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Development of Universal Journal Bearing Test Rig (UJBTR) and Experimental Setup for Oil Film Lubrication Enhancement Regarding Marine Applications

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ABSTRACT

In fact, attaining the final most beneficial target of improving the oil film lubrication for marine purposes can be said to have passed through several main stages up till now. The first stage has involved the initial design and construction of the journal bearing test rig marked by sufficient validity for embracing the potential experimental studies. Those studies were concerned with the lubricating oil within the journal bearing [1]. Notwithstanding, the need has then arisen for the second stage which involved carrying out a comprehensive modification and conversion in regard to the journal bearing test rig, aiming at enlarging its capacity and range to endure more sophisticated experiments. The modification has involved adding a hydraulic loading system as well as full monitoring process via SCADA system, for the sake of facilitating conducting all potential experiments relating the critical operating factors that might otherwise affect the journal bearing performance. This paper is representing the second step in the long uninterrupted series of efforts seeking to outline the results of a proposed research program for marine applications under the title of "Theoretical and Experimental Analysis of the Performance of Journal Bearing". The program will deal with different design and construction aspects of journal bearing, with special reference to marine applications.

Keywords: Hydrodynamic Lubrication, Grooved Bearing, Hydraulic Loading System, SCADA System, Propulsion Shafting System.

1. INTRODUCTION

It is just a fact to state that the marine transmission industry has of late witnessed a really considerable and tangible shift represented in the form of promotions achieved in ship energy efficiency. Moreover, in order to realize the full targets concerning performance enhancement of the journal bearing, the essential design and operational factors have to be very closely and accurately observed. On the other hand, Journal bearings are definitely among the most crucial elements in ship shafting propulsion systems and other marine fields. Also, being in certain critical conditions obliged to work at slow speeds which negatively affect behavior, the journal bearing design requirements have to be very much observed as a means of avoiding most of the boundary lubrication problems.

Consequently, the researchers [2], have launched a beneficial study entitled (Journal Bearing Performance – State of The Art), aiming at tracing and examining all the critical and influential factors affecting the journal bearing, which if closely observed and applied would eventually culminate in the most possible optimal journal bearing construction. Based on the derived outcomes, a research programme with the title of "Experimental and Theoretical Study on the Performance of Journal Bearings for Marine Applications", which will deal with different designs aspects of journal bearing with special reference to marine applications has been proposed. The main objective of the suggested programme is to build up a Universal Journal Bearing Test Rig (UJBTR), which will be able to carry out numerous experiments concerning the journal bearing performance.

1.1. Efforts for Test Rig Design

The following lines would shed light on the continuous and uninterrupted series of endeavors exerted on the road towards acquiring test rigs that would possibly facilitate conducting the versatile processes and experiments, and would as well allow the most possible accurate outcomes to be accessible and attainable for interested researchers.

Seeking to determine the oil film pressure in hydrodynamic journal bearings under realistic operating conditions, [3] has conducted an experimental study utilizing a test rig of his own design in which optical sensors were inserted in the bearings as a means of measuring the oil film pressure. Feeding the oil into the bearing has been done through the rotating union and the shaft. The results have manifested the key operating parameters in the study, which were the oil film temperature, the oil film pressure and the oil film thickness. Moreover, there have been notable variations between the measured and simulated oil film pressure distributions. The measured area of high pressure in the lubricating oil film was noted to be wider than the simulated one. The outcomes could possibly be used in the development and validation of mathematical methods for research into hydrodynamic journal bearings.

[4] have introduced the design of a machine helping identify basic tribological features of real journal bearings. Further, the authors have made use of a self-lubricant porous material that was suitable for static and dynamic load. Also, the Shaft rotational frequency was 0 – 6000 rpm, whereas the loading force was 0:1 kN. The results have implicated the possibility of attaining the steadiness of the tested bearings, by means of changing the load and the rotational speed.

[5] aimed at experimentally measuring the friction torque during startup, with varying specific pressure regarding hydrodynamic journal bearings. Moreover, the shaft was supported by an assembly consisting of high precision rolling element ball bearings, driven by a variable speed DC motor. Also, for ensuring a very good alignment between the shaft and the housing the researchers have used hydrostatic bearings. The maximum torque at startup was found to increase linearly with specific pressure, as long as the geometry and the materials were the same.

[6] was able to create a design of a suitable test rig which helped in the determination of the load carrying capacity and the journal bearing pressure distribution. It is noteworthy that the bearing was lubricated by gravity and was manufactured of mild steel, so that it wouldn't get damaged while applying load. The devised design has facilitated visualizing the journal bearing behavior under varying loads.

Following the above mentioned contributions, and in exactly the year of 2014, [7], have investigated the reasons for the tribological failure of a heavy loaded, slow speed hybrid journal bearing. A test setup has been developed to perform testing on four types of bearing arrangements. Also, Operating the journal bearing at heavy load and slow speed conditions (load 373 N, journal speed 27 rpm), the cylindrical magnetic bearing arrangement was found to have the minimum static load carrying capacity and was thus concluded to be unsuitable to use for heavy load and low speed conditions. It was suggested that the use of lubricant with the magnetic bearing arrangement was the optimal solution regarding mitigating and containing the severity of the magnetic bearing failure.

A study was conducted for the realization and evaluation of a start-stop journal bearing test rig by [8]. Further, the study involved the manufacturing, building and evaluation of a test rig and a development of a software for the test rig utilizing MATLAB. The lubrication process has been carried out by force utilizing 10-W-30 engine oil. Also, the measurements have involved shaft speed range that started from 0 rpm and up to 1000 rpm in the duration of roughly 60 seconds under the different loads of 500 N, 1000 N, 3000 N and 5000 N respectively. Noteworthy that the method of the mechanical load that was used was able to shear. A quality that allowed measuring of the frictional torque between the shaft and the bearing. Besides, the project aimed at building a functioning test-rig for extensive studying of journal bearing during transient states. The test-rigs concept has been proven to work and repeatability for the tests ran has shown good consistency.

Attempting to suppress vibrations in rotating shafts, [9] have introduced a journal bearing with variable geometry in its final form with the detailed design procedure. Noteworthy that the speed operating range throughout the conducted tests has been from 500 rpm to 5000 rpm. In addition, the preloading for the external springs has been applied to the bearing via the displacement of the beams. It was possible to minimize the vibration amplitude at resonance by up to 7%, compared to a conventional journal bearing, via introducing a journal bearing of variable geometry (VGJB). In addition, such kind of journal bearing has facilitated the process of changing the effective damping and stiffness of the system, via selective activation of an additional fluid film during critical operation.

A study was conducted by [10], for creating measure and control system for test parameters of tribological values and validating these results. To create true operational conditions of journal bearing, dynamic test bearing rig was designed and manufactured by a research team.

It is noteworthy that the introduced test rig has comprised thermocouples, displacement sensors and oil film pressure and temperature sensors. Also, the oil film pressure measuring range of the sensor has been from 0 bar up to 1000 bar. The test rig was equipped with three hydraulic cylinders, creating dynamic alternating loads, static, cyclic and rotating. In addition, the applied load has ranged from 0 up to 100 kN, under a shaft speed ranging from 0 rpm to 3000 rpm. The results have shown that test bearing friction would be reduced when the oil pressure was lowered and also friction would increase on making oil pressure higher. This increased cooling effect of oil and temperature rise of oil was found to be lower in bearing contact area. Also, comparison test between static and rotational load proved higher friction on rotational load case.

An experimental study has been carried out by [11], with view to determining the pressure distribution around the circumferences of a journal bearing incurred as a result of variations made in speed and loads. The research has mainly aimed at designing and developing journal bearing experimental setup for determining the pressure distribution owing to hydrodynamic action. Based on the conducted tests, it was concluded that the location of the maximum pressure for the given operating conditions was close to the position where radial clearance between journal and casing was minimum. Also, readings at various speeds were taken by means of adding the weight. Hydrodynamic journal bearing was demonstrated to be able to create load supporting fluid film according to shape and relative motion of the sliding surface and that would help avoid the metal to metal contact between the shafts and the bearing. Hence, no friction would occur and pressure profile was created as a result of load action on journal bearing.

It was for the sake of facilitating the possible experimental studies, regarding single grooved journal bearing, presented in figure 1, that the researchers [1], have launched a study on the base of designing and setting up of a multi-function journal bearing test rig. Also, the study has involved a careful selection and design, regarding the test rig components such as the drive motor, the drive shaft, the bearing assembly as well as the data acquisition system. The derived conclusions have ascertained the ability of such test rig unit to be used for versatile journal bearing lubrication tests. On operating the test rig for various speeds of 50 rpm, 100 rpm, 150 rpm and 200 rpm respectively at constant load, it was found to be in complete accordance with the theoretical investigations. Such realization has granted firm grounds regarding the ability of that constructed discipline to embrace the potential experiments that would possibly utilize it in the future. The following figure illustrates the structure of the test rig by which the above mentioned study has been carried out.

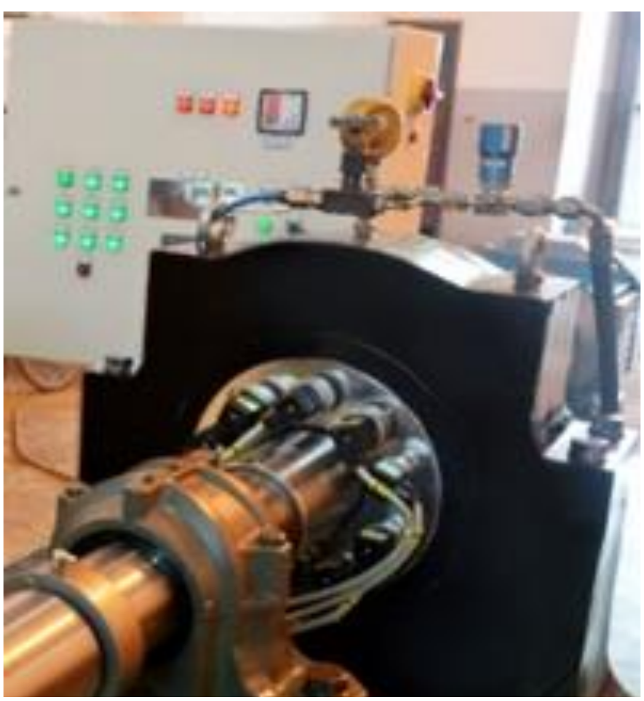


Figure 1: Journal bearing test rig structure. [1]

2.UJBTR DESIGN AND MANUFACTURE

On accomplishing the task of providing a journal bearing test rig characterized by assured precision and result accuracy, there emerged the need to carry out even more extensive thorough modifications. The main objective behind those amendments has been to prepare the structure namely, the Universal Journal Bearing Test Rig (UJBTR), for embracing even more complicated processes and operations and also for ensuring the results derived from the potential calculations are accurate and faultless. The following lines would shed light on the efforts exerted concerning the versatile modifications carried out on the road towards procuring a discipline of much more enhanced capacity and ability.

2.1.Journal Shaft

The shaft is an essential element for transferring motion. Thus, the design requirements of the shaft have necessitated making it of strong materials and balancing it on bearing supports. The motor shaft and the shaft were connected by pin and bush coupling, made flexible for adjusting differences in shaft alignment. Additionally, the material utilized in the manufacture of the shaft has been a medium strength steel (C45), because of its resistance to deformation under high pressure and because of its hardness and availability to work under variable speeds and loads. Also, specific calculations regarding the shaft design had to be observed and those were essentially related to the deflection as well as the maximum shear stresses and forces working on the shaft and resulting from the pressure of the two hydraulic pistons. The following figure is a representation of the dimensions related to the drive shaft.

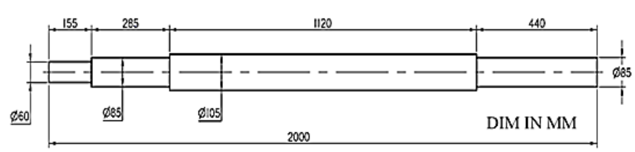


Figure 2: Drive shaft dimensions.

The following table represents the calculations regarding the forces impacting the shaft as well as the torque at different shaft rotational speeds and a constant power.

Table 1: Forces affecting the shaft and the torque at different rotational speeds

Power	N	T (N.m)	F (N)	Power	N	T (N.m)	F (N)
5.5×10^3	50	1051	6.66×10^4	**5.5×10^3**	500	105.042	6.66×10^3
5.5×10^3	100	525.211	3.33×10^4	**5.5×10^3**	550	95.493	6.06×10^3
5.5×10^3	150	350.141	2.22×10^4	**5.5×10^3**	600	87.535	5.55×10^3
5.5×10^3	200	262.606	1.66×10^4	**5.5×10^3**	650	80.842	5.13×10^3
5.5×10^3	250	210.085	1.33×10^4	**5.5×10^3**	700	75.068	4.76×10^3
5.5×10^3	300	175.07	1.11×10^4	**5.5×10^3**	750	70.063	4.44×10^3
5.5×10^3	350	150.06	9.52×10^3	**5.5×10^3**	800	65.684	4.17×10^3
5.5×10^3	400	131.303	8.33×10^3	**5.5×10^3**	850	61.821	3.92×10^3
5.5×10^3	450	116.714	7.41×10^3	**5.5×10^3**	900	58.386	3.70×10^3

The graph to follow is an illustration of the relation therein between the shaft rotational speeds and the suitable forces acting on the shaft.

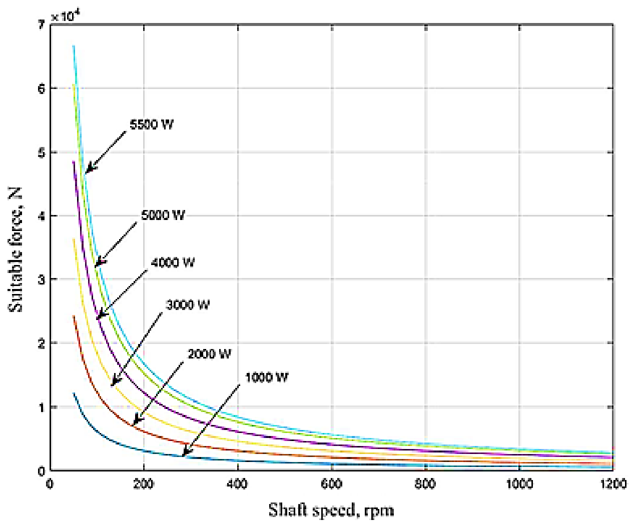


Figure 3: The shaft rotational speeds Vs the forces acting on the shaft.

2.2.Manufacture of Journal Shaft

In fact, the turning and the polishing processing of the journal shaft had to be subjected to continuous measurements, as it was the most crucial part of the test rig. While machining, it was essential for the shaft to be properly supported between centers and special precautions had also to be taken to avoid deflection during lathing. The lathe machine rotates the shaft at the 750 rpm, and the number of rotations depends primarily on the hardness of the shaft material, that was adjusted by the operator. The carriage fed the German make cutting tool of the type (H10), into the shaft at a specified rate for each revolution of the spindle. Yet, the feed rate was the speed at which the tool was fed into the shaft. It was measured in millimeters per revolution. Finally, the finishing was to promote the surface finish quality and appearance of a shaft. The shaft was polished with very high tolerance to exact size for each bearing. After that, the shaft had to be accurately balanced.

Figure 4: Shaft manufacturing procedures aiming to obtain the optimum required balance.

2.3.Clearance Calculations

Being among the most critical factors impacting the journal bearing test rig performance, clearance is in need of thorough investigations for identifying the versatile variables that may possibly affect it negatively. Those may basically include the oil viscosity, that could be obtained from the oil type and grade selection. Noteworthy that a number of interrelated factors play a major part regarding the function of the journal bearing test rig lubrication system. Those comprise the journal bearing operating oil pressure and temperature, the speed of the test rig drive shaft, the bearing grooving and other bearing design features. Also, having conducted numerous trials for acquiring the value of clearance, it turned out that the optimal method for measuring clearance could be via a dial bore gage that measures the bearing inner diameter, when the test rig bearings are installed at the specified torque, without the shaft in place. Additionally, it is of topmost importance to take measurements at front, center and rear of each bearing position. Besides, the clearance factor, occurring between the drive shaft and the plain bearing of the journal bearing, has a starting point of **(0.00075" to 0.001")**. The maximum as well as minimum clearance factors relating to the main journal bearing could be calculated with the help of the following formula, [12]:

The shaft diameter $\times$ 0.00075" $=$ the minimum bearing clearance:$4.132" \times 0.00075" = 0.00307" = (0.078\ mm)$

The maximum main bearing clearance could be inferred through the following relation:
The shaft diameter $\times$ 0.0010" $=$ the maximum bearing clearance: $4.132" \times 0.0010" = 0.004094" = (0.104mm)$

Thus, the actual main bearing clearance applied is **0.1 mm**.

2.4.Modification Process of Main Journal Bearing

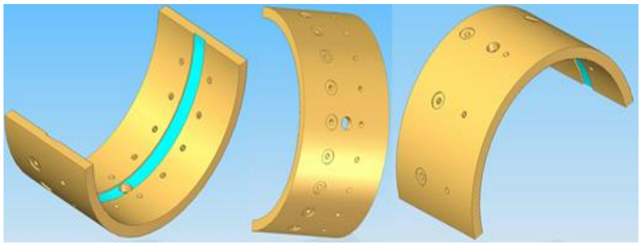
The main journal bearing already integrated in the structure, has been subjected to certain modifications utilizing the milling machine in the process of creating all of the holes regarding the oil film pressure and temperature distribution in a way that would guarantee that the holes drilled into the groove bearing be adjusted with their counterparts drilled within the housing bearing. Another reason why such step was carried out was the necessity to ensure that there was no internal leakage within the main journal bearing; a step that was so important in the process of acquiring accurate readings regarding the pressure and temperature distributions. Furthermore, a number of fourteen thermowells have been inserted within such holes and they were made of copper for being a good conductor of temperature. Those thermowells were then attached to the temperature sensors. They have as well been provided with two grooves so that some oil seals could be created for preventing oil from escaping and for deterring any likelihood of internal leakage of the lubrication oil. (see figure 5)

Figure 5: The thermowells

2.5.Modification of Grooved Bearing

For the accuracy considerations, the groove bearing comprising both the upper and lower bearing has been subjected to certain modifications. The milling machine being marked by high precision, has been utilized to drill a number of fourteen holes circumferentially located on the right side of the bearing so as to measure the lubricating oil pressure. The distribution of the holes has involved nine holes on the lower part of the bearing where the distance between each of them was exactly 18^0. The upper part has involved a number of five holes and the angle separating each of them was precisely 36^0. On the other hand, the left side of the bearing has featured the existence of the temperature sensor holes having the same distribution carried out regarding the groove bearing right side mentioned before. Further, the following figure represents the pressure and temperature hole distribution.

Figure 6: The temperature and pressure holes



distributed circumferentially.

Having carried out all the modification processes regarding the main journal bearing according to the preset design criteria, the following figure would be regarded as a representation of the pressure transmitters and temperature sensors circumferentially distributed around the groove journal bearing.

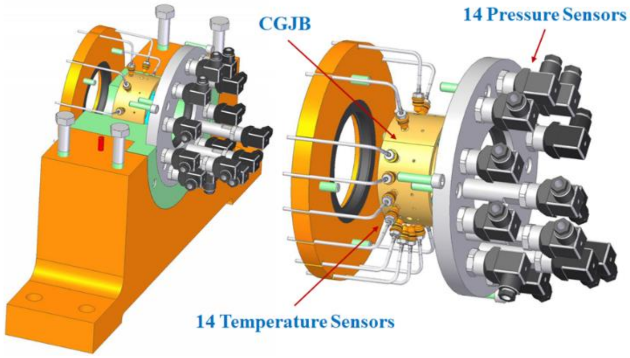


Figure 7: Modifications in regard to the pressure transmitters and temperature sensors.

2.6.Modification Processes of Supporting Journal Bearings

The modifications have been carried out and involved drilling holes for permitting oil in the upper part of the two supporting journal bearings and their sleeves. In this way, the lubrication of this region has become by force due to the existence of different loads on the journal shaft. Besides, the oil supply inlet lines related to the two supporting journal bearings have been provided with two pressure gauges, whereas the oil outlet lines have been supplied with two thermometers for identifying the temperature of the supporting journal bearing oil film.

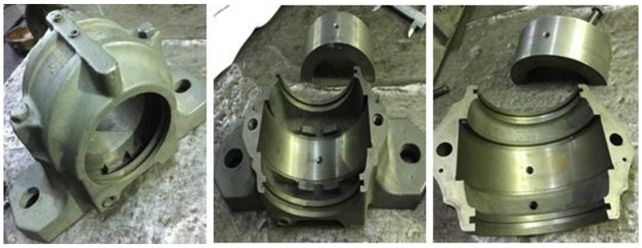


Figure 8: The modified supporting journal bearing

2.7.Loading Hydraulic System

The load factor is definitely among the most crucial operational factors impacting the journal bearing. Hence, the need has arisen for designing and constructing a variable loading system with the function of better identifying, studying and enhancing the lubricating oil film. Considering the great impact of load, a hydraulic loading system has been designed and constructed. Noteworthy that the load on the journal bearing has been generated by means of the loading system. Besides, the main components concerning the hydraulic loading system have comprised numerous essential parts. Those parts have involved two identical hydraulic pistons, a hydraulic power unit and an electrical control unit.

2.7.1.Hydraulic cylinder design

The design of hydraulic cylinders has entailed the calculation of both speed and power in dependence of the existing pressure in the cylinder space and the volume flow available. Thus, much consideration had to be given to the permissible values regarding the operating pressure as well as the admissible oil speed there in the hydraulic ports.

Table 2: Characteristics of hydraulic power unit

Type	Erhart + Leimer GmbH
Main Voltage	400 V/ 50-60 Hz
Control Voltage	24 V DC
Pump Capacity	4 L/min
Pressure Max	30 bar
Part No.	501580

Figure (9) shows the main parts of the hydraulic piston and its dimensions. It consists of cylinder, piston, and piston rod, end of eye and holder of bearing. Design calculations can be done as follows:

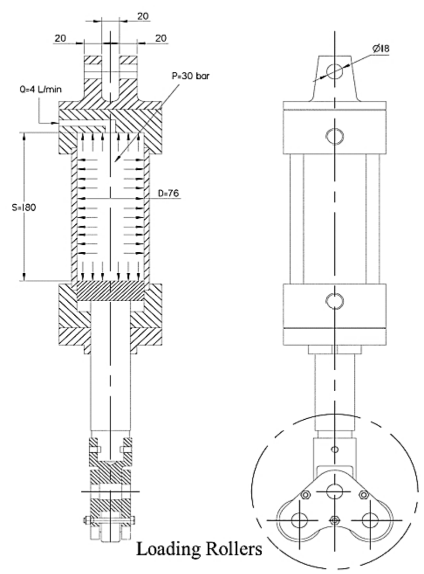


Figure 9: Hydraulic pistons with loading rollers.

2.7.2.Piston dimensions

Inside diameter of cylinder: D = 76 mm = 0.076 m
Stroke of rod piston: S = 180 mm = 0.18 m
Max oil pressure: p = 30 bar = $30 \times 10^5 = 3 \times 10^6$ N/m2
Flow rate: Q = 4 L/min = $\frac{4}{1000\times60} = 6.667 \times 10^{-5}\ m^3/sec$

The following equations would represent the way by means of which the values related to the Cross-Section area of the cylinder, the maximum force of piston, the power of the hydraulic oil pump and the motor torque respectively may be derived.

Cross-Section area of cylinder

$A = \frac{\pi D^2}{4} = 0.00454\ m^2$ (1)

The piston is subjected to axial force due to pressure.
Maximum force of piston

$F = p \times A = 13609.37938\ N$ (2)

From the following equation we can find the mechanical power

Power of oil pump could be derived as follows

$P = Q \times p = 200\ watt$ (3)

But we can assume the efficiency of motor (η) to be 0.8

Motor power $= \frac{P}{\eta} = 250\ watt$ (5)

Speed of pump: N = 1400 rpm

Torque of motor: $T = \frac{250\times60}{1400} = 10.714\ N.m$ (6)

2.7.3.Hydraulic oil pump

A hydraulic gear pump is used and integrated in the hydraulic power pack unit and is driven by an electric motor. The pump takes suction of the hydraulic oil through a metal fine filter, then pumps the oil to the system through an electrically controlled flow directional valve. For more control of the flow and pressure of the oil, an inverter is connected to the motor to control the motor/pump revolutions and the piston movement speed can thus be easily manipulated.

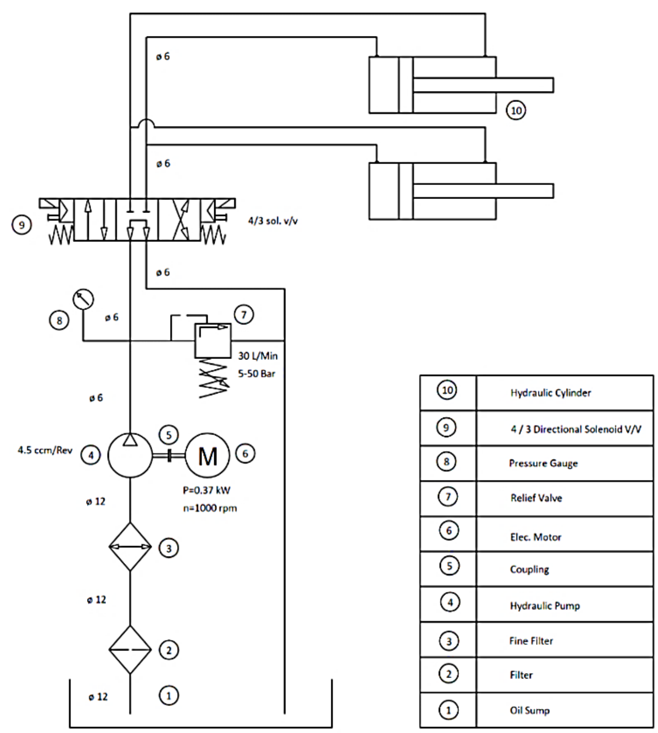


Figure 10: A configuration of hydraulic oil system.

2.7.4.Manufacturing of hydraulic foundation

The design of the foundation was done according to the maximum load calculations and the reaction resulting from the hydraulic piston. As per the calculated reactions, channel beams were chosen to be installed to fulfill the application requirements and the high factor of safety. UPN-

Table 3: Main components of lubrication system

Item	Component	Item	Component
1	Gear Pump Unit	8	Oil Hoses
2	Oil Filter	9	Lub Oil Cooler
3	Suction Strainer	10	Electric oil heater
4	Inline discharge filter (LF)	11	Temperature Sensors
5	Level - Temperature Switch	12	Pressure Transmitter
6	Discharge Pressure transmitter	13	Pressure Gauges
7	Regulator valve		

100 channel beams were chosen to be utilized in the application. The foundation was installed in a workshop with great precision and with assured quality so as not to have any negative impact or repercussions leading to undesirable misalignment between the hydraulic piston assembly and the rotating shaft. The design of the foundation passed through different crucial phases, which comprises the surface cleaning and the cutting. It also included the fitting and reaming processes, the fastening (bolting &welding) and finally the finishing process.

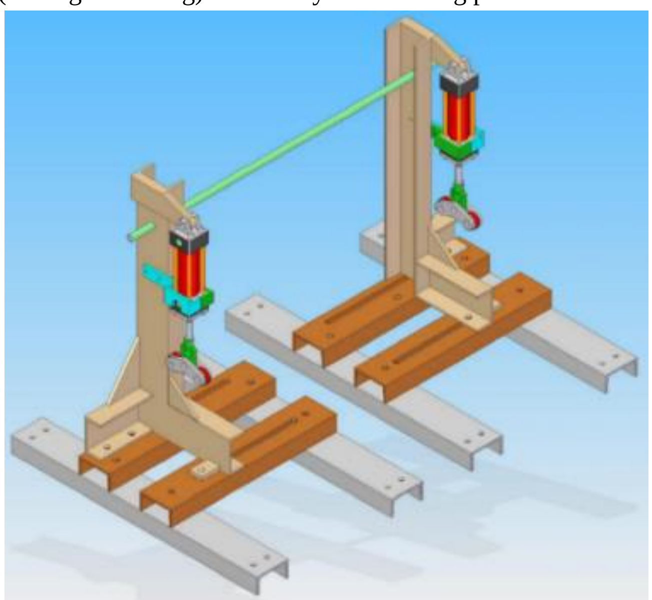


Figure 11: Test rig hydraulic foundation.

2.8.Lubricating Oil System

It is important to say that the success of journal bearings is basically dependent on the design of the lubrication oil system. Hence, creating the optimal environment for hydrodynamic lubrication is the main target for attaining stable bearing lubrication. This could merely be achieved by lifting the journal away from the bearing surface through the use of a film of oil. In this way, it is ensured that there would not be any kind of friction between the two surfaces, and the friction might only occur between the oil molecules resulting in the load carrying capacity. Noteworthy that modifying the lubricating oil system to be fully controlled, monitored and provided with alarm system has successfully been carried out via SCADA system.

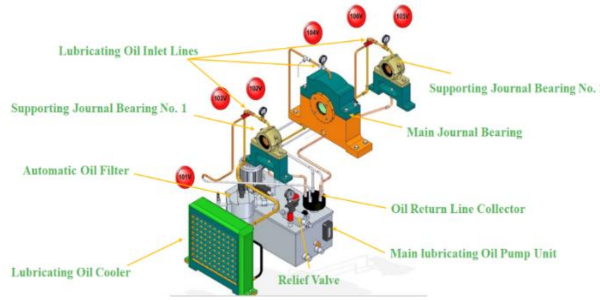


Figure 12: lubricating oil system.

3. UJBTR SETUP

3.1.UJBTR Assembly based on Risk Assessment Considerations

On carrying out UJBTR assembly process, conducting a risk assessment based on the acceptable criteria is a must. A risk or a hazard can accurately be defined as a substance, situation or certain practice that has the potential to cause

Table 4: Risk assessment with respect to the assembly process of the UJBTR

Test Rig Name		Universal Journal Bearing		Assembly Components of The Test Rig				Date		4,8, Dec, 2020	
Team composition		Team leader		Assistant engineer		2 Fitters	Wiper	Electrical engineer			
Step No.	Description of task step	Hazard or potential incident	Who or what may be harmed	severity	likelihood	risk	Control measure	Residual Severity	Residual Likelihood	Residual Risk	Action
				Severity × Likelihood = Risk							
1	Pre job meeting	Lack of knowledge	Personnel	4	4	16	Explain assembly procedures	2	2	4	Team leader
2	Checking all lit areas	Poor lighting & personal injury	Equipment & personnel	3	3	9	Improve lighting levels and placement of light fittings to ensure more even lighting of all floor areas	2	1	2	Team leader
3	Checking all floor are clean of oil spillage	personal injury	All personnel working on the test rig	3	4	12	Clean spills up immediately, if a liquid is greasy, make sure a suitable cleaning agent is used. After cleaning the floor can be wet for some time	2	2	4	Assistant engineer
4	Preparing job	Machine components are heavy	Equipment & personnel	4	5	20	Check condition of lifting tools and supervise use	3	2	6	Team leader
5	Checking and ensuring a steady test rig base	Test rig base is mobile	Equipment	3	4	12	Secure base using leveling pads, on level stable ground	2	1	2	Assistant engineer
6	Ensuring all weights are safely installed	Personal injury through dropping weights or test rig components	Equipment & personnel	5	5	25	Using PPE & Minimum of two people should be in attendance whilst assembling the test rig	2	2	4	Assistant engineer
7	Ensuring all electrical components are accurately fitted	Electrical control panels damage	Electrical control panels	4	4	16	Control panel electrically supervised by an electric engineer.	2	3	6	Electric engineer
8	Assembly of the test rig	Equipment damage & personal injury	Equipment & all personal working on test rig	4	3	12	Follow supervisor instruction	3	2	6	Team leader
9	Testing test rig	Equipment damage	Equipment & all personal working on test rig	5	4	20	Check the system before conducting test	2	1	1	Team leader

Supervisor: Nour Ahmed Marey **Signature:** **Date reviewed: 08 / 12 / 2020**

1-6 - May be acceptable; however, review task to see if it can be further reduced.

7-14 - Tasks should only proceed with the appropriate approval. Where possible, the task should be redefined to take account of the hazards involved or the risk should be reduced further prior to task commencement.

15-25 - Task must not proceed. It should be refined or further control measures put in place to reduce risk. The controls should be re-assessed for adequacy prior to task commencement harm. It is the result of combining the likelihood to the severity. The risk assessment illustrates the essential control actions including selecting the correct special tools, lifting tools, and using the Personal Protective Equipment "PPE". Further, those control actions must comprise the process of checking tools in addition to supervising their usage.

3.2. UJBTR Assembly

Assembly of UJBTR involves consecutive steps. Those procedures could be elaborated as follow:

1. Positioning the stand on the workshop floor.
2. Fixing of the foundations on the stand surface.
3. Installation of the journal bearings.
4. Installation of the journal shaft.
5. Locating the drive motor in position.
6. Fixing of the flexible coupling.
7. Checking the journal shaft alignment.
8. Preparing and installing of the temperature sensors into the main journal bearing.
9. Installing of the copper tubes into the main journal bearing.
10. Installing the upper housings related to the journal bearings.
11. Fixing the oil film pressure transmitters and temperature sensors.
12. Installation of the hydraulic piston foundation.
13. Connecting the hydraulic power pack unit to the hydraulic pistons.
14. Integration of the lubrication oil system.
15. Mountings and fittings related to the UJBTR.

3.2.1. Laser technique utilized for shaft alignment

The alignment adjustment involves specific procedures. Firstly, the measurement program ought to be fed with the essential data concerning the distances between measuring units and the UJBTR feet. Besides, it is necessary to ensure that the UJBTR is balanced and resting evenly on all its feet by means of performing a soft foot check utilizing the leveling pads. This is actually of topmost importance regarding adjusting the alignment. Additionally, it is vital to pave the way for precise measurements via turning the shafts with measuring units to three positions via pressing the enter button at each position to record the value. Following the previous step, it is now easy to obtain a clear display of the offset, angular values, and shim and adjustment values. Both horizontal and vertical values are shown "live", making it easy and simple to adjust the UJBTR alignment. Further, it is very crucial to check the obtained measurement results against pre-defined and predetermined tolerance tables and values. This step would surely provide the firm grounds for acquiring the desired alignment that is within the approved tolerances. This would also lead to shortening the times consumed for alignment considerably. Here, the speed range is selected from the tolerance setting menu. In addition to that, filled coupling symbols are displayed once the UJBTR has been aligned within the tolerances. Noteworthy that in many cases, the UJBTR parts are likely to expand considerably from a cold to a hot state (operating conditions). That is why, it is very important for the measurement system to calculate the correct shim and adjustment values in these cases by means of the thermal growth compensation function. More important still, all the derived measurement results ought to be documented for reference and further manifestation.

In fact, adjusting alignment has essentially necessitated carrying out precise measurements concerning the "Runout", or rather the degree of deviation of the shaft by means of the dial gauge indicator where the shaft was rotated and readings were recorded. The measurement processes have comprised a number of steps that are outlined as follows:

Firstly, the runout related to the shaft and the coupling of the motor was measured involving both the radial and angle or face. Next, the runout of the journal shaft and its coupling was also measured in the same way. Parallel to that, it was necessary to carry out continuous measurements and adjustments in relation to the line bore alignment concerning the main journal bearing as well as the two supporting journal bearings. Furthermore, it was of much importance to measure the clearance pertaining to all the journal bearings.

In addition, it was also necessary to adjust the laser shaft alignment between the drive motor and the journal shaft. Besides, the vibration of the drive motor in the absence of the shaft load was essential to be measured. More measurements had also to follow the laser shaft alignment regarding the vibration of the drive motor under the effect of the shaft load so as to register the variations in vibration values before and after applying the shaft load and to be able to assess whether such vibration was in tolerance or out of tolerance.

Figure 13: Journal shaft alignment via laser technique.

The results were obtained at both horizontal and vertical positions and were also recorded digitally for the UJBTR in the course of the alignment adjustment procedures via the Easy Laser Shaft Alignment System **(D525 of Sweden)**. The following table would represent the results concerning the laser shaft alignment as between the journal shaft and the drive shaft. More important still, those registered values were subject to a continuous update process throughout the alignment adjustment processes.

Table 5: Vertical and horizontal alignment results

Alignment Status		
Result Vertical		
Result		**Acceptable Tolerance**
Offset	0.04 mm	0.13 mm
Angle	0.04 mm/100 mm	0.10 mm
Result Horizontal		
Result		**Acceptable Tolerance**
Offset	0.03 mm	0.13 mm
Angle	0.03 mm/100 mm	0.10 mm

4. PRESSURE TRANSMITTERS

It was basically for the sake of preventing any likelihood of errors, miscalculations or disorder as well as providing accurate results that a number of fourteen pressure transmitters have been circumferentially installed into the journal bearing. There was a need for a type of pressure transmitters that could be characterized by a superior accuracy and an affordable cost. They also ought to have an assured guarantee from an established company that was recognized to produce certified instrumentations. That is why, the German "WIKA" company, founded in 1946, was chosen to provide the target required pressure transmitters. Thus, the company was contacted for having the best advice in relation to the consistent pressure transmitters that could carry out the expected targets. The tips received suggested the use of pressure transmitter for general industrial applications (Model A-10), whose advantages turned to outweigh its counterparts in relation to the predetermined required goals. The following figure (14) illustrates the finally selected pressure transmitters matching the journal bearing test rig:

Figure 14: Pressure transmitter, [13]

The model (A-10) pressure transmitter, (German make) for general industrial applications, is characterized not only by its peerless compact design, but it also offers an excellent quality. The target model (A-10) is set up for worldwide use through the international Eurasian Conformity "EAC" certification and European Conformity "CE", which indicate that the products conform to all technical regulations of "the Eurasian Customs Union" and "the European Economic Area". Besides, the A-10 pressure transmitters comprise a unit of the type (bar). Noteworthy that the following table would better illustrate the technical data regarding use of pressure transmitters.

Table 6: Technical data for pressure transmitter, [13]

Pressure Transmitters Model	**A-10**
Measuring range	0 … 40 bar gauge
Output signal	4 … 20 mA, 2-wire
Power supply	8 … 30 V DC
Non-linearity	0.5% BFSL
Accuracy at room temperature	$\leq \pm 1.0\%$ of span
Measuring deviation of the zero signal	$\leq \pm 0.3\%$ of span
Permissible medium temperature	0 … +80 ℃
Service life	100 million load cycle
Wetted parts	Stainless steel 316L
Process connection	G ¼ A DIN EN ISO 1179-2
Electrical connection	Circular connector M12× 1,4 −Pin
Overload safety	2 times
Manufacturing date	28-2-2020

5. CONTROL PANELS OF UJBTR

No doubt that the UJBTR is completely dependent on the existence of efficient and fully controlled control panels, for manipulating and carrying out all the vital processes and measurements planned for the structure. Additionally, the control panels are meant to operate smoothly and with utmost precision under the most possible control and monitoring system here featured in the SCADA system. Also, the control panel are equipped with the optimal alarm system protecting the discipline from any possible operational or human errors, undesirable stoppage or delays in achieving the goals for which that very important structure was basically structured. The control panels have also comprised the necessary measuring systems related to the oil film pressure and temperature distribution within the journal bearing represented mainly in the pressure transmitters and temperature sensors. Besides, other temperature and pressure sensors have been integrated into the structure and pertaining to the hydraulic power pack and lubrication oil systems.

It is important to point out that the electrical control of the whole structure has been carried out via two main control panels. Also, the following elaborations would help better identify the contents, mechanisms and characteristics related to the first control panel.

5.1.First Control Panel

The first control panel is regarded as a multifunctional device which comprises the following items ensuring the efficient operation of UJBTR.

- A feed power for second panel comprising SCADA and physical measurements.
- A processing three mode cooling fan manipulated by Zelio controller, VFD.
- A processing hydraulic system controlled by Zelio controller, VFD.
- Thermos Couples (TC) for measuring oil temperature where the values are displayed on the temperature controller.
- A multimeter instrument for measuring each of the voltage, current and frequency.

Table 7: Detailed components of first control panel

Safety Equipment	Power Equipment	Control Equipment
Fuse	Main Power Switch	Zelio Logic
Circuit Breaker	Contactor	Signal Converter
Earth Leakage	Power Supply	VFD
GV2 Circuit Breaker	Multimeter	Digital Controller
Terminal Blocks		Temp Controller

Figure 15: First control panel contents.

5.2.Second Control Panel

On the other hand, the second control panel plays the most crucial role in carrying out the vital manipulating processes via integrating the intrinsic components shown below.

- SCADA system (Wincc explorer software) for monitoring all processes and watch keeping.
- Working on sending and receiving data and values such as system stability, pressure and temperature values.
- It is assigned with the task of showing the shaft motor status, lubricating oil pump and three mode oil cooling fan status.
- It has the ability to measure the oil pressure and temperature as well as recording the resultant data.
- Measuring shaft motor frequency and revolution and recording the data.
- Measuring hydraulic oil pressure for hydraulic power pack.
- Securing SCADA system by means of admin operator.
- Involving emergency and shutdown status regarding the whole system.
- Comprising an effective operating system for processing and controlling the UJBTR.
- The data log and trend views are all processed via Wincc explorer
- PLC (S7-314C/2Dp) contains work memory for storge programming.
- The motor shaft is controlled through VDF.
- The panel is assigned with monitoring phases and earth.
- Controlling lubricating oil cooling system utilizing PID controller.

Table 8: Components of second control panel

Safety Equipment	Power Equipment	Control Equipment
Fuse	Contactors	Plc S7-314c/2dp
Circuit Breakers	Power Supply's	Analog Modules
Earth Leakage		Phase Monitoring
Relays		VFD
Terminal Blocks		Rack S7
		Work Station
		Communication Processor

Figure 16: Second control panel components.

On fulfilling the task of constructing the control panels pertaining to the UJBTR structure, the following step was to create the SCADA system control program marked by the highest possible degree of accuracy and adjustment. The SCADA system was to comprise a number of essential components that would guarantee optimum outcomes regarding each of the operation, the monitoring processes, the trend views and the alarm system related to the pressure and temperature distribution profiles as well as the loads acting on the journal shaft. For more illustration, the following figures would shed light on the SCADA system pages assigned with accomplishing the essential processes and operations outlined above.

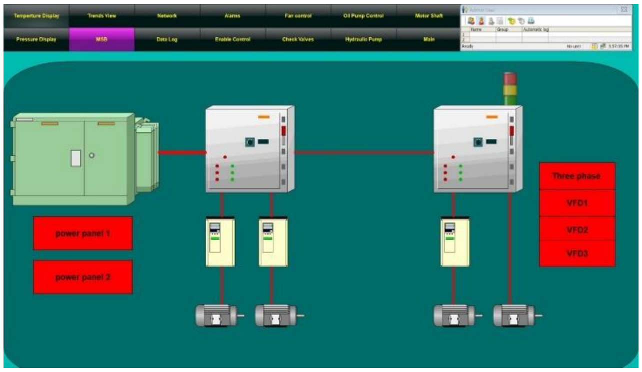


Figure 17: Main switch board (MSB).

Figure 18: UJBTR main page.

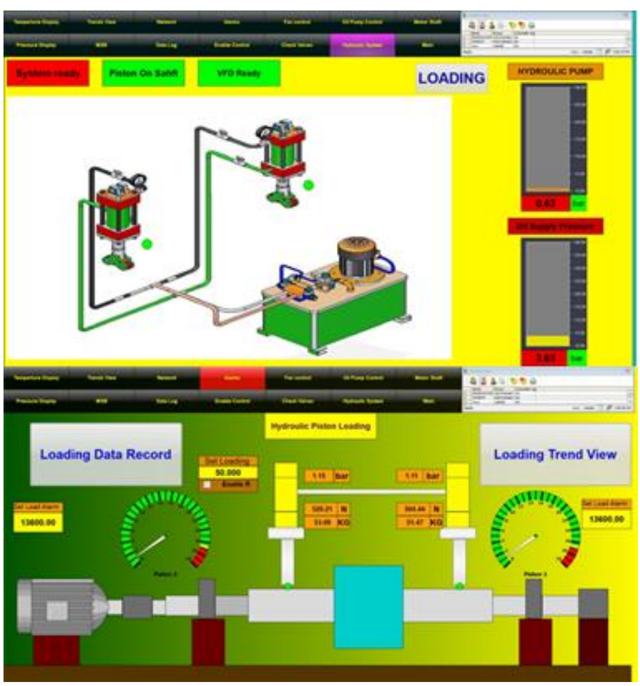


Figure 19: The loading acting on journal shaft.

Figure 20: The loading trend view regarding shaft.

Figure 21: Pressure distribution value display.

Figure 22: Oil film pressure distribution trend view.

Figure 23: Oil film temperature distribution display page.

The laborious endeavors have ultimately culminated in obtaining the most possible optimum discipline, characterized by high accuracy. A quality that would ensure the safety, smoothness and availability to endure and embrace the wide and comprehensive complicated operations and tests that would potentially be carried out in the future for the sake of attaining tangible promotions in as far as the oil film lubrication within the journal bearing is concerned. The following figure illustrates the fully constructed structure.

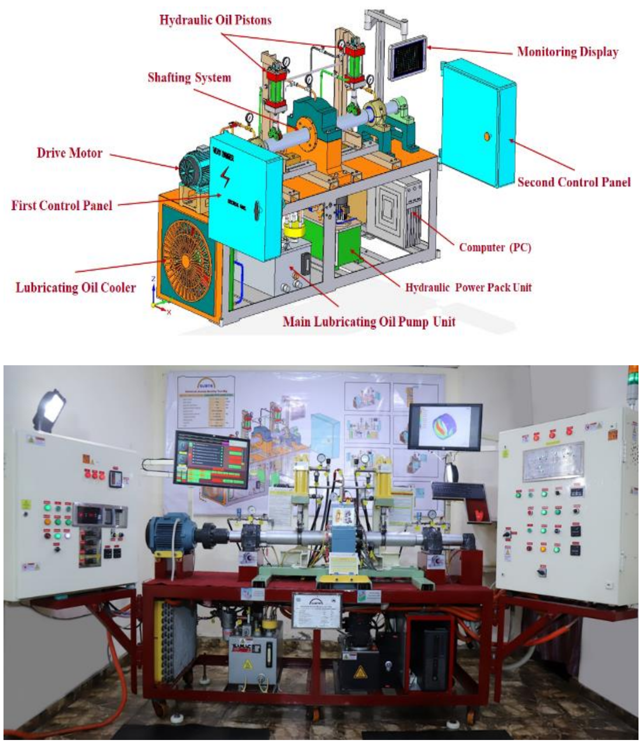


Figure 24: The fully constructed UJBTR

6. CONCLUSION

In conclusion, the crucial calculation processes related to the requirements of acquiring a UJBTR have been successfully achieved. Also, each step in the stages of planning, manufacture and assembly has been conducted with special care given to a number of considerations comprising the design material stresses, manufacturing standards and last but not least the assembly risk assessment criteria. Additionally, all components and equipment have been appointed, purchased and utilized with great precision for the sake of satisfying the targeted plans. Noteworthy, having accomplished the crucial task of constructing the UJBTR intended to contain and embrace all the potential experiments regarding the enhancement of the lubrication oil film, the next step will be to publish a paper concerned with ensuring the validity of the proposed discipline for enduring the intended processes and calculations and for providing the most satisfactory outcomes for which the structure has primarily been thought of, designed, constructed and assembled in light of the research program previously referred to.

Nomenclature

A	Cross-Section area of cylinder, m^2
A	Current, A
C	Pump Capacity, L/min
CE	European Conformity
D	Inside diameter of cylinder, mm
F	Force, N
f	Frequency, HZ
N	Rotational speed of journal, rpm
P	Motor power, Kw
P	Pressure, bar
PLC	Programmable Logic Controller
Q	Flow rate, m^3/sec
S	Stroke of rod piston, mm
SCADA	Supervisory Control and Data Acquisition
T	Max torque, Nm
TC	Thermocouple, ℃
V	Voltage, V
VFD	Variable Frequency Drive
η	Efficiency of motor

Credit Authorship Contribution Statement:

Nour Marey: Methodology, Design, Structure, Modelling, Writing, Visualization, resources, original draft, and Reviewing.
El-Sayed Hegazy: Conceptualization, methodology, Supervising and Reviewing.
Hassan El-Gamal: Conceptualization, methodology, Supervising and Reviewing.
Amman Ali: Conceptualization, methodology, Supervising, Writing, Reviewing and Editing.
Randa Ramadan: Conceptualization, methodology, Supervising, Writing, Reviewing and Editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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