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Experimental Evaluation of the Effect of Oil Supply Pressure related to Marine Slow Speed Diesel Engine on Oil Film Pressure and Temperature Profiles within Journal Bearing

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ABSTRACT

Marine journal bearing is so often subject to the risk resulting from the loss of lubricating oil pressure, which negatively affects its performance. The inevitable result of such a condition is the complete failure of the main journal bearing of marine slow speed diesel engine. The study at hand introduces an experimental investigation aiming at better identifying the impact of oil supply pressure in relation to the pressure and temperature distribution within circumferential grooved bearing. Test trials have involved tracing those two critical profiles in case of optimal supply pressure as well as when it is either decreased or increased by 25%. The experimental procedures have also extended to cover the influence of two different oil grades on the outcomes derived for the previously mentioned operational conditions. All of the conducted experimental test trials were carried out with observation to the loading program of marine slow speed diesel engine involving different speeds and loads. It was concluded that maximum oil film pressure is seriously affected when oil supply pressure is decreased especially under high loads. In regard to the oil film temperature profile, it was observed that it is slightly affected under such operational conditions in which speeds are slow and range from 32 rpm up to 102 rpm.

Keywords: Hydrodynamic Lubrication, Grooved Bearing, Oil Supply Pressure, SCADA System, Marine Diesel Engine.

1. INTRODUCTION

Operation of main journal bearings related to marine slow speed diesel engines is considerably affected by the oil film lubrication. The function of the oil supply pressure is to continuously deliver sufficient quantity of lubricating oil to the journal bearing. Effective feeding of the lubricating oil ensures the reduction of friction losses, power consumption and journal bearing wear. Oil supply pressure is mainly determined according to the working conditions of journal bearings. If the oil supply pressure is poor or stopped, the failure of journal bearing is the inevitable consequence. In such a condition, the possibility of metal-to-metal contact between journal shaft and stationary bearing rises and leads to seizure. Consequently, misalignment occurs between the crankshaft of marine diesel engine and the shafting system related to the propulsion system of the ship. Further, the ship navigation will not be safe and the final negative results will be represented in the ship becoming off hire with very high incurred maintenance costs. Several research studies have investigated the impacts of oil supply pressure in regard to the performance of journal bearing.

Costa et al. [1], Brito.et al [2] and Ahmad et al. [3] investigated the impacts of oil supply on journal bearing performance, utilizing thermo-hydrodynamic analysis and a mass-conserving cavitation model with realistic supply conditions. Costa. et al [1] determined the oil film and bush temperature. Sensitivity of power loss, maximum bush temperature and minimum film thickness to oil supply temperature was demonstrated. Brito et al. [2] introduced experimental study concerning the influence of oil supply temperature and pressure on the performance of a hydrodynamic plain journal bearing with two axial grooves. It was concluded that oil flow rate, shaft eccentricity and maximum temperature could be increased by increasing supply pressure. Ahmad et al. [3] determined the impact of oil supply pressure at different groove positions on torque and frictional force in hydrodynamic journal bearing. Increasing oil supply pressure at certain positions was found to increase torque and frictional force of the bearing. Investigating the steady state characteristics of a hydrodynamic short bearing supplied with a circumferential central feeding groove, Naïmi et al. [4], demonstrated the ability to decrease the maximum oil film pressure for a given eccentricity. Ahmad et al. [5] experimentally determined the impact of oil groove location on temperature and pressure of hydrodynamic journal bearings. Measurements were taken at journal speeds of 300, 500 and 800 rpm, for various loads of 10 kN and 20 kN. Changes in oil groove location were concluded to affect the temperature and pressure profiles. Further, Ahmad. et al [6] traced the impacts of oil supply pressure on the temperature and pressure at different groove locations on a hydrodynamic journal bearing. Changing oil supply pressure was concluded to reduce temperature values and to increase pressure profile values. Increasing oil supply pressure at different groove locations was evident to affect the pressure profiles of journal bearing lubrication. Investigating twin groove journal bearings performance under steady-state condition via computational fluid dynamic techniques, Solghar. et al [7] ascertained the impact of lubricant feeding conditions on bearing design. Increased feeding oil pressure was demonstrated to decrease maximum bush temperature and to increase oil flow rate, load capacity and power loss. Mansour and Shayler [8] experimentally investigated the impact of oil feed pressure on the friction torque of plain bearings under light, steady loads. The reduction of pressure of oil feed to a plain short bearing was concluded to reduce the friction torque significantly. Moreover, cavitation area was increased and pressure in the low-pressure zone of the film was reduced with the reduction of feed pressure. Sakai. et al [9] conducted a CFD analysis concerning journal bearing with oil supply groove, considering two-phase flow and utilizing VOF (Volume of fluid) method. The analysis could help significantly predict the cavitation area in both cases of flood lubrication as well as starved lubrication conditions. Rostek. et al [10] have investigated the impacts of oil pressure in the lubrication system of the engine on friction losses. The variables during test stand measurement have mainly comprised oil temperature, oil pressure and rotational speed of the crankshaft. It was concluded that friction losses do not directly rely on the oil pressure related to the combustion engine crank mechanism. Zhang.et al [11] and Zhang et al. [12] traced impacts of circumferential oil groove, working on the critical operating parameters of load capacity, bearing torques, oil supply conditions, temperature distribution and mechanical power. Zhanget .al [11] introduced evaluation of the nonlinear oil-film forces and torques. Reduction of load capacities and bearing torques due to grooves was concluded to exert a large impact on the nonlinear rotor oscillations. Zhang et al. [12] demonstrated that oil supply conditions could lead to different impacts on operation. Increased pressure was concluded to increase flow rate both through inner and outer film regions, and hence it could reduce inner and outer film temperatures. Marey et al carried out a series of research programs for investigating the possible ways of enhancing the oil film lubrication within journal bearing for marine application. Marey et al. [13] designed and constructed a journal bearing test rig (JBTR) that made it possible to trace the oil film pressure distribution at different speeds and constant load. Marey et al. [14] implemented a numerical study to examine the oil film pressure profile within journal bearing. A new Computational Fluid Dynamic (CFD) model was created to combine experimental and computerized test trials. Marey. [15] Utilized different oil grades for experimentally investigating the pressure behaviour of different lubricants within the hydrodynamic journal bearing, at different speeds ranging from 50 to 400 rpm at constant load. Based on the conducted study, a positive relation was confirmed between the oil film pressure profile and both the rotation speed and the oil viscosity grade. Marey et al. [16] conducted comprehensive modification processes on JBTR so that it could contain even more extensive experimental test trials. The modifications included adding a hydraulic loading system and a full monitoring process via Supervisory Control and Data Acquisition (SCADA) system. The structure has thus become a Universal Journal Bearing Test Rig (UJBTR) that allowed for researching the most critical operational factors that impact the lubricating oil film within journal bearing. Uncertainty and validation measurement analysis of UJBTR has been conducted by Marey et al. [17] for ensuring the accuracy of the obtained outcomes. Roy and Dey [18] conducted uncertain hydrodynamic analysis of a two-axial groove journal bearing including randomness in bearing oil viscosity and oil supply pressure. It was concluded that the uncertainties of oil viscosity and oil supply pressure need to be included in the design procedures.

Scanning the above mentioned research efforts clearly shows that the impacts of insufficient oil supply pressure on marine slow speed diesel engine performance were not given enough investigation.

2. IMPACTS OF OIL SUPPLY PRESSURE ON JOURNAL BEARING

Decreased oil supply pressure is known to have risky impacts on journal bearing performance, represented in the lubrication moving from hydrodynamic region to boundary region. Feeding journal bearing related to marine slow speed diesel engine with the adequate oil supply pressure is thus so crucial in maintaining efficient operation. Oil supply pressure of journal bearing crank shaft usually ranges from 2 bar up to 4 bar depending on the design and operational conditions. In certain operational conditions, where the range of oil supply pressure is less than 0.4 bar, the marine slow speed diesel engine suffers slow down and then shut down. In such a condition, the engine is protected via remotely activating a standby main lubricating oil pump. However, such safety measures are not sufficient to prevent the complete failure of journal bearing, resulting from the poor oil supply pressure especially during the maneuvering conditions of ships. Based on the previously mentioned facts, the study at hand is primarily focused on the impacts of variations made in oil supply pressure both in case it is decreased by 25% and in case it is increased by 25% on oil film pressure and temperature distribution within journal bearing. Also, the purposes of the investigation have involved tracing the influence of variations made in the critical operational conditions of journal shaft speed and applied loads related to the loading program of marine slow speed diesel engine with different oil grades.

3. EXPERIMENTAL UJBTR SETUP

The structure of Universal Journal Bearing Test Rig (UJBTR) Figure 1 consists of the shafting system which involves drive shaft, journal shaft, main journal bearing, supporting journal bearings and thrust bearing. The type of bearing utilized for experimentation is the Circumferential Grooved Bearing (CGB), because it is the most commonly used bearing type in marine slow speed diesel engines and marine applications in general. CGB of UJBTR is made of white metal. It is a composite bearing in which hard crystals are dispersed through a softer metal. Such softer material provides protection for journal bearing from deterioration from abrasive particles. It is made of composite alloys involving copper, tin and antimony. White metal provides the bearing with structural support and its softer lining guarantees optimum friction and wear properties.

Further, journal shaft of UJBTR is used as a scale model (scale 3:16), of a marine slow speed main engine crank shaft type (SHD-MAN B&W 6S50MC) [19]. In addition, the lubricating oil system contains the lubricating oil pump unit which feeds the lubricating oil to journal bearings. It involves filters with the function of purifying the lubricating oil from hard particles. Further, the system contains the lubricating oil cooler which works on maintaining the temperature of the lubricating oil during operation. For tuning the pressure and flow rate of the lubricating oil fed to journal bearings according to the applied loads, the system involves the regulator valves. Also, other fittings and mountings comprising pressure gauges, pressure sensors, thermocouples and oil hoses are integrated. For applying lateral loads, UJBTR contains the hydraulic oil system with the hydraulic pack unit, filters, two hydraulic pistons, hydraulic hoses, proximity sensors, pressure gauges and pressure sensors. Table 1 represents the dimensions of main journal bearing related to UJBTR under study. More important still, UJBTR is fully controlled via Supervisory Control and Data Acquisition (SCADA) system Figure 2. Such highly precise control system ensures obtaining accurate outcomes for all UJBTR experimental procedures and test trials. The whole design and structure setup related to UJBTR are outlined in detail in Marey. et al [16].

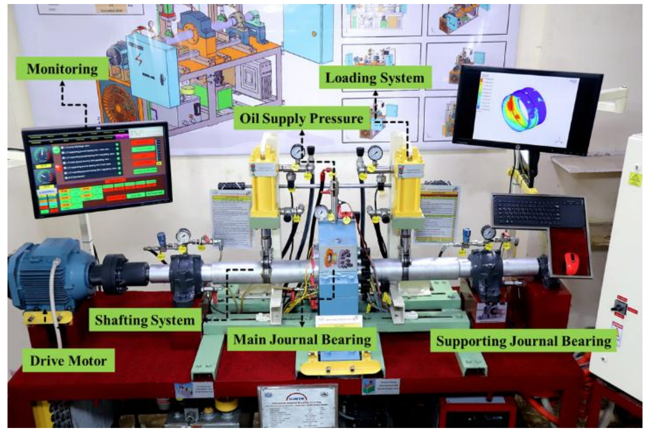

Figure 1: A schematic of UJBTR components [16].

Table 1: Technical data of UJBTR main journal bearing [16]**.**

Parameters	Value
L, Bearing Length	58 mm
D, Inner Diameter for CGB	105.05 mm
Φs Shaft Diameter	104.97 mm
r, Radius for Journal Shaft	52.425 mm
C_0, Total Clearance	0.104 mm
C, Radial Clearance	0.052 mm
L/D ratio	0.55 mm
Eccentricity	0.031 mm : 0.014 mm

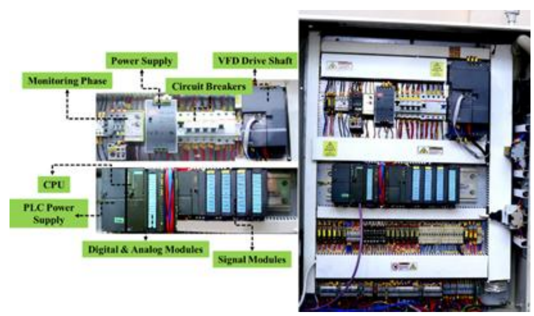

Figure 2: Supervisory control and data acquisition.

4. EXPERIMENTAL TEST TRIAL PROGRAMME

The lubricating oil pressure and temperature profiles within CGB are continuously evaluated along the circumference of journal bearing for the different tested oil grades involving 5W40 and 0W30. The first oil grade is commonly utilized in marine applications, whereas the second was selected due to its lower viscosity and based on the availability in the market. Table 2 shows the properties of the lubricating oil grades utilized in test trials. For obtaining the pressure and temperature distribution values along the circumference of CGB, a number of pressure sensors (14No's) and thermocouples (14No's) are mounted on the main journal bearing as pointed out in Figure 3. The experimental test trials have been carried out to trace the effect of the oil supply pressure in regard to the oil film pressure and temperature distribution within CGB. The experimentations utilizing the different oil viscosities of 84.7 mm2/s and 61 mm2/s have been simulated in accordance with the loading program for marine slow speed diesel engine shown in Table 3. Oil supply pressure was controlled through the Variable Frequency Drive (VFD) of the main lubricating oil pump and it was determined according to the lateral applied loads set in the loading program. As for the oil supply temperature, it was constant throughout the conducted test trials and was set to 40 ℃. Additionally, the trials on the oil supply pressure of journal bearing were conducted under both of the optimal supply pressure and also in case it is decreased by 25% and when it is increased by 25%. Control of speed variations has been carried out via VFD related to the drive motor. Regarding the lateral loads on journal bearing, they were applied by means of the hydraulic piston of UJBTR. All test trial procedures as well as the related outcomes were carried out and obtained depending on the UJBTR SCADA system.

Table 2: Specifications for oil grades [20] & [21]

Parameters	Oil Grade Properties	
	5W40	0W30
Density at 15 ℃	0.85 g/ml	0.838 g/ml
Kinematic Viscosity at 100 °C	14 mm^2/s	11.8 mm^2/s
Kinematic Viscosity at 40 °C	84.7 mm^2/s	61 mm^2/s
Viscosity Index	171	193
Flash Point	236 ℃	217 ℃
Pour Point	-36 ℃	-42 ℃

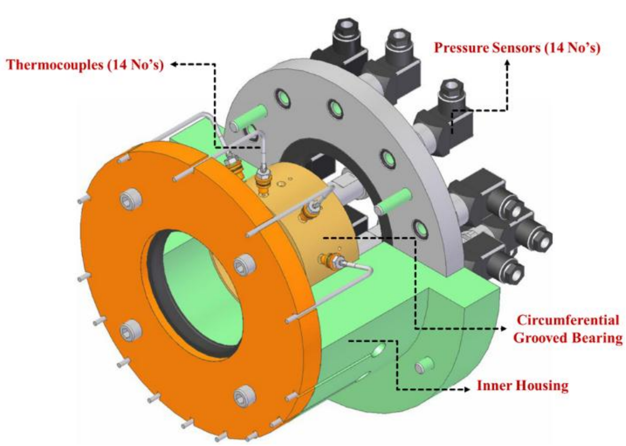

Figure 3: Pressure sensors and thermocouples along grooved bearing circumference.

Table 3: Loading program for slow speed diesel engine

Load	Optimal Load Oil Grade		rpm	Maneuvering Speed
	5W40	0W30		
25%	2453 N	1962 N	32	Dead Slow
50%	3434 N	2649 N	43	Slow
75%	4415 N	3532 N	65	Half
90%	4905 N	5396 N	85	Full
100%	5396 N	6082 N	102	Navigation Full

5. RESULTS AND DISCUSSION

5.1. Results of Lubricant 5W40

The research at hand involves a comprehensive experimental analysis of the impact of oil supply pressure of journal bearing utilizing UJBTR. The effect of the optimal oil supply pressure on the oil film pressure and temperature distribution within journal bearing according to the loading program as specified in Table 3 and utilizing 5W40 oil grade is represented in Figures 4 and 5.

According to the loading program, the value of the oil supply pressure of journal bearing is observed to increase with the increase of the applied load. Further, with the increase in both the speed and the applied load, the maximum oil film pressure P_{max} value at the angle of 198° is always on the rise. Also, the pressure values obtained at journal shaft speeds of 32 rpm (Dead Slow) and 43 rpm (Slow), are observed to be very low, where they ranged from 0.3 bar up to 0.52 bar at the angles of 108°, 126°, 144°, 234° and 252°. It is in these two particular regions that the cavitation phenomenon occurs owing to the decreased oil pressure values, which negatively affects the journal bearing performance. However, cavitation gradually disappears with the increase of oil supply pressure to 8 bar at the load of 4905 N (90%) and 8.8 bar at the load of 5396 N (100%), together with the increase of shaft speed to 85 rpm (Full) and 102 rpm (Full Navigation). Moreover, the values of the oil film maximum temperature at the angles of 108°, 126° and 144° have recorded 49 ℃, 49 ℃ and 49.5 ℃ respectively. The significant rise in the oil film temperature values corresponds to the decreased pressure values at this region.

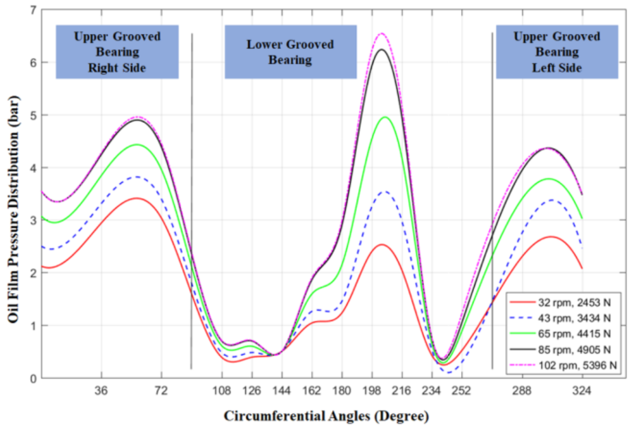

Figure 4: Variation of pressure along CGB at different speeds and loads under optimal oil supply pressure for lubricating oil 5W40.

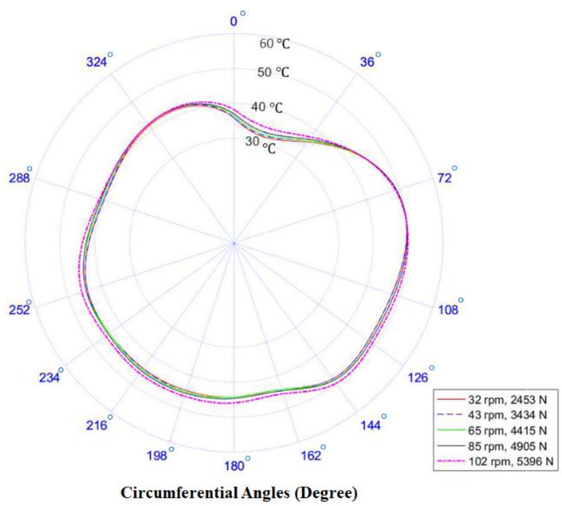

Figure 5: Variation of temperature along CGB at different speeds and loads under optimal oil supply pressure for lubricating oil 5W40.

The experimental test trials have also been carried out with a decrease in the optimal oil supply pressure by 25% for all shaft speeds and under the different applied loads as shown in Figures 6 and 7. Here, the value of the P_{max} was noted to decrease where it ranged from 5% up to 6.5%. Such decrease in the value of the P_{max} can be explained by the decrease of the oil supply pressure. In light of the previously mentioned observations, oil supply pressure is concluded to be among the most crucial operational factors affecting the lubricating oil film within journal bearing. That is, the decrease in the oil supply pressure represents a major risk regarding the performance of journal bearing. It is in such a case that the lubrication turns from the hydrodynamic region to the risky boundary region. This is considered as a very detrimental condition particularly at the speed ranges of 85 rpm (Full) and 102 rpm (Full Navigation). As for the oil film temperature distribution profile when oil supply pressure is decreased by 25%, it does not feature notable changes if compared to its counterpart under optimal supply pressure condition. This can be ascribed to the slow speeds that have ranged from 32 rpm up to 102 rpm which represent the marine slow speed diesel engine.

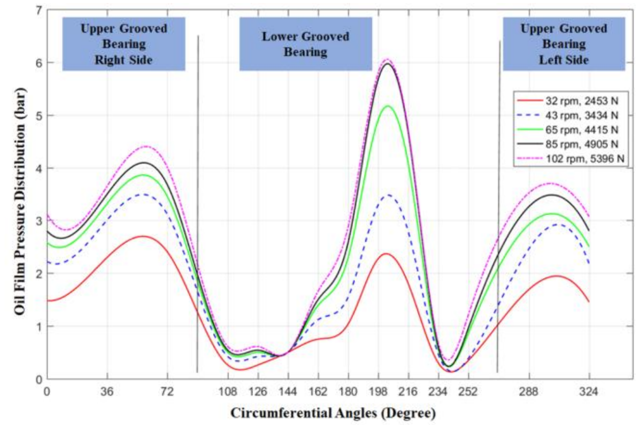

Figure 6: Variation of pressure along CGB at different speeds and loads under a 25% decrease of optimal oil supply pressure for lubricating oil 5W40.

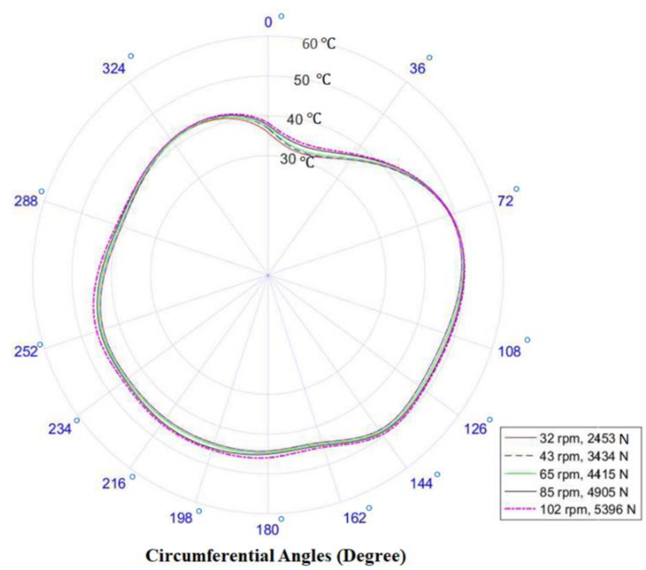

Figure 7: Variation of temperature along CGB at different speeds and loads under a 25% decrease of optimal oil supply pressure for lubricating oil 5W40.

When the optimal supply pressure was increased by 25% for the same test trial procedures mentioned before Figures 8 and 9, other observations have been drawn. There was a slight increase in the P_{max} value at the speeds that ranged from 32 rpm up to 85 rpm under applied loads ranging from 2453 N up to 4905 N. Yet, there was a significant rise in the value of the P_{max} at the speed range of 102 rpm (Full Navigation) under the applied load of 5396 N (100%) with a percentage of 8.4%.Based on these observations, the increase of the oil supply pressure by 25% does not evidently have considerable impact on journal bearing performance unless in the case of full navigation at 102 rpm representing 100% of load. Increasing the oil supply pressure by 25% does not incur any changes in the oil film temperature profile in such a case.

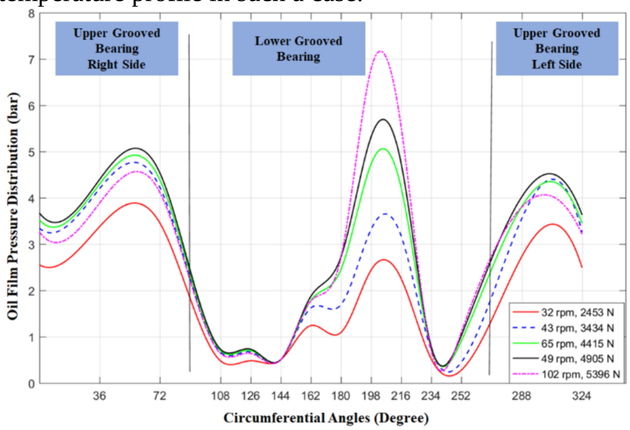

Figure 8: Variation of pressure along CGB at different speeds and loads under a 25% increase of optimal oil supply pressure for lubricating oil 5W40.

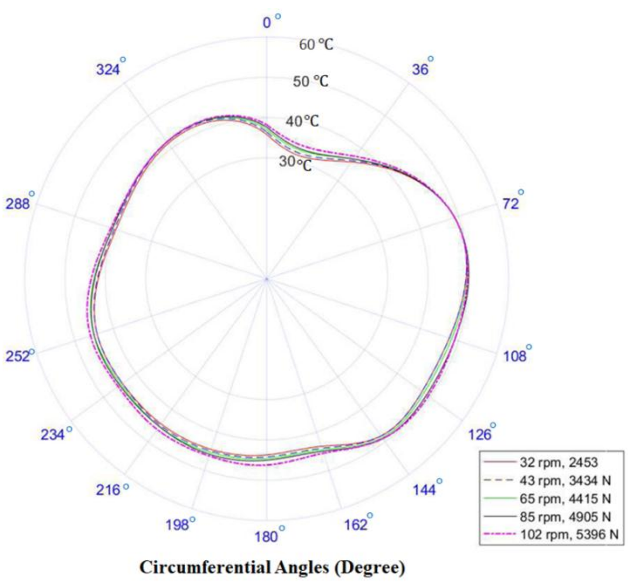

Figure 9: Variation of temperature along CGB at different speeds and loads under a 25% increase of optimal oil supply pressure for lubricating oil 5W40.

5.2. Results of Lubricant 0W30

Experimenting with the different lubricant grade of 0W30 of the low viscosity degree of 61 mm^2/s and with the same procedures followed for oil grade 5W40 has yielded another group of important observations Figures 10 and 11. Compared to the effects of 5W40 in case of optimal supply pressure, the P_{max} has obtained lower values with oil grade 0W30 at journal shaft speeds of 32 rpm, 43 rpm and 65 rpm and those values were 1.76 bar, 2.36 bar and 4.5 bar respectively. The decreased values assumed by the P_{max} can be explained by the lower applied loads and oil supply pressure determined by the loading program for the lower viscosity oil grade of 0W30. However, with the increase of shaft speed to 85 rpm (90% load) and 102 rpm (100% load), the recorded values of P_{max} were higher than their peers obtained with 5W40 where they recorded the values of 5.95 bar and 6.64 bar at 5396 N and 6082 N respectively. The higher values of P_{max} in this case can also be attributed to the increase of the oil supply pressure as corresponding to the applied loads on journal bearing according to the loading program. In regard to the temperature profile with 0W30, the oil film maximum temperature values at 102 rpm (100% load) and at the angles of 108°, 126° and 144° have recorded 49.5 ℃, 49.5 ℃ and 50.4 ℃ respectively. The difference in the values obtained for the same profile with 5W40 at the same angles was thus evidently marginally different with 0.9 ℃ increase for 0W30.

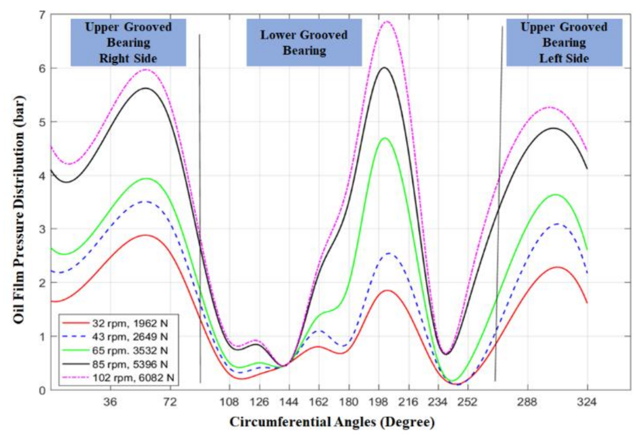

Figure 10: Variation of pressure along CGB at different speeds and loads under optimal oil supply pressure for lubricating oil 0W30.

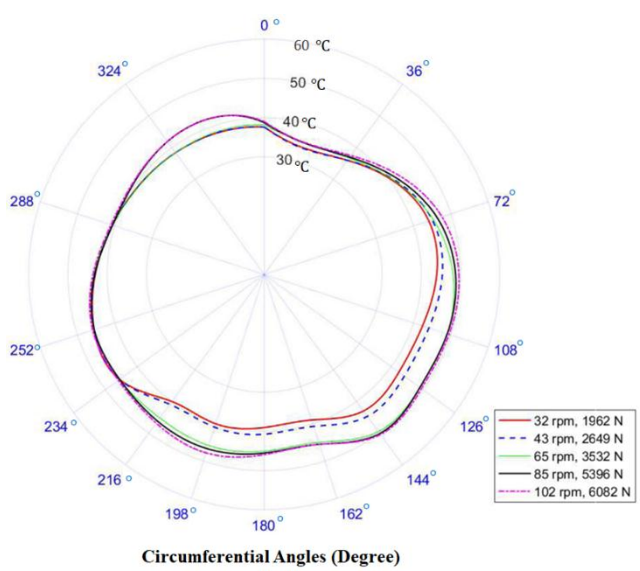

Figure 11: Variation of temperature along CGB at different speeds and loads under optimal oil supply pressure for lubricating oil 0W30.

In case oil supply pressure was decreased by 25% for 0W30 Figures 12 and 13 and compared to 5W40 in the same case, P_{max} values have maintained the same trend of increase and decrease for all experimented shaft speeds as well as the applied loads related to the loading program. Again, at journal shaft speeds of 32 rpm, 43 rpm and 65 rpm, P_{max} has also assumed degrading values where they recorded 1.72 bar, 2.37 bar and 4.36 bar under the same applied loads. Yet, as shaft speed accelerated to 85 rpm (90% load) and 102 rpm (100% load), P_{max} have risen to 6.38 bar and 7.11 bar, that is, by10.8% and 18.3% respectively. As for the temperature profile with 0W30, the oil film maximum temperature has acquired the values of 50.1 ℃, 50.1 ℃ and 50.7 ℃ at the same angles mentioned before, that is, with a slightly more difference increase of 1.1 ℃ for 0W30 than 5W40.

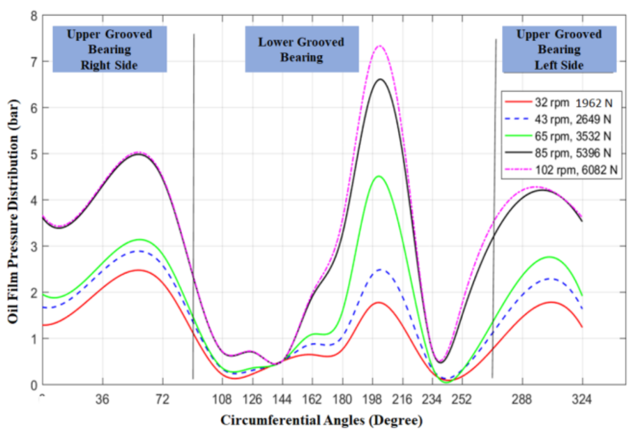

Figure 12: Variation of pressure along CGB at different speeds and loads under a 25% decrease of optimal oil supply pressure for lubricating oil 0W30.

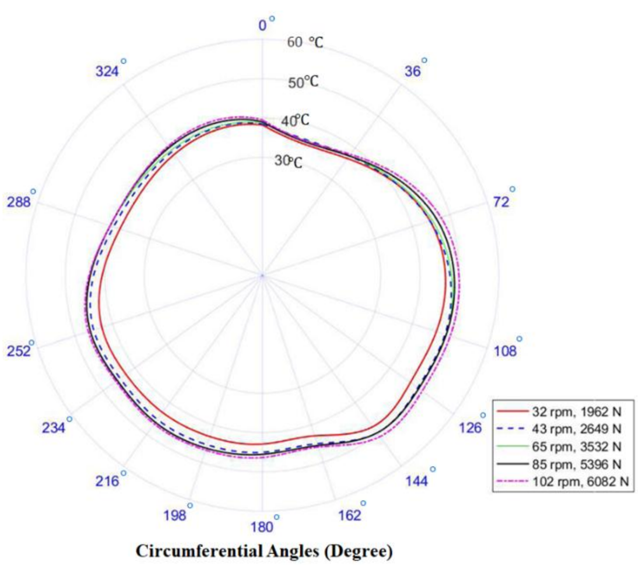

Figure 12: Variation of temperature along CGB at different speeds and loads under a 25% decrease of optimal oil supply pressure for lubricating oil 0W30.

On increasing oil supply pressure by 25% for oil 0W30, and once again in comparison with 5W40 in the same test trial conditions, P_{max} was observed to keep the same orientation recorded before in the nature of increase and decrease in the values. Figure 13 illustrates the variations in the values of P_{max} at the different journal shaft speeds and under applied loads. Figure 14 shows the behavior of oil film temperature distribution of 0W30. As clearly outlined, the temperature profile in this case has been very similar to that observed for 5W40 except for that recorded at the angle of 144°. It was in that particular angle that the value of oil film maximum temperature was higher with 0W30 than its peer with 5W40 by 3.35 %.

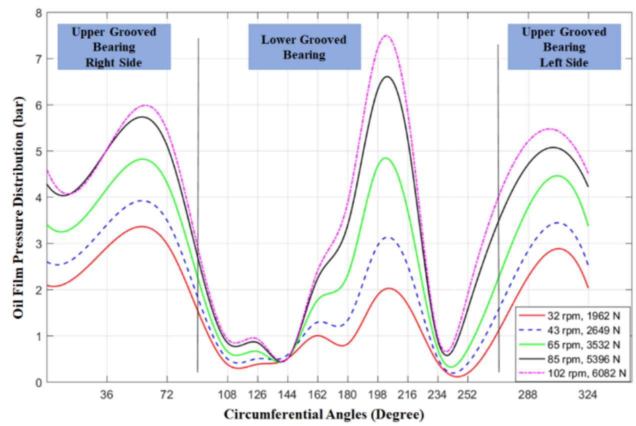

Figure 13: Variation of pressure along CGB at different speeds and loads under a 25% increase of optimal oil supply pressure for lubricating oil 0W30.

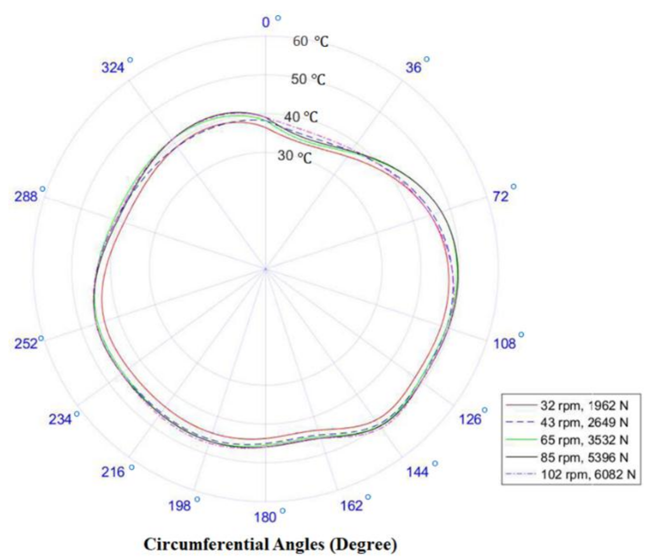

Figure 14: Variation of temperature along CGB at different speeds and loads under a 25% increase of optimal oil supply pressure for lubricating oil 0W30.

6. CONCLUSIONS

Effects of oil supply pressure on the behaviour of oil film pressure and temperature profiles within CGB has been investigated via UJBTR. Versatile test trials have been conducted based on the loading program related to marine slow diesel engine. The following conclusions were drawn based on the different conducted experiments during the study.

i. The maximum oil film pressure (P_{max}) at the angle of 198° increases under optimal supply pressure condition with the increase of both speed and load for the two grades of lubricating oil.

ii. Journal bearing performance is negatively affected due to the low pressure values obtained at the angles of 108°, 126° and 144°, where the cavitation region appears at shaft speeds of 32 rpm (Dead Slow) and 43 rpm (Slow). However, increasing oil supply pressure as a result of increasing load to 4905 N (90%) at 85 rpm and 5396 N (100%) at 102 rpm leads to the disappearance of cavitation.

iii. Compared to the optimal supply pressure condition, decreasing oil supply pressure by 25% does not affect oil film temperature distribution significantly owing to the slow shaft speeds ranging from 32 rpm up to 102 rpm.

iv. In case oil supply pressure is decreased by 25% for all tested lubricants, the P_{max} value has decreased for all shaft speeds as well as applied loads.

v. Journal bearing performance is not considerably affected when oil supply pressure is increased by 25% except in full navigation condition at 102 rpm which represents 100% of load. Oil film temperature profile is not significantly affected under such operational condition.

vi. The maximum oil film pressure P_{max} was observed to assume lower values with oil grade 0W30 in all conducted test trials on oil supply pressure (Optimal, 25% decrease and 25%), if compared to their peers recorded for 5W40 at the same shaft speeds of 32 rpm, 43 rpm and 65 rpm. While increase of speed to 85 rpm (90% load) and 102 rpm (100% load) leads to higher values of P_{max} with oil grade 0W30.

vii. The low viscosity oil grade of 0W30 is thus concluded not to be favorable concerning marine slow speed diesel engines because in such operational conditions speed ranges are often slow while the applied loads are higher.

viii. The decrease of oil supply pressure represents a major risk on the lubricating oil film within journal bearing. Consequently, the main lubricating oil pump must be fully controlled to adjust its speed to provide the required oil supply pressure for all speeds and loads corresponding to the loading program of marine slow speed diesel engine.

Nomenclature

C_0	total clearance	mm
C	radial clearance	mm
D	inner diameter for CGB	mm
L	bearing length	mm
L/D	bearing length/inner diameter	
N	shaft speed	rpm
P_{max}	maximum oil film pressure	bar
P_0	nominal bearing pressure	bar
r	Radius for Journal Shaft	mm
T	temperature	℃
W	applied load	N
Φ_s	shaft diameter	mm

Dimensionless Group

P_0/P_{max}	maximum film pressure ratio

Greek Letters

μ	dynamic oil viscosity	Pa.s
ρ	lubricant Density	kg/m^3

Abbreviations

CGB	circumferential grooved bearing
CP	communication processor
PLC	programmable logic controller
Profinet	process field net
PS	power supply
PT	pressure transmitter
SCADA	supervisory control and data acquisition
SM	signal module
TC	thermocouple
UJBTR	universal journal bearing test rig
VFD	variable frequency drive

Credit Authorship Contribution Statement:

Nour Marey: Methodology, Conceptualization, Design, Structure, Modelling, Writing, Visualization, resources, original draft, and Reviewing.

Declaration of Competing Interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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