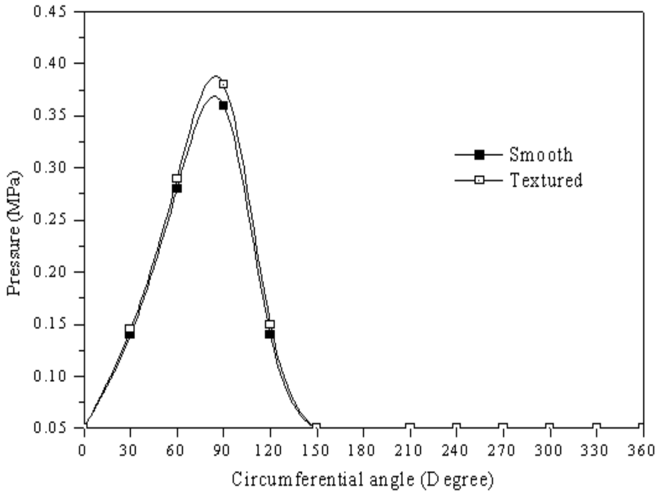

Figure 9 (d): Pressure distribution in the center plane of smooth and textured journal bearing at W= 800 N, N=3000 rpm and Ps = 0.05 MPa.

It is observed that-

1. Figure 7 (a, b, c and d) show that pressure distribution in smooth and textured journal bearing at different loads and speed 1000 rpm. From the Fig. 7 (a, b, c and d) it is observed that maximum pressure is increased in textured journal bearing as compared to smooth journal bearing because in hydrodynamic lubrication regime surface textures (micro-dimples) act as a micro-reservoirs of oil and due to inertia of lubricant asymmetric pressure distribution in the dimple area generates extra hydrodynamic pressure to separate the surface. Maximum pressure (Pmax) obtained in textured journal bearing for N=1000 rpm and W=200 N is 0.135 MPa and maximum pressure increased by about 3.85% for textured journal bearing w.r.t to smooth journal bearing. The maximum pressure found in texture journal bearing for N=1000 rpm and W= 400 N is 0.22 MPa and maximum pressure increased by 4.76% w.r.t to smooth journal bearing. Moreover maximum pressure increased in texture journal for N=1000 rpm and W=600N is 0.315 MPa and maximum pressure increased by 5 % w.r.t to smooth journal bearing. It can be seen that maximum pressure increases by 5.12% w.r.t to smooth journal bearing for N=1000 rpm and W=800N.
2. Figure 8 (a, b, c and d) show that pressure distribution in smooth and textured journal bearing at different loads and speed 2000 rpm. From Fig. 8 (a, b, c and d) it is observed that maximum pressure in textured journal bearing for N=2000 rpm and W=200 N is 0.135 MPa and maximum pressure increased by about 3.85% for textured journal bearing w.r.t to smooth journal bearing. The maximum pressure found in texture journal bearing for N=2000 rpm and W= 400 N by 0.210 MPa and maximum pressure increased by 5% w.r.t to smooth journal bearing. It can be seen that the maximum pressure in texture journal bearing for N=2000 rpm and W=600 N is 0.305 MPa and maximum pressure increased by 5.17 % w.r.t to smooth journal bearing. Maximum pressure increases by about 5.41 % w.r.t to smooth journal bearing for N=2000 rpm and W=800 N.
3. Figure 9 (a, b, c and d) show that pressure distribution in smooth and textured journal bearing at different loads and speed 2000 rpm. From Fig. 9 (a, b, c and d) maximum pressure obtained in textured journal bearing for N=3000 rpm and W=200 N is 0.135 MPa and maximum pressure increased by about 3.85 % for textured journal bearing w.r.t to smooth journal bearing. The maximum pressure found in texture journal bearing for N=3000 rpm and W=400 N is 0.200 MPa and maximum pressure increased by 5.26 % w.r.t to smooth journal bearing. Moreover the maximum pressure increased in texture journal bearing for N= 3000 rpm and W= 600 N is 0.300 MPa and maximum pressure increased by 5.26 % w.r.t to smooth journal bearing. Maximum pressure increases by about 5.55 % w.r.t to smooth journal bearing for N= 3000rpm and W= 800 N.

VII. CONCLUSIONS

On the basis of the investigation following conclusions have been drawn:

1 Experiment shows that the textured surface affected the journal bearing performance. It is observed that pressure increases more in textured journal bearing as compared to smooth journal bearing. With the increase of loads (200N to 800N) at constant speed and constant oil supply pressure (0.05 MPa), percentage increased of maximum pressure (% Pmax) is more in textured journal bearing w.r.t smooth journal.

2 With the increase of speeds (1000 rpm to 3000 rpm) at constant load and constant oil supply pressure (0.05 MPa), percentage increased of maximum pressure more in textured journal bearing w.r.t smooth journal bearing. It is concluded that influences of surface textures are affected by speed variation.

3 Experiment also shows that the surface textures (micro-dimples) are more effective in converging zone of bearing.

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