

Research Article

Hydrostatic And Hydrodynamic Bearing On Grinding Machine

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Abstract

In recent years, the demand for hydrostatic bearing application has been increasing due to the possibilities and advantages they offer. Advances in the understanding of hydrostatic lubrication and the improvement of computer technology have opened new avenues for improving hydrostatic bearing performance and precision.

This paper reviews the geometry, advantages and disadvantages of hydrostatic bearings, including the hydraulic system. Hydrostatic bearing applications operate using relatively high viscosity oil, but have the potential for extremely low motion errors with high damping, high stiffness and high load capacity. Another important advantage of hydrostatic bearing is the negligible wear of the sliding surfaces, which are completely separated by the oil film. In general, pocket depths of 0.5-5 mm and bearing clearance of 0.001-0.01 mm are preferred in hydrostatic bearings.

In hydrodynamically lubricated bearings, the friction efficiency between the spindle and the bearing can be controlled when the spindle shaft starts the rotational movement of the spindle shaft while the spindle shaft passes from the stationary state to the contact state and when the appropriate speed is reached. Therefore, the liquid film thickness in hydrodynamic bearings is at the level of 0.0254 mm. In order for these systems to operate safely and efficiently, the presence of a suitable lubricant is always required.

*Hydrostatic grinding and hydrodynamic grinding machines were used in the experiments carried out within the scope of this study, and especially the crusher roll with dimensions of 250*1000 mm was used*

in the experiments. Depending on the use of the grinding machine, the advantages of hydrodynamic bearing and hydrostatic bearing options were compared. In this comparison data, especially the results of how much current these two different bearing applications draw during the operation of the grinding machine and what level of surface roughness they produce are analyzed.

Keywords: *Hydrostatic bearing, Hydrodynamic bearing, Hydraulic system, Flow, Surface roughness.*

1. Introduction

In applications where the motion transmission elements encounter high load and speed options, instead of the rolling contact bearing (roller bearing) option, sliding bearing options are prioritized as a more dominant alternative. In hydrodynamic lubricated bearing, which is one of the shaft bearing types that we frequently encounter in industrial applications, the shaft is located in a circular bearing. The shaft diameter is usually between 99.8% and 99.9% of the bearing diameter, and there is usually oil in the gap between. The shaft is in contact with the lower part of the bearing when it is stationary and loaded with a fixed load. If the shaft starts rotating clockwise at a low speed, it will climb in the clockwise or counterclockwise direction depending on the direction of movement of the bearing. If the speed is gradually increased, an oil flow occurs between the shaft surface and the bearing surface, and the shaft begins to swim in the oil film formed. In this case, there is no surface-to-surface contact, therefore, the bearing is made with hydrodynamic sliding bearing, which is a situation where a decrease in sliding friction is observed compared to the initial situation. Friction and heat are released between the parts that transmit force by moving relative, which causes power loss due to wear effect, and lubricants are placed between the parts that move relative to reduce power loss. This is one of the most common situations in all other machine designs, including grinding. In addition, converting the bearing option to hydrostatic lubrication application, that is, by providing a film formed by an externally pressurized fluid between the surfaces with relative movement, power loss can be prevented by controlling friction, heat and wear data. In this study, the advantages of converting hydrostatic lubrication bearing to hydrodynamic lubrication bearing in grinding machines will be emphasized, and the details expressing the design difference have been questioned in particular, and the advantage in energy consumption has been brought to the fore.

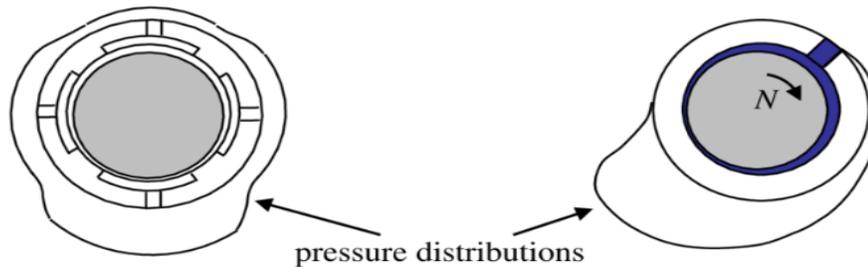


Figure 1: Difference between hydrodynamic and hydrostatic bearing

In grinding machines, bearings with rollers have been used for bearing the spindle shaft until now. The purpose of bearings is to prevent deflection by supporting them with rollers due to the distance that will occur due to the design difference between the spindle shaft and the motor, the minimum contact area is desired as the working principle of the bearings in order to minimize the friction and wear problem that will occur in between, but no matter how small the contact area is kept, a small friction force occurs in between, and due to effects such as temperature differences in the lubricants used, they can lose their properties over time due to the increasing friction force and wear, bearings can lose their properties and cause damage and harm, even if periodic maintenance is done, the calculations made and the results arising from energy losses have led us to the idea of hydrodynamic sliding bearings. Hydrodynamic sliding bearings were made with the idea that they would provide less energy loss and longer life compared to roller bearings. It has been observed that hydrodynamic lubricated bearings have a longer life compared to roller bearings, and that heating, friction and wear problems depending on the machine's movement speed and stopping and restarting are reduced compared to roller bearings. The biggest difference between hydrodynamic lubricated bearings and roller bearings is that friction is theoretically equal to zero when the required speed is created, which is an advantage for us as less energy and longer material life during operation. Hydrodynamic lubricated bearings are not constantly exposed to friction force like roller bearings, the bearing material that is in contact when the spindle shaft is stationary and the spindle shaft starts to break contact with the effect of the compressed lubricant inside when the movement starts, completely eliminating the contact with the appropriate speed and continuing to work completely frictionless, and when the working state ends, it comes back to contact, this situation repeats every time it stops and starts to work again,

and it starts to wear with the friction force that occurs. It causes unwanted damages due to the wear problem. Today, since we see the results that provide longer-lasting machines and more precise processing technology as the primary demands of the market, studies have started on hydrostatic lubricated bearings in the direction of developing hydrodynamic lubricated bearings. Hydrodynamic lubricated bearings are mounted in certain positions as support elements to prevent deflection in the cylindrical drive element. They are seated in their housings in a way that passes through the outer diameter of the shaft that provides the drive. The lubricant liquid inside the hydrodynamic lubricated bearing is designed to provide sealing conditions without leaking out, the lubricating liquid filled inside is in contact with the lower surface of the hydrodynamic lubricated bearing due to its weight when the machine is not working, i.e. when the drive shaft is not rotating, it will continue to be in contact until it reaches a certain speed when the machine starts working, i.e. when the drive shaft is given a rotating motion. This speed must be greater than the sum of the centrifugal force, the weight of the drive shaft and the forces coming from the cutting tool used, the heat and friction created at this time will cause wear on the drive shaft and the hydrodynamic lubricated bearing. Due to the wear problem, the machine will undergo maintenance operations depending on the usage, which can lead to significant cost and time losses in terms of the business.

Materials and Methods

2.1. Hydrostatic Bearings

The most important advantage of hydrostatic bearings is the very low friction and negligible wear of the sliding surfaces, which are completely separated by the oil film formed by the pressurized fluid. Compared to hydrodynamic bearings, which require higher rotational speeds, the hydrostatic bearing ensures that the bearing operates without the hydrodynamic effect of the carrier oil film between the sliding surfaces, even at very low operating speeds. Since the bearing cavity is filled with pressurized fluid, the hydrostatic bearing exhibits high damping ability and high rigidity, while noise emission and vibration transmission are also very low. Due to the absence of solid contact, hydrostatic bearings provide very high motion accuracy and stability [7].

It is used where conventional plain bearings cannot perform the demanding applications of a grinding machine [2]. In hydrostatic plain bearings, the pressure required to form a continuous oil film between the metallic surfaces is provided externally by a high-pressure pump. The oil sent by the pump enters a pocket and flows out from there between the shaft and bearing surfaces. The oil is sent directly to the bearing by the pump [1]. Generally, pocket depths are 0.5-5 mm and bearing clearances are 10-100 μm [4].

Hydrostatic bearings require an external pressure feed system and some type of flow restrictor. The advantages and disadvantages of hydrostatic bearings are given in Table 1. [3].

Table 1: Advantages and disadvantages of hydrostatic bearings

Advantage	Disadvantage
It can handle very high loads.	Requires auxiliary equipment. Higher installation and maintenance costs.
The load is not dependent on the film thickness or the lubricant viscosity.	Fluid filtering equipment is needed.
It has an infinite life since there is no wear on the surfaces.	High power consumption due to pumping losses.
It provides good rigidity and has a high damping coefficient. It provides high accuracy of movement and rigidity.	Damping loss at low and high operating frequencies due to the suitability of trapped fluid volumes and time delay

Due to these properties, hydrostatic bearings have been used to carry and operate large tunnel boring machines, large ship shafts, thrust shaft bearings, thrust bearings, antenna or telescope structures such as the Large Magellan Telescope. Such bearings can be used for large ship propellers, crushing machines, large rotary knives. Another important area where hydrostatic bearings are used is shock load and vibration damping, which is a great advantage in the use of CNC rotary tables and grinding machines for precision workpieces [7].

The hydrostatic bearing consists of two main parts: the hydrostatic pad and the hydraulic circuit. The hydrostatic pad is a fixed part that supports the rotating shaft under load. The second basic part of the hydrostatic bearing is the hydraulic circuit. A fixed low-feed system has a separate hydrogenator for each recess. Therefore, the multi-pad hydrostatic bearing is supplied by a pump with flow dividers and restrictors. The pump supplies a sufficient amount of fluid to the hydrostatic pad at a pressure higher than that required

by the pad. Thus, the flow volume and pressure are controlled by hydraulic valves. Three types of hydraulic valves are used: the path control valve to control the direction of fluid flow, the pressure control valve to control the pressure, and the flow control valve to control the flow rate in the circuit. Flow control valves are particularly important components of the hydrostatic bearing because they maintain constant film thickness by balancing the pressure difference during shock, asymmetrical loading, and vibration [7]. Hydrostatically lubricated bearings allow the element to be lubricated to move without being exposed to friction force and wear problems. Hydrostatic lubricating fluid is provided by an external high-pressure pump to separate the contacting surfaces from each other. Since the high-pressure pump cannot provide separate pressures for each pocket, the required pressure value is given to each pocket using a pump system for each pocket. The lubricating fluid is sent to the contacting surfaces with pressure. In this case, fluid friction can be provided in systems regardless of the kinematic and geometric conditions of the surfaces. Hydrostatic fluid friction is also valid in stationary environments. In other words, there is no wear problem.

2.1.1. Hydrodynamic Bearings

Hydrodynamic bearings are widely used in high-performance machinery to provide long-term, reliable operation. The hydrodynamic bearing process is largely non-contact and, when properly designed and maintained, provides theoretically infinite life. These bearings play a critical role in the operation of equipment found in power plants, oil refineries, petrochemical plants and grinding machines [5]. Bearings transmit the loads of the rotating shaft to the machine support. Hydrodynamic bearings float the load on a self-renewing film of lubricant. Thrust bearings support axial loads. Radial loads are supported by journal bearings. Based on his theoretical study of cylindrical journal bearings, Professor Osborne Reynolds showed that the oil, due to its adhesion to the journal and its resistance to flow (viscosity), is dragged between the journal and journal bearing as the journal rotates, forming a wedge-shaped film (Figure 2.) [6].

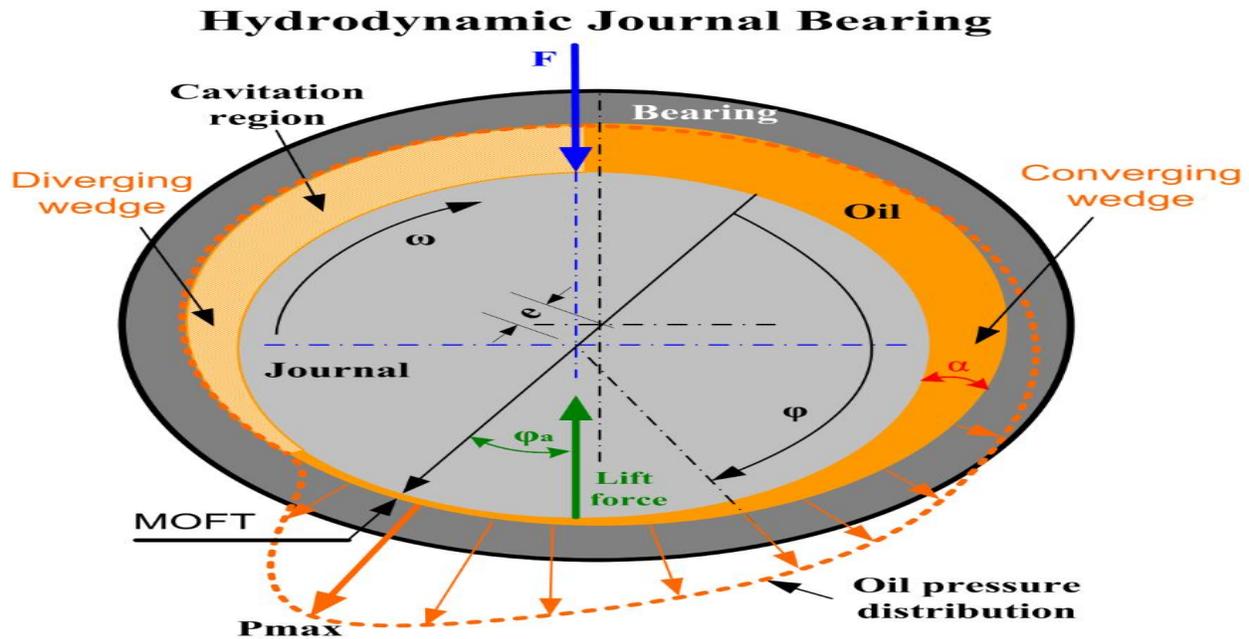


Figure 2: Repetition of pressure and Film thickness

In hydrodynamic bearings, the fluid film is 0.0254 mm (.001") thick. For safe and efficient operation of hydrodynamic bearings, a suitable lubricant must be present on the ring and journal surfaces at all times. The lubricant must be cooled to remove the heat generated by the shearing of the oil before it reenters the bearing. It must also be hot enough to flow freely and filtered so that the average particle size is less than the minimum film thickness [6].

3. EXPERIMENTAL DESIGN

First, the experiment was started on the hydrostatic grinding machine. In hydrostatic grinding, 2 radial bearings were used on the shaft to which the stone was attached. (Figure 3.1)

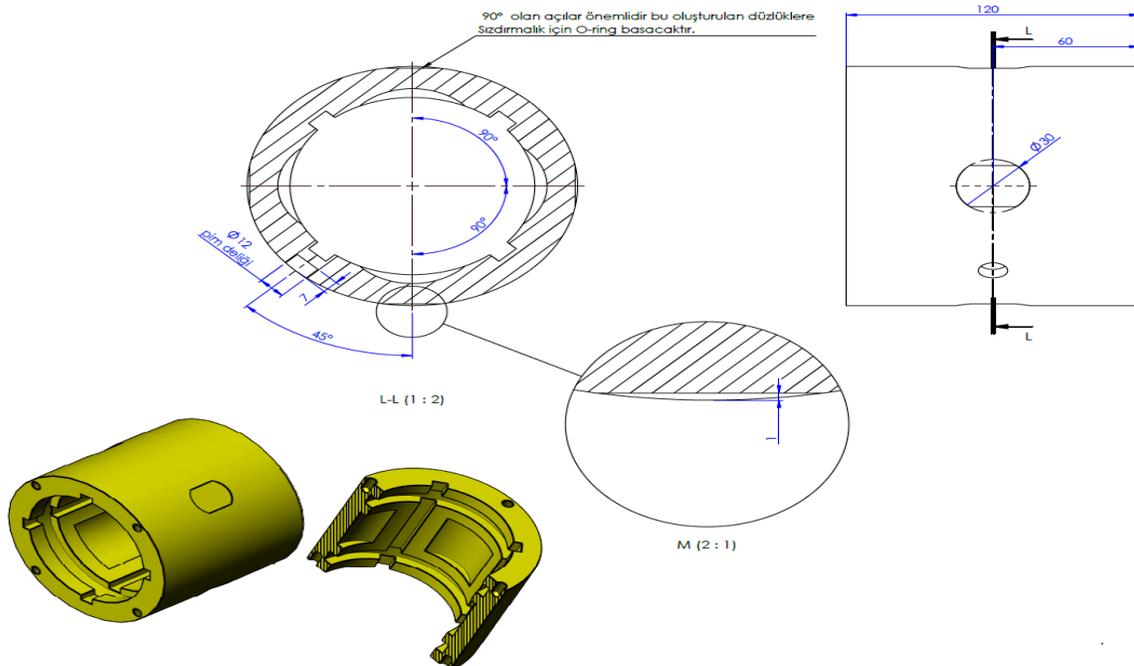


Figure 3: Hydrostatic Radial Bearing

A separate pump was used for each pocket. (Figure 3.2) There are 4 round pockets in each radial bearing. The total number of pockets is 8. ISO VG 10 was used as oil.

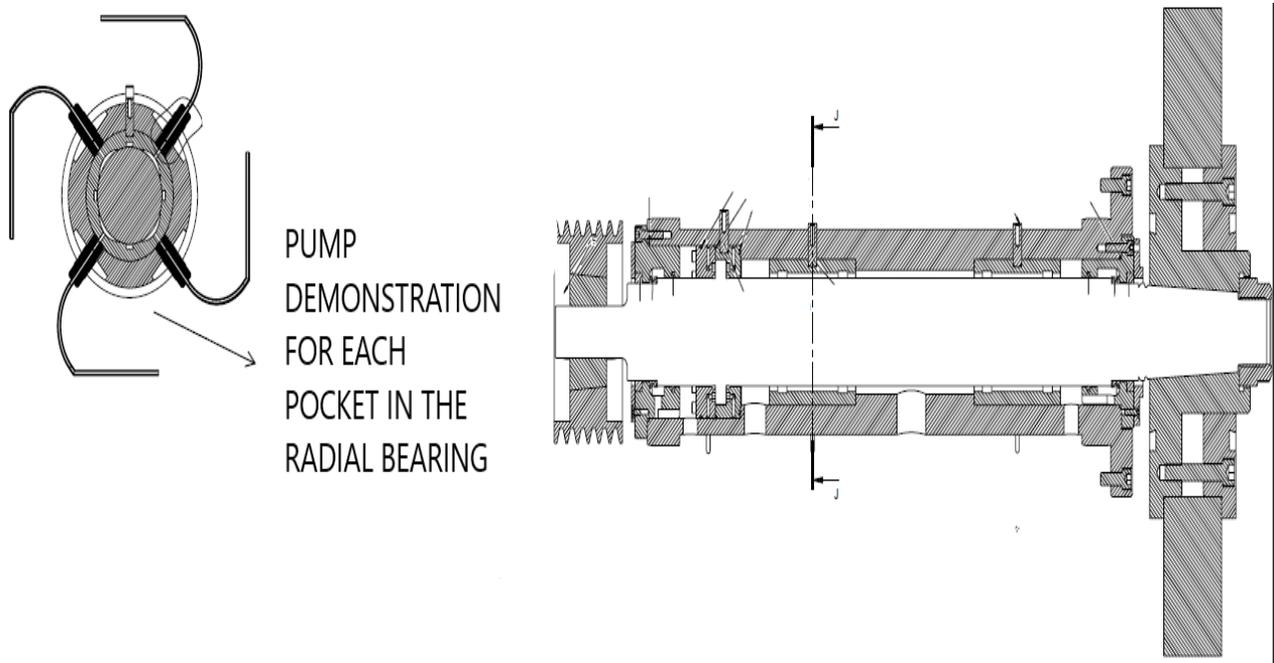


Figure 3.2: Hydrostatic Grinding Spindle Shaft Assembly and Pump Display for Each Pocket



Figure 4: Showing that the hydraulic system is active and there is no contact between the shaft and the bearing.

Thanks to the pressure applied to the pockets in the bearings, the bearing and the shaft do not come into contact. (Figure 3.3) As can be seen, there is a gap between the shaft and the bearing as long as the hydraulic system is active.



Figure 5: Indication of Contact Between Shaft and Bearing When Hydraulic System is Not Active

When the hydraulic system is not active, the shaft and bearing are seen to be in contact. Since the hydraulic system is not active, the pump leaves the oil to press and the smallest bearing clearance of 0.024 mm is seen (Figure 3.4).

In the experiments, a 250x1000 crusher roller cylinder was used. The roller cylinder was placed on the machine with the help of crane and the shaft diameters in the roller cylinder were bearing from the right and left sides. The bearings were tightened and the machine was operated. Then, the zeroing process was started, the right and left sides of the cylinder were seen with the help of a stone, the cone was taken by moving the bearing and the grinding process was started. The hydrostatic grinding machine is shown in Figure 3.5.



Figure 6: Hydrostatic grinding machine demonstration

While the grinding process was in progress, the amount of power exerted by the grinding wheel of the hydrostatic bearing was measured and after the grinding was completed, the surface roughness was examined. The surface roughness was examined from three points, namely the beginning, middle and end (Figure 3.6) and these values are shown (Table 3.1).

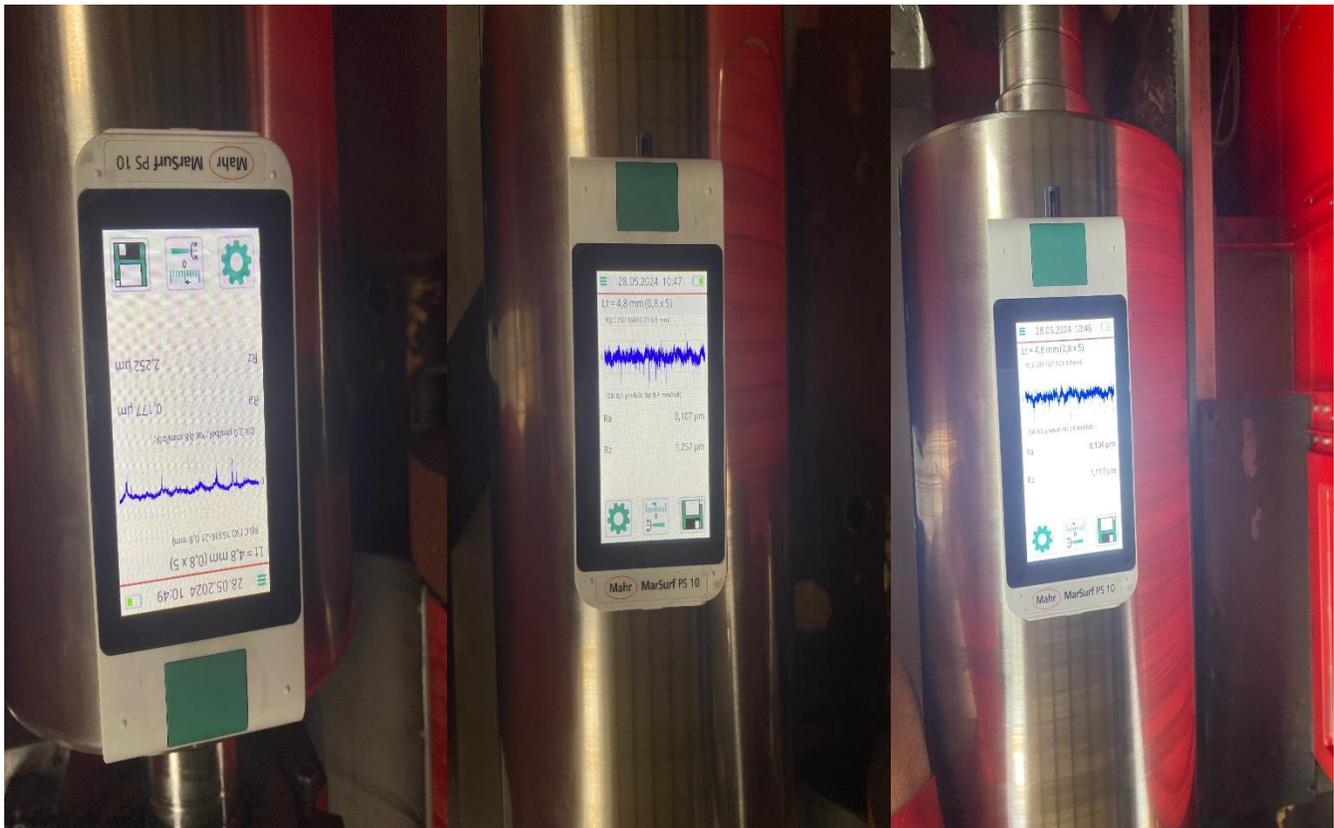


Figure 7: Surface Roughness Values Measured from Three Points in Hydrostatic Grinding

Table 2: Values Measured While the Hydrostatic Grinding Machine is Operating

	VALUE	UNIT
CURRENT	13,70	AMPERE
VOLTAGE	275	VOLT
DC VOLTAGE	522	VOLT
FREQUENCY	34,32	HZ
SURFACE ROUGHNESS (Ra)	0,104-0,107-0,177	μm
SURFACE ROUGHNESS (Rz)	1,117-1,257-2,252	μm
TIME	21	Min

Secondly, the experiment was started on the hydrodynamic bearing grinding machine. In hydrodynamic grinding, 2 radial bearings were used on the shaft where the stone was attached and a single pump was used for the 2 bearings. There are 8 round pockets in each bearing. The total number of pockets is 16. ISO VG 10 was used as oil. Bearing representation (Figure 3.7)

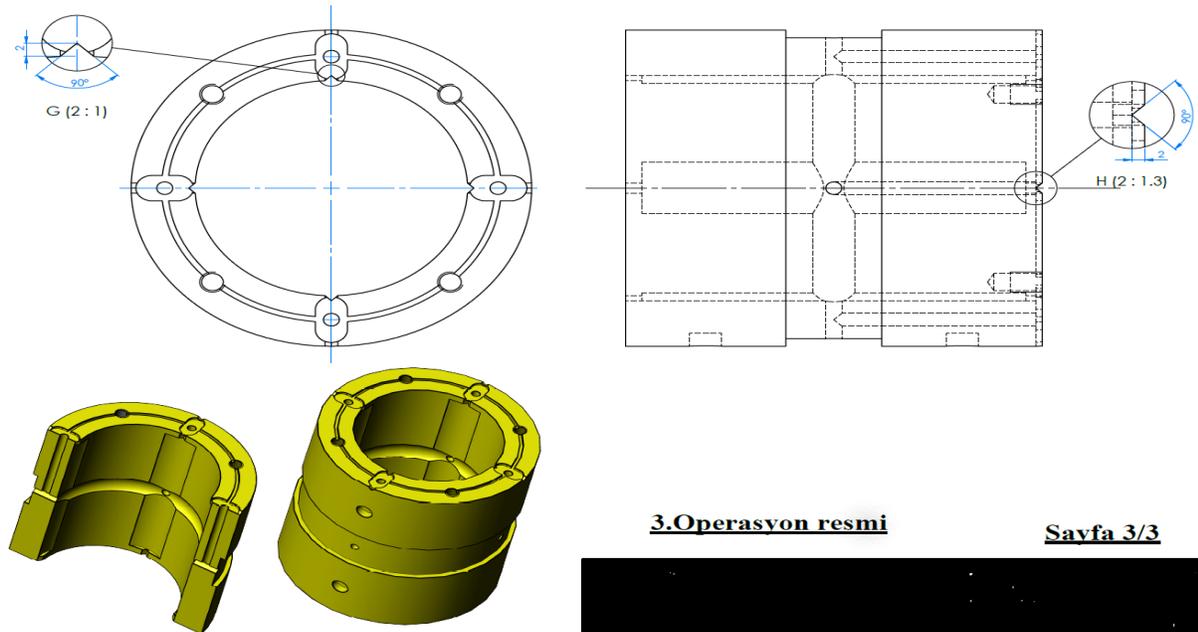


Figure 8: Hydrodynamic Bearing Representation

There are 2 oil inlets and 2 oil drains in the shaft bearing assembly. The shaft bearing assembly is shown in Figure 3.8. Thanks to the oil applied to the pockets in the bearings, the shaft and the bearing come into contact as much as the oil film. It is known that some time is required for the formation of the oil film. As seen in Figure 3.8, the contact between the shaft and the bearing is initially theoretically between 0.008-0.02 mm and the contact disappears after the shaft starts rotating.

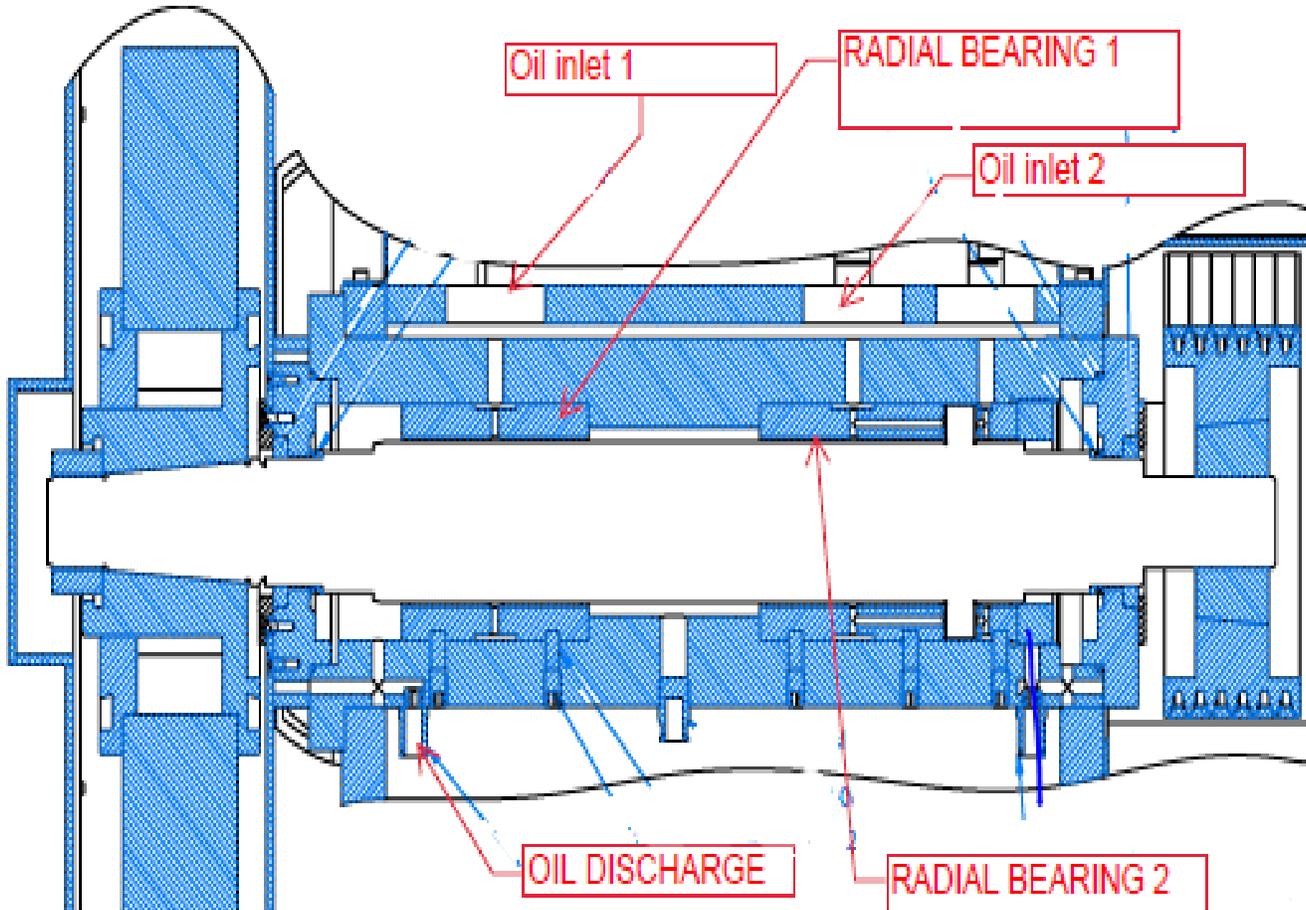


Figure 9: Demonstration of Spindle and Bearing Assembly in Hydrodynamic Grinding

In the experiment, a 250x1000 crusher roller cylinder was used. The roller cylinder was placed on the machine with the crane half and the shaft diameters in the roller cylinder were bearing from the right and left sides. The bearing was tightened and the machine was operated. Then, the resetting process was started, the amount of conic on the right and left sides of the cylinder was seen with the help of a stone, the bearing was moved and the cone was taken and the grinding process was started. The machine picture is shown in Figure 3.9.



Figure 10: Hydrodynamic Grinding Machine

While the grinding process was in progress, the amount of power exerted by the grinding machine with hydrodynamic bearing was measured and after the grinding was completed, the surface roughness was examined. The surface roughness was examined from three points, namely the beginning, middle and end (Figure 3.10) and this value is shown in Table (3).

Table 3: Values Measured While the Hydrodynamic Grinding Machine is in Operation

	Value	
CURRENT	18,32	AMPER
VOLTAGE	387	VOLT
DC VOLTAGE	519	VOLT
FREQUENCY	33,45	HZ
SURFACE ROUGHNESS (R_a)	0,212-0,266-0,217	μm
SURFACE ROUGHNESS (R_z)	1,956-2,173-1,765	μm
TIME	21	min



Figure 11: Surface Roughness Values Measured from Three Points in Hydrodynamic Grinding

4. Results

This article examines hydrostatic and hydrodynamic bearings. Literature research on hydrostatic and hydrodynamic bearings has been conducted and compared with experiments. In the hydrodynamic bearing type, which is one of the spindle bearings we use in grinding machines, there is a gap of 0.01-0.02 between the spindle and the bearing, and there is oil in this gap. In the bearings we use in hydrostatic grinding machines, it is 10-100 μm and the spindle rotates in the gap thanks to the oil coming from each pocket in the bearings thanks to the pump. In the experiments we conducted on both machines, a 250 mm diameter and 1000 mm long crusher roll cylinder was used. In the experiments, current, voltage, frequency, surface roughness and time were taken into consideration and compared. In line with these results, it was concluded that the hydrostatic bearing grinding machine is more efficient and has a better surface processing quality when the current drawn and surface roughness are taken into consideration.

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