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An Experimental Study Of Effect Of Speed Variation On The Performance Of Fluid Film Journal Bearing System

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ABSTRACT

The objective of this work is to highlight the influence on performance and useful life of bearing under the varying journal speeds. When a journal bearing operates in hydrodynamic regime of lubrication, a hydrodynamic film develops. Under these conditions conformal surface are fully separated and a copious flow lubricant is provided to prevent overheating. In these circumstances of complete separation, mechanical wear does not take place. However, this ideal situation is not always achieved. Hydrodynamic (Full Film) Lubrication is obtained when two mating surfaces are completely separated by a cohesive film of lubricant. The thickness of the film thus exceeds the combined roughness of the surfaces. Contact may occur at the instant or starting (before the hydrodynamic film is developed between two contacting surfaces), the bearing may be overload from time to time. The oil wedge formed in a hydrodynamic bearing is a function of speed (RPM), load (cylinder pressure), and oil viscosity (at operating temperature). Under fluid film conditions, an increase in viscosity increases the oil film thickness and the coefficient of friction, while an increase in load decreases them.

Keywords: *hydrodynamic journal bearing, cylinder pressure, oil viscosity, coefficient of friction, oil film thickness.*

I. Introduction

The main function of a rotating shaft is to transmit power from one end of the line to the other. It needs support for stability and frictionless rotation known as “bearing”. The shaft has a “running fit” in a bearing. All bearing are provided some lubrication arrangement to reduce friction between shaft and bearing. Fluid bearings use a thin layer of liquid or gas fluid between the bearing faces, typically sealed around or under the rotating shaft.

There are two principal ways of getting the fluid into the bearing:

- In fluid static, hydrostatic and many gas or air bearings, the fluid is pumped in through an orifice or through a porous material.
- In fluid-dynamic bearings, the bearing rotation sucks the fluid on to the inner surface of the bearing, forming a lubricating wedge under or around the shaft.

Hydrostatic bearings: It relies on an external pump. The power required by that pump contributes to system energy loss just as bearing friction otherwise would. Better seals can reduce leak rates and pumping power, but may increase friction.

Hydrodynamic bearings: It relies on bearing motion to suck fluid into the bearing and may have high friction and short life at speeds lower than design or during starts and stops. An external pump or secondary bearing may be used for startup and shutdown to prevent damage to the hydrodynamic bearing. A secondary bearing may have high friction and short operating life, but good overall service life if bearing starts and stops are infrequent [3].

1.2 Bearing design

1.2.1 Type of bearing First we have to specify or select the type of bearing depending upon the type of load or application of load

1.2.2 Material Selection of the material depends upon the limit of the load. For lighter loads we can use even plastic bearings and for heavy application there is a requirement of more rigid material which will bear the various types of stresses without failure. Some of the commonly used bearing materials are Babbitt Metal, Tin Aluminum, Lead Bronzes, Overlay, Flash Layer, and Tri-Metal Bearings. [2]

1.2.3 Lubrication Thin low shear strength layers of gas, liquid and solid layers of material separate contacting solid bodies and are usually very thin and often difficult to observe. In general, the thicknesses of these films range from **1 – 100** [μm], although thinner and thicker films can also be found. Knowledge that is related to enhancing or diagnosing the effectiveness of these films in preventing damage in solid contacts is commonly known as ‘**lubrication**’. [1] Detailed analysis of gaseous or liquid films is usually termed ‘**hydrodynamic lubrication**’ while lubrication by solids is termed ‘**solid lubrication**’. A specialized form of hydrodynamic lubrication involving physical interaction between the contacting bodies and the liquid lubricant is termed ‘**elastohydrodynamic lubrication**’ and is of considerable practical significance. Another form of lubrication involves the chemical interactions between contacting bodies and the liquid lubricant and is termed ‘**boundary lubrication**’. [9] In the absence of any films, the only reliable means of ensuring relative movement is to maintain, by external force fields, a small distance of separation between the opposing surfaces. A form of lubrication that operates by the same principle, i.e. forcible separation of the contacting bodies involving an external energy source, is '**hydrostatic lubrication**' where liquid or gaseous lubricant is forced into the space between contacting surfaces.

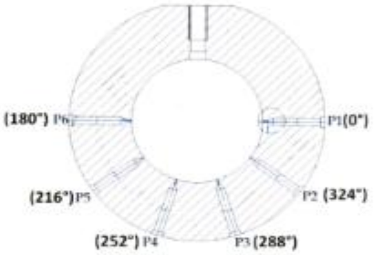
1.3 Effect of Speed and Load on Bearing Friction [7]

The primary requirement for hydrodynamic lubrication (oil wedge) is that oil of correct viscosity and sufficient quantity be present at all times to flood the clearance spaces. The oil wedge formed in a hydrodynamic bearing is a function of speed (RPM), load (cylinder pressure), and oil viscosity (at operating temperature). Under fluid film conditions, an increase in viscosity or speed increases the oil film thickness and the coefficient of friction, while an increase in load decreases them. The separate consideration of these effects presents a complex picture that is simplified by combining viscosity Z, speed N, and unit load P, into a single dimensionless factor called the ZN/P factor. Although no simple equation can be offered that expresses the coefficient of friction in terms of ZN/P. A similar type curve could be developed experimentally for any fluid film bearing.

Good practice is to design with a reasonable factor of safety so that the operating value of ZN/P is in the required value limits. The ratio of the operating ZN/P to the value of ZN/P for the minimum coefficient of friction is called the bearing safety factor. Common practice is to use a bearing safety factor on the order of 5.In an operating bearing, if it becomes necessary to increase speed, ZN/P will increase and it may be necessary to decrease oil viscosity to keep ZN/P and the coefficient of friction in the design range. An increase in load will result in a decrease in ZN/P, and it may be necessary to increase the oil viscosity to keep ZN/P and the coefficient of friction in the design range. In general, film thickness increases if ZN/P is increased -- for example, if the load is reduced while the oil viscosity and journal speed remain constant. With a proper bearing safety factor, the film thickness will be such that normal variation in speed, load and oil viscosity will not result in the reduction of film thickness to the point at which metal-to-metal contact will occur.

2. Description of equipment and Methodology

The experimentation work has been performed on a 'DUCOM' made journal bearing test rig. An aluminum bearing of 80 mm diameter with aspect ratio (L/D) =0.5 has been chosen for experimentation. The test rig unit includes the test bearing, housing with seal ring covers, oil splash guard (surrounding the housing) shaft (journal), supporting bearings (inside housing) and a loading arm. The rotating shaft (journal) is supported horizontally on self-aligned bearings with negligible bearing play inside the housing mounted on the base plate; the journal is rotated by AC motor with timer belt having 1:2 pulley ratios to increase the motor base speed to achieve 3000 rpm. The manifold plate is tightened to the front face bearing and 6 no's of pressure sensors are mounted at 36^{o} apart covering the lower half of the bearing, the cable ends of sensors are terminated over the splash guard A rectangular loading bracket is suspended vertically from the loading lever with the cut out at the middle of bracket positioned on the outer dia of test bearing. The vertical bracket is pulled upwards by a roller chain to apply force on bearing. To create hydrodynamic condition during rotation, between shaft and test bearing, oil is pumped to contact area from the top of bearing through a re-circulating lubrication unit. [3]



3. Experimentation & Results

A complete set of readings are being taken with discussed equipment maintaining a constant watch on various properties and parameters of the lubricant fluid. The various pressure variations instigated in the journal bearing system during the accomplishment of hydrodynamic regime are visualized and analyzed.

The parameters which are taken in account and made constant are shown below

- Inlet pressure
- Inlet temperature
- Bearing material (aluminum)

The parameters which are varied during the test for analyzing the properties are shown below:

- Load (in kgs)
- Journal speed (in rpm)

The parameters which are taken as result of the testing are given below:

- Film thickness
- Outlet temperature
- Individual pressures measured by the 6 pressure sensors mounted circumferentially on the lower half of the bearing at an angle distance of 36^{o}

While maintaining lubricant inlet pressure at two constant values i.e. 4 bars and 6 bars different readings are taken at varying loads and speeds shown in the tabulated form.

Table 1: Pressure 4 Bar

Constant RPM 500

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
500	**500**	**-8**	**-29**	**0.2**	**1.0**	**2.6**	**5.1**	**-0.3**	**-0.0**	**58**	**35**
500	**700**	**-9**	**-32**	**0.3**	**1.2**	**3.7**	**7.0**	**-0.3**	**-0.0**	**57**	**32**
500	**900**	**-9**	**-33**	**0.3**	**1.5**	**4.9**	**9.2**	**-0.3**	**-0.0**	**55**	**32**
500	**1100**	**-12**	**-35**	**0.4**	**1.8**	**6.2**	**11.4**	**-0.3**	**-0.0**	**52**	**33**
500	**1300**	**-15**	**-38**	**0.4**	**2.0**	**7.4**	**13.5**	**-0.2**	**-0.0**	**50**	**30**
500	**1500**	**-15**	**-40**	**0.4**	**2.0**	**7.5**	**14.6**	**-0.2**	**-0.0**	**49**	**30**
500	**1700**	**-21**	**-48**	**0.5**	**2.6**	**10.6**	**18.4**	**-0.2**	**-0.0**	**43**	**29**
500	**1900**	**-25**	**-51**	**0.5**	**2.8**	**11.4**	**19.5**	**-0.2**	**-0.0**	**39**	**28**
500	**2100**	**-44**	**-59**	**0.4**	**3.1**	**12.6**	**20.8**	**-0.4**	**-0.0**	**30**	**28**
500	**2300**	**-48**	**-66**	**0.4**	**3.4**	**14.2**	**22.7**	**-0.4**	**-0.0**	**23**	**28**
500	**2500**	**-52**	**-68**	**0.4**	**3.6**	**15.8**	**24.2**	**-0.4**	**-0.1**	**18**	**28**
500	**2700**	**-59**	**-69**	**0.4**	**3.8**	**17.2**	**25.6**	**-0.4**	**-0.1**	**15**	**28**
500	**2900**	**-62**	**-77**	**0.4**	**4.2**	**19.0**	**26.9**	**-0.5**	**-0.1**	**9**	**29**

Constant RPM 1000

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
1000	**500**	**-14**	**-32**	**0.5**	**1.3**	**2.5**	**4.5**	**0.7**	**0.0**	**53**	**36**
1000	**700**	**-20**	**-44**	**0.5**	**1.6**	**3.6**	**6.7**	**0.2**	**0.0**	**49**	**38**
1000	**900**	**-25**	**-50**	**0.5**	**1.8**	**4.8**	**8.9**	**0.1**	**0.0**	**41**	**38**
1000	**1100**	**-25**	**-54**	**0.5**	**2.0**	**6.1**	**11.2**	**0.1**	**0.0**	**37**	**38**
1000	**1300**	**-31**	**-57**	**0.6**	**2.2**	**7.3**	**13.6**	**0.0**	**0.0**	**33**	**39**
1000	**1500**	**-35**	**-59**	**0.6**	**2.4**	**8.6**	**15.8**	**0.0**	**0.0**	**30**	**39**
1000	**1700**	**-41**	**-63**	**0.6**	**2.7**	**9.9**	**17.9**	**0.0**	**0.0**	**27**	**39**
1000	**1900**	**-46**	**-66**	**0.6**	**2.9**	**11.2**	**19.9**	**0.0**	**0.0**	**24**	**40**
1000	**2100**	**-53**	**-70**	**0.6**	**3.1**	**12.6**	**21.7**	**0.0**	**0.0**	**21**	**40**
1000	**2300**	**-54**	**-73**	**0.7**	**3.4**	**14.0**	**23.4**	**0.0**	**0.0**	**16**	**40**
1000	**2500**	**-59**	**-76**	**0.7**	**3.7**	**15.6**	**24.8**	**0.0**	**0.0**	**11**	**40**
1000	**2700**	**-62**	**-80**	**0.7**	**3.9**	**17.0**	**26.1**	**0.0**	**0.0**	**5**	**40**
1000	**2900**	**-71**	**-85**	**0.7**	**4.2**	**18.9**	**27.8**	**0.0**	**0.0**	**-2**	**40**

Constant RPM 1500

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
1500	**500**	**-6**	**-33**	**0.3**	**1.1**	**2.3**	**4.2**	**0.5**	**-0.1**	**55**	**43**
1500	**700**	**-12**	**-41**	**0.4**	**1.4**	**3.4**	**6.3**	**0.0**	**-0.1**	**49**	**43**
1500	**900**	**-18**	**-50**	**0.4**	**1.6**	**4.7**	**8.7**	**-0.3**	**-0.1**	**43**	**44**
1500	**1100**	**-22**	**-55**	**0.4**	**1.9**	**5.9**	**11.1**	**-0.3**	**0.0**	**39**	**44**
1500	**1300**	**-29**	**-58**	**0.5**	**2.1**	**7.2**	**13.6**	**-0.3**	**0.0**	**34**	**44**
1500	**1500**	**-34**	**-60**	**0.5**	**2.3**	**8.5**	**15.7**	**-0.2**	**0.0**	**29**	**45**

1500	**1700**	**-40**	**-63**	**0.5**	**2.6**	**9.8**	**18.0**	**-0.2**	**0.0**	**25**	**46**
1500	**1900**	**-47**	**-71**	**0.3**	**2.7**	**11.6**	**20.2**	**-0.2**	**0.0**	**19**	**50**
1500	**2100**	**-52**	**-75**	**0.3**	**2.9**	**13.1**	**22.1**	**-0.2**	**0.0**	**15**	**52**
1500	**2300**	**-57**	**-78**	**0.4**	**3.2**	**14.4**	**23.7**	**-0.2**	**0.0**	**11**	**52**
1500	**2500**	**-62**	**-83**	**0.4**	**3.4**	**16.0**	**25.2**	**-0.2**	**0.0**	**7**	**53**
1500	**2700**	**-70**	**-89**	**0.4**	**3.9**	**17.3**	**25.9**	**-0.2**	**0.0**	**2**	**54**
1500	**2900**	**-75**	**-91**	**0.5**	**4.3**	**19.1**	**27.3**	**-0.2**	**0.0**	**-3**	**54**

Constant RPM 2000

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
2000	**500**	**-13**	**-38**	**0.3**	**1.2**	**2.3**	**3.9**	**0.7**	**-0.1**	**50**	**44**
2000	**700**	**-21**	**-44**	**0.3**	**1.5**	**3.5**	**6.0**	**-.1**	**-0.0**	**45**	**46**
2000	**900**	**-27**	**-53**	**0.3**	**1.8**	**4.9**	**8.6**	**-0.3**	**-0.0**	**39**	**47**
2000	**1100**	**-32**	**-57**	**0.3**	**2.0**	**6.2**	**11.0**	**-0.3**	**-0.0**	**32**	**48**
2000	**1300**	**-38**	**-61**	**0.3**	**2.2**	**7.4**	**13.4**	**-0.3**	**-0.0**	**29**	**48**
2000	**1500**	**-44**	**-66**	**0.4**	**2.5**	**8.6**	**15.8**	**-0.3**	**0.0**	**24**	**49**
2000	**1700**	**-46**	**-68**	**0.4**	**2.7**	**9.9**	**18.0**	**-0.3**	**0.0**	**19**	**51**
2000	**1900**	**-54**	**-71**	**0.4**	**2.9**	**11.3**	**20.2**	**-0.3**	**-0.0**	**15**	**52**
2000	**2100**	**-59**	**-76**	**0.4**	**3.2**	**12.7**	**22.1**	**-0.3**	**0.0**	**11**	**52**
2000	**2300**	**-65**	**-79**	**0.4**	**3.4**	**14.1**	**23.9**	**-0.3**	**0.0**	**8**	**52**
2000	**2500**	**-66**	**-83**	**0.4**	**3.8**	**15.5**	**25.4**	**-0.3**	**0.0**	**4**	**52**
2000	**2700**	**-74**	**-87**	**0.4**	**3.8**	**17.5**	**26.8**	**-0.3**	**0.0**	**-1**	**55**
2000	**2900**	**-75**	**-91**	**0.4**	**3.9**	**19.7**	**28.1**	**-0.3**	**0.0**	**-4**	**55**

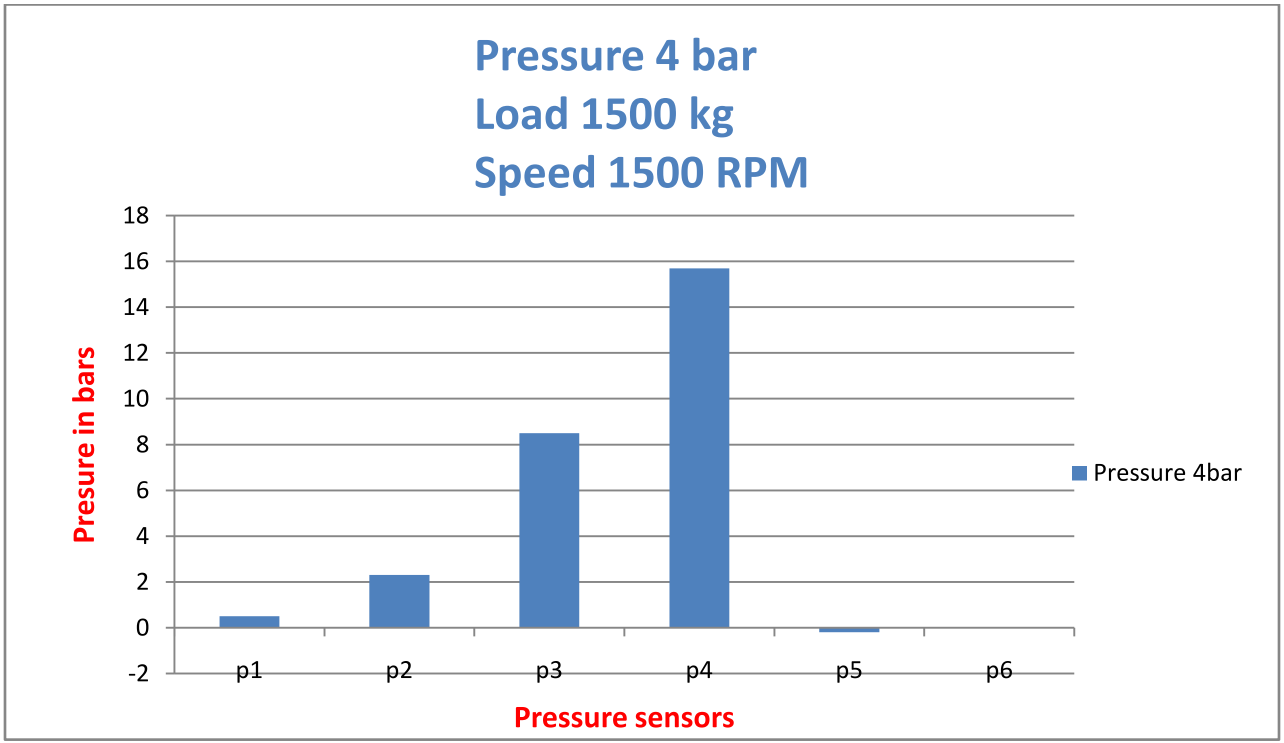
Constant RPM 2500

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
2500	**500**	**-28**	**-58**	**0.1**	**1.1**	**3.1**	**4.9**	**-0.2**	**0.0**	**37**	**54**
2500	**700**	**-37**	**-67**	**0.0**	**1.2**	**4.4**	**7.1**	**-0.2**	**0.0**	**28**	**57**
2500	**900**	**-42**	**-76**	**0.0**	**1.4**	**5.8**	**9.6**	**-0.2**	**0.0**	**19**	**59**
2500	**1100**	**-46**	**-79**	**0.0**	**1.5**	**7.2**	**11.8**	**-0.2**	**0.0**	**14**	**60**
2500	**1300**	**-55**	**-8 2**	**0.0**	**1.7**	**8.5**	**14.4**	**- 0.2**	**0.0**	**9**	**61**
2500	**1500**	**-55**	**-85**	**0.0**	**2.0**	**9.8**	**16.5**	**-0.2**	**0.0**	**6**	**61**
2500	**1700**	**-59**	**-89**	**0.1**	**2.2**	**11.1**	**19.1**	**-0.1**	**0.0**	**3**	**63**
2500	**1900**	**-66**	**-94**	**0.1**	**2.5**	**13.3**	**21.1**	**-0.1**	**0.0**	**0**	**63**
2500	**2100**	**-68**	**-96**	**0.1**	**2.9**	**13.8**	**2.2**	**-0.1**	**0.0**	**-3**	**64**

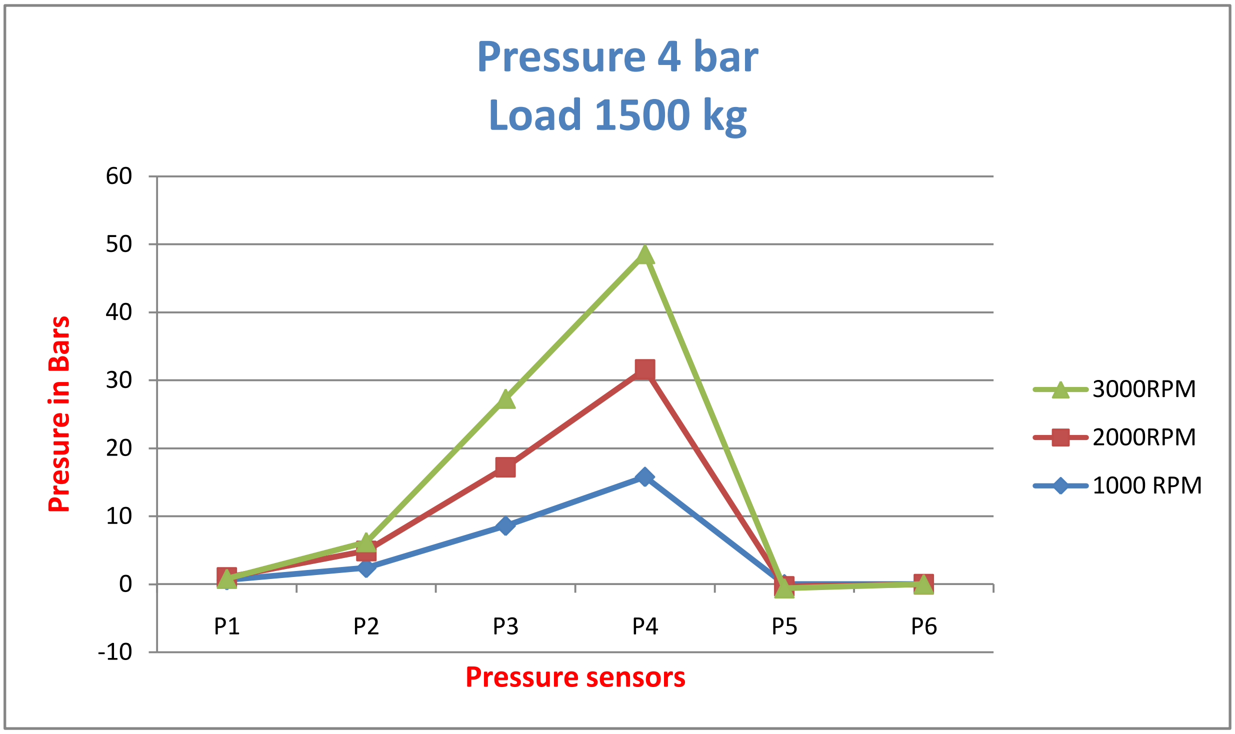
Constant RPM 3000

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
3000	**500**	**-16**	**-47**	**0.0**	**1.1**	**3.9**	**4.5**	**-0.2**	**-0.1**	**44**	**54**
3000	**700**	**-30**	**-56**	**0.0**	**1.3**	**4.2**	**6.9**	**-0.3**	**-0.1**	**34**	**57**

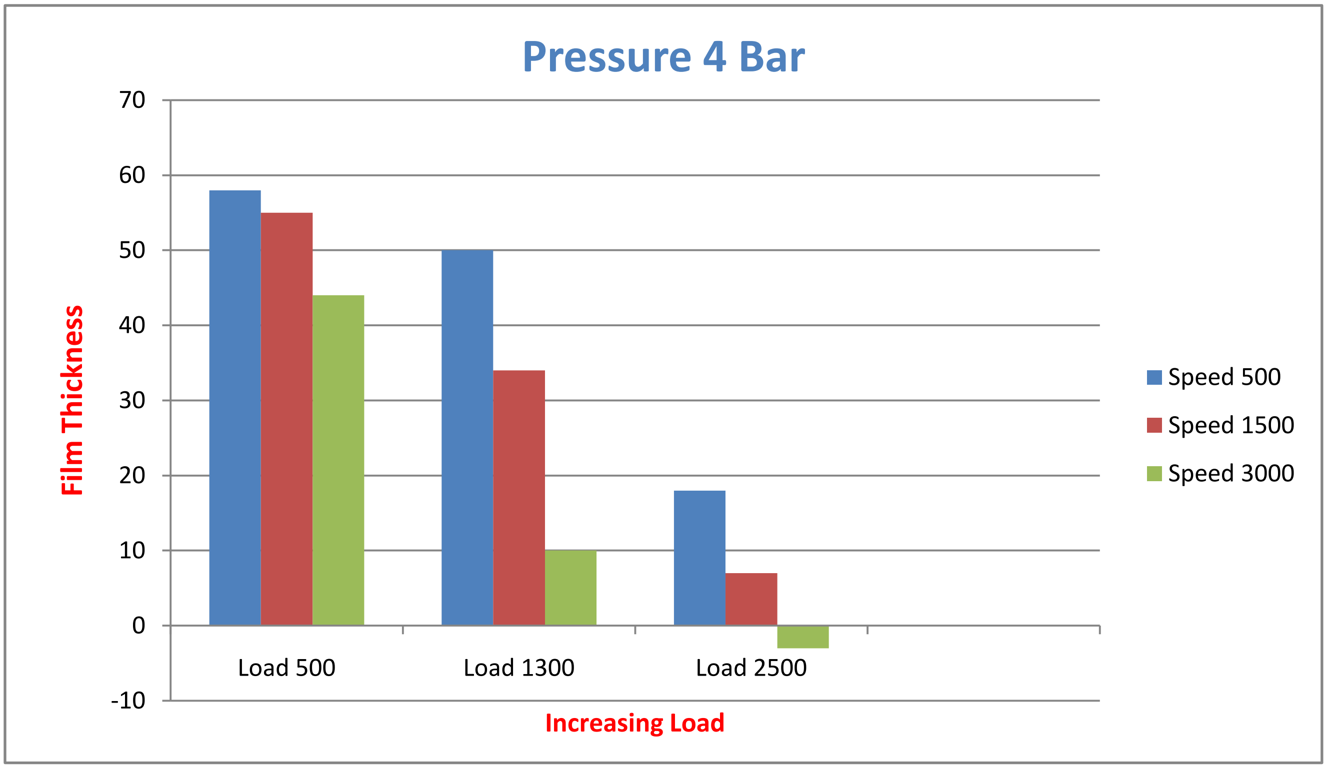
3000	**900**	**-35**	**-66**	**0.0**	**1.5**	**5.6**	**9.3**	**-0.3**	**-0.1**	**27**	**58**
3000	**1100**	**-41**	**-71**	**0.0**	**0.7**	**6.7**	**11.6**	**-0.3**	**-0.1**	**22**	**60**
3000	**1300**	**-47**	**-85**	**-0.2**	**1.2**	**8.8**	**14.5**	**-0.3**	**0.0**	**10**	**64**
3000	**1500**	**-56**	**-92**	**-0.2**	**1.3**	**10.1**	**17.0**	**-0.3**	**0.0**	**04**	**67**
3000	**1700**	**-61**	**-92**	**-0.2**	**1.7**	**11.3**	**19.4**	**-0.3**	**0.0**	**01**	**70**
3000	**1900**	**-68**	**-96**	**-0.2**	**2.0**	**12.9**	**21.7**	**-0.3**	**0.0**	**-3**	**72**



Graph1: Graphical presentation of pressure variation in six pressure sensor, at constant lubricant inlet pressure, load and journal speed



Graph2: Plot showing increase in pressure with varying journal speeds



Graph3: Plot showing decrease in film thickness with increasing journal speeds at constant loads

Table 2: Pressure 6 Bar

Constant RPM 500

Rpm	Load	X	Y	P1	P2	P3	P4	P5	P6	Film thickness	Outlet temp
500	500	-4	-24	0.2	1.0	2.6	4.7	-0.3	0.0	61	26
500	700	-12	-29	0.2	1.3	3.7	6.7	-0.5	0.0	59	26
500	900	-16	-32	0.3	1.5	5.1	9.0	-0.5	0.0	55	26
500	1100	-17	-36	0.3	1.8	6.3	11.2	-0.5	0.0	51	26
500	1300	-23	-36	0.3	2.0	7.5	13.3	-0.5	0.0	49	26
500	1500	-29	-40	0.3	2.2	8.9	15.5	-0.5	0.0	42	27
500	1700	-31	-45	0.3	2.3	10.2	17.7	-0.5	0.0	39	27
500	1900	-38	-48	0.3	2.6	11.6	19.5	-0.5	0.0	36	29
500	2100	-43	-50	0.3	2.8	13.0	21.2	-0.5	0.0	31	29
500	2300	-46	-53	0.3	3.2	14.3	22.5	-0.5	0.0	27	29
500	2500	-49	-54	0.4	3.4	15.7	23.9	-0.5	0.0	24	29
500	2700	-55	-60	0.4	3.6	17.4	25.2	-0.5	0.0	20	30
500	2900	-59	-64	0.4	3.9	18.7	26.2	-0.5	0.0	17	31

Constant RPM 1000

Rpm	Load	X	Y	P1	P2	P3	P4	P5	P6	Film thickness	Outlet temp
1000	500	-6	-24	0.3	1.1	2.8	4.9	-0.0	0.0	63	31
1000	700	-9	-24	0.3	1.3	3.7	6.5	-0.3	0.0	60	31
1000	900	-14	-33	0.3	1.5	4.9	8.9	-0.4	0.0	55	32
1000	1100	-17	-35	0.4	1.8	6.2	11.2	-0.4	0.0	51	32
1000	1300	-22	-39	0.4	2.0	7.3	13.2	-0.4	0.0	47	32
1000	1500	-30	-44	0.4	2.2	8.8	15.8	-0.4	0.0	40	34
1000	1700	-37	-50	0.4	2.3	10.0	17.8	-0.4	0.0	35	35
1000	1900	-39	-51	0.4	2.5	11.2	19.6	-0.4	0.0	31	35
1000	2100	-45	-55	0.5	2.8	12.9	21.7	-0.4	0.0	27	36
1000	2300	-49	-60	0.5	3.1	14.2	23.1	-0.4	0.0	24	36
1000	2500	-55	-64	0.5	3.3	15.7	24.6	-0.4	0.0	19	38
1000	2700	-57	-64	0.5	3.7	17.1	25.6	-0.4	0.0	15	38
1000	2900	-61	-67	0.5	4.0	18.7	26.8	-0.4	0.0	12	38

Constant RPM 1500

Rpm	Load	X	Y	P1	P2	P3	P4	P5	P6	Film thickness	Outlet temp
1500	500	-2	-30	0.3	1.1	2.4	4.2	0.3	-0.0	59	37
1500	700	-10	-35	0.3	1.3	3.5	6.4	-0.3	0.0	52	39
1500	900	-14	-40	0.3	1.6	4.7	8.5	-0.4	0.0	48	40
1500	1100	-25	-52	0.3	1.7	6.0	11.3	-0.4	0.0	38	41
1500	1300	-31	-55	0.3	1.9	7.2	13.7	-0.4	0.0	35	42

1500	**1500**	**-38**	**-60**	**0.4**	**2.1**	**8.5**	**16.1**	**-0.4**	**0.0**	**31**	**43**
1500	**1700**	**-44**	**-63**	**0.4**	**2.3**	**9.8**	**18.2**	**-0.4**	**0.0**	**25**	**45**
1500	**1900**	**-47**	**-65**	**0.4**	**2.5**	**11.2**	**20.2**	**-0.4**	**0.0**	**21**	**47**
1500	**2100**	**-52**	**-69**	**0.4**	**2.7**	**12.7**	**21.9**	**-0.4**	**0.0**	**17**	**48**
1500	**2300**	**-58**	**-75**	**0.4**	**3.0**	**14.2**	**23.6**	**-0.4**	**0.0**	**13**	**50**
1500	**2500**	**-63**	**-77**	**0.4**	**3.1**	**15.8**	**25.0**	**-0.4**	**0.0**	**8**	**51**
1500	**2700**	**-66**	**-81**	**0.5**	**3.5**	**17.0**	**25.9**	**-0.4**	**0.0**	**3**	**52**
1500	**2900**	**-74**	**-91**	**0.5**	**3.5**	**19.2**	**27.3**	**-0.4**	**0.0**	**-2**	**53**

Constant RPM 2000

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
2000	**500**	**-10**	**-48**	**0.3**	**1.2**	**2.4**	**4.2**	**0.8**	**-0.0**	**44**	**39**
2000	**700**	**-18**	**-55**	**0.3**	**1.5**	**3.6**	**6.5**	**0.1**	**-0.0**	**39**	**42**
2000	**900**	**-24**	**-61**	**0.4**	**1.8**	**4.8**	**8.8**	**-0.3**	**-0.0**	**32**	**42**
2000	**1100**	**-28**	**-64**	**0.4**	**2.0**	**5.9**	**11.0**	**-0.4**	**-0.0**	**29**	**42**
2000	**1300**	**-33**	**-68**	**0.4**	**2.2**	**7.1**	**13.5**	**-0.4**	**-0.0**	**24**	**43**
2000	**1500**	**-43**	**-72**	**0.4**	**2.3**	**8.4**	**16.1**	**-0.4**	**0.0**	**19**	**45**
2000	**1700**	**-49**	**-76**	**0.4**	**2.6**	**9.7**	**18.4**	**-0.4**	**0.0**	**15**	**47**
2000	**1900**	**-52**	**-81**	**0.5**	**2.8**	**11.0**	**20.3**	**-0.4**	**0.0**	**12**	**49**
2000	**2100**	**-61**	**-83**	**0.5**	**3.0**	**12.6**	**22.6**	**-0.3**	**0.0**	**7**	**50**
2000	**2300**	**-64**	**-85**	**0.5**	**3.3**	**13.8**	**23.9**	**-0.3**	**0.0**	**3**	**50**
2000	**2500**	**-69**	**-91**	**0.5**	**3.6**	**15.6**	**25.8**	**-0.3**	**0.0**	**-2**	**51**
2000	**2700**	**-72**	**-95**	**0.5**	**3.7**	**17.2**	**27.2**	**-0.3**	**0.0**	**-4**	**51**
2000	**2900**	**-77**	**-97**	**0.5**	**3.9**	**19.3**	**29.5**	**-0.3**	**0.0**	**-7**	**52**

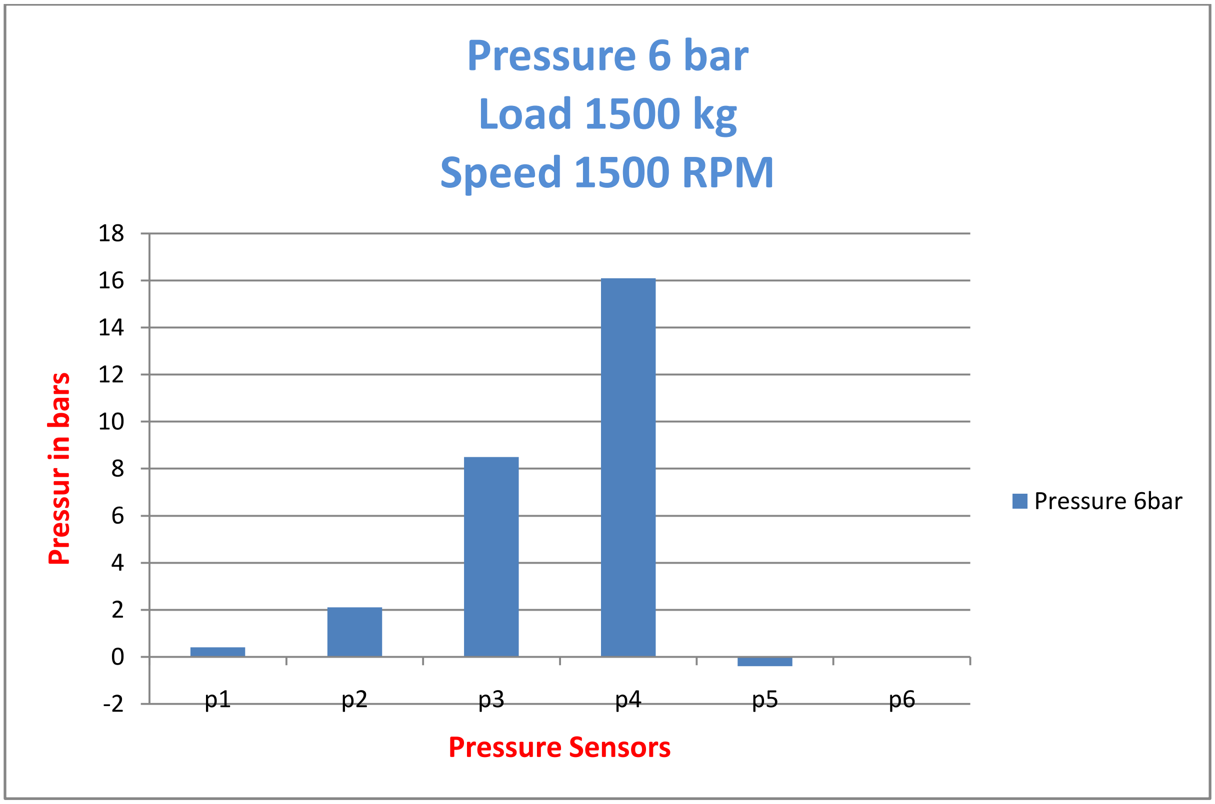
Constant RPM 2500

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
2500	**500**	**2**	**-31**	**0.3**	**1.2**	**2.5**	**4.3**	**0.5**	**0.0**	**58**	**47**
2500	**700**	**-2**	**-37**	**0.4**	**1.4**	**3.6**	**6.4**	**-0.1**	**0.0**	**54**	**49**
2500	**900**	**-10**	**-43**	**0.4**	**1.7**	**4.7**	**8.7**	**-0.3**	**0.0**	**48**	**49**
2500	**1100**	**-14**	**-50**	**0.5**	**1.9**	**5.9**	**11.1**	**-0.3**	**0.1**	**42**	**50**
2500	**1300**	**-20**	**-54**	**0.5**	**2.1**	**7.1**	**13.6**	**-0.3**	**0.1**	**40**	**50**
2500	**1500**	**-27**	**-55**	**0.5**	**2.4**	**8.4**	**16.0**	**-0.3**	**0.1**	**34**	**50**
2500	**1700**	**-31**	**-59**	**0.6**	**2.6**	**9.6**	**18.2**	**-0.3**	**0.1**	**32**	**51**
2500	**1900**	**-38**	**-60**	**0.6**	**2.9**	**11.0**	**20.4**	**-0.3**	**0.1**	**28**	**52**
2500	**2100**	**-43**	**-65**	**0.6**	**3.1**	**12.2**	**22.2**	**-0.3**	**0.1**	**23**	**52**
2500	**2300**	**-49**	**-72**	**0.6**	**3.4**	**13.7**	**24.1**	**-0.3**	**0.1**	**19**	**53**
2500	**2500**	**-55**	**-75**	**0.6**	**3.6**	**15.1**	**25.6**	**-0.3**	**0.1**	**13**	**54**
2500	**2700**	**-59**	**-80**	**0.7**	**3.9**	**16.6**	**26.8**	**-0.3**	**0.1**	**9**	**54**
2500	**2900**	**-64**	**-82**	**0.7**	**4.1**	**18.1**	**27.8**	**-0.3**	**0.1**	**4**	**54**

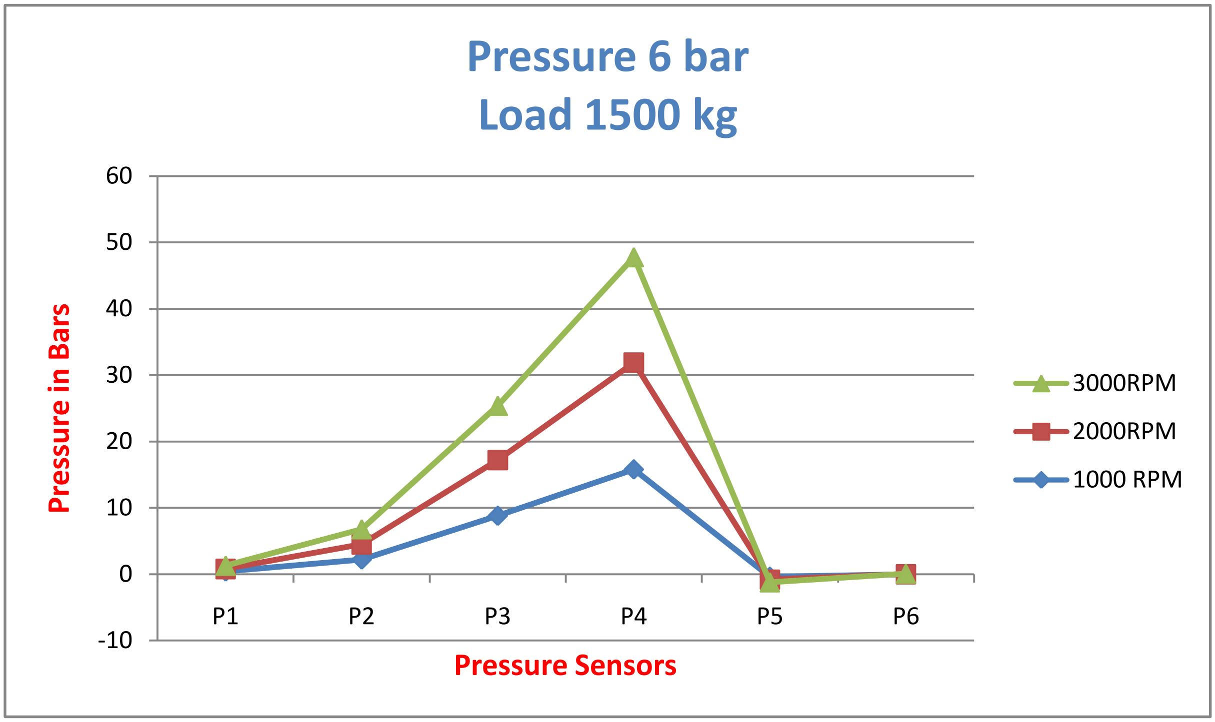
Constant RPM 3000

Rpm	**Load**	**X**	**Y**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Film thickness**	**Outlet temp**
3000	**500**	**-11**	**-25**	**0.4**	**1.2**	**2.4**	**3.8**	**0.8**	**0.0**	**57**	**42**

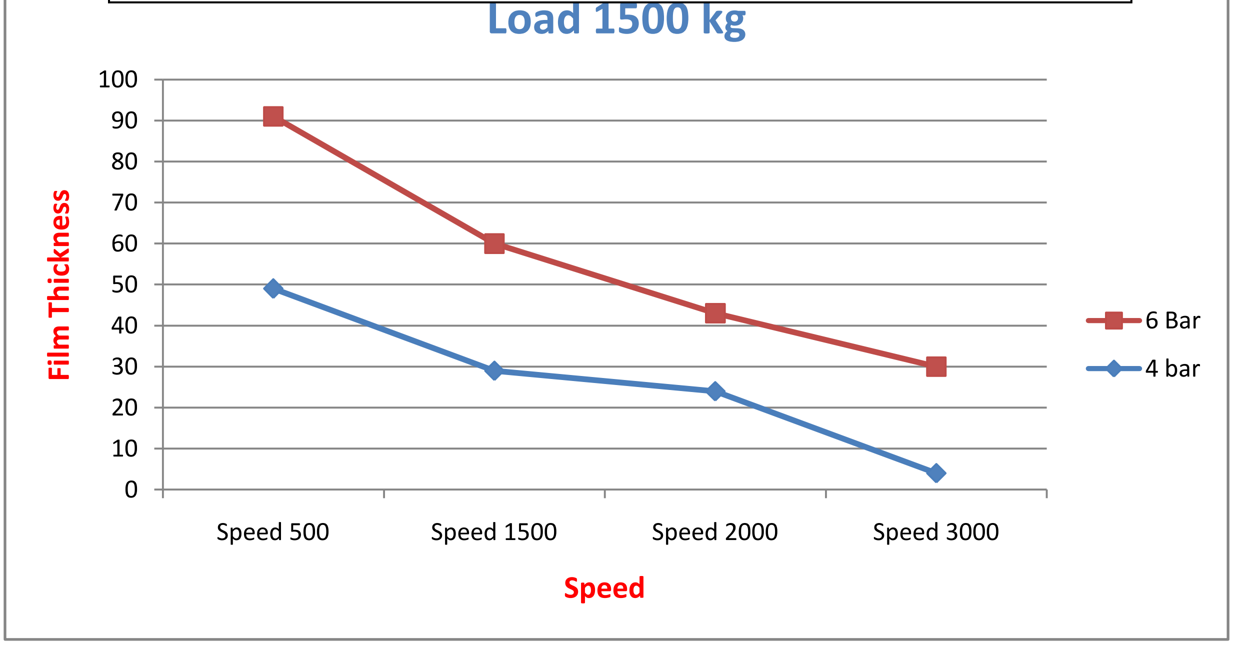
3000	**700**	**-28**	**-38**	**0.4**	**1.5**	**3.5**	**6.1**	**0.0**	**0.1**	**47**	**49**
3000	**900**	**-34**	**-44**	**0.4**	**1.7**	**4.3**	**8.1**	**-0.2**	**0.1**	**40**	**50**
3000	**1100**	**-39**	**-54**	**0.5**	**1.9**	**5.8**	**10.9**	**-0.4**	**0.1**	**34**	**52**
3000	**1300**	**-43**	**-59**	**0.5**	**2.2**	**7.1**	**13.6**	**-0.4**	**0.1**	**29**	**53**
3000	**1500**	**-48**	**-58**	**0.5**	**2.3**	**8.2**	**15.9**	**-0.4**	**0.1**	**26**	**53**
3000	**1700**	**-55**	**-63**	**0.6**	**2.6**	**9.5**	**18.2**	**-0.4**	**0.1**	**21**	**54**
3000	**1900**	**-60**	**-64**	**0.6**	**2.8**	**10.7**	**20.3**	**-0.4**	**0.1**	**18**	**54**
3000	**2100**	**-65**	**-70**	**0.6**	**3.1**	**12.0**	**22.3**	**-0.4**	**0.1**	**12**	**55**
3000	**2300**	**-70**	**-75**	**0.7**	**3.3**	**13.4**	**24.1**	**-0.4**	**0.1**	**7**	**56**
3000	**2500**	**-75**	**-78**	**0.7**	**3.6**	**14.9**	**25.7**	**-0.4**	**0.1**	**2**	**56**
3000	**2700**	**-79**	**-83**	**0.7**	**3.9**	**16.4**	**27**	**-0.4**	**0.1**	**-2**	**57**



Graph4: Graphical presentation of pressure variation in six sensors at constant lubricant inlet pressure, load and journal speed



Graph5: Plot showing increase in pressure with varying journal speeds



Graph6: Plot showing patterns of decrease in film thickness at different lubricant inlet pressures at constant load and increasing speed

4. Discussion and conclusion

- From Graph 2: it is observed that maximum pressure in journal bearing system increases with increase in speed while maintaining all other parameters at constant value i.e. lubricant inlet pressure (4 bars), load (1500 kg). variation taken in speed is in interval of 1000 rpm i.e. 1000, 2000,3000 rpm
- It has been observed that with the increase in speed the bearing pressure also increases. The pressure is measured by the six sensors and the maximum pressure was found at P4 which is at an angle of 252^o from positive X-axis
- From Graph 3: it is observed that film thickness decreases with increase in speed while maintaining all other parameters at constant value in plotted graph it is apparent that even if speed is increased with value 500,1500,3000 rpm at different constant loads 500, 1500, 2500 kg the film thickness is decreasing
- From Graph 5: it is construed that at 6 bars lubricant inlet pressures there is maximum value of pressure at P4 sensor. It has been observed that with increase in speed the pressure value increases. Comparing to 4 bar plot (Graph 3) these pressure variation are quite similar hence it can be concluded that inlet pressure plays a lesser role in altering the generation of maximum pressure at journal bearing interface than the journal speed.
- From Graph 6: this is a plot observed between the film thicknesses v/s varied inlet lubricant pressures at constant load of 1500 kg. At journal speed of 500 rpm and 4 bar lubricant inlet pressure the value of film thickness is lowest, at inlet pressure of 6 bar there is a slight increase in the film thickness and at pressure of 8 bar it further increases and at a journal speed of 1500 rpm the film thickness decrease abruptly as compared to that of 500 rpm. Then the value increases with increase in pressure. Similarly the film thickness decreases at very high speed of 3000 rpm and goes on increasing gradually with increase in pressure

5. Future Scope

In this testing we have graphically proved the variation of maximum pressure at journal bearing interface and film thickness with variation of load & speed. However these variations are not linearly proportional to the variation of load and speed. So a mathematical formulation can be developed in order to find these variations analytically.

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