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Controlling the Surface Friction of Rotating Rods by Laser Surface Engraving

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Abstract: The method of creating a design or pattern on a substance with a laser is called laser engraving. Material is removed from the material's surface using laser, leaving a lasting mark in its wake. A wide range of materials, including glass, metal, plastic, and wood, can be engraved using a laser. Laser engraving is an extremely accurate method that can yield excellent outcomes. Designs and patterns that are laser-etched can be incredibly complex and detailed. Additionally, laser engraving is a quick and efficient technology that can be used to swiftly and efficiently engrave vast quantities of objects. One popular kind of bearing that finds usage in many different applications is a rolling shaft in a hole. It is made up of a shaft that rolls inside a hole on a bearing surface. Its rolling motion lowers wear and friction, making it a very effective kind of bearing. Numerous devices, such as engines, gearboxes, compressors, pumps, motors, turbines, aircraft, cars, and industrial machinery, require rolling shafts with holes in them. The shaft and bearing surface materials need to be suitable and strong enough to handle the application's load and speed. To cut down on friction, the bearing surface and the shaft's surface polish should be smooth. Shaft wobbling should be avoided by maintaining a small enough but sufficient gap between the shaft and the bearing surface to permit lubrication. The kind of lubricant that is utilized needs to be suitable for the temperature range and the application. The bearing's load capacity should not be exceeded by the load placed on it. In this study, the rod was engraved with slots using a laser engraving machine so that it could be filled with oil to lower temperature and friction while rotating. With the hole, the rod will act as its lubricant.When the number of slots increases, the temperature and friction decrease, especially in high speeds, compared to without slots.

Keywords: laser engraving, shaft, bearing, self-lubricant, friction.

1. Introduction

There are many uses for laser engraving, making it an extremely flexible method [1]. Among the many applications for laser engraving are: personalizing goods like jewelry, pens, and signs, making moulds and dies, engraving artwork and photos, marking industrial items and components, and creating product labels and tags. Laser engraving is an extremely accurate method that can yield excellent outcomes. Designs and patterns created by laser engraving can be incredibly complex and detailed [2]. Additionally, quick and efficient, laser engraving is a technology that can be used to swiftly and efficiently engrave vast quantities of objects.

The following are a few benefits of laser engraving: Precision: Laser engraving is a highly accurate technique that yields excellent outcomes.Speed: Laser engraving is a highly quick procedure that may be utilized to efficiently and swiftly engrave a huge number of objects [3]. Versatility: Wood, metal, plastic, and glass are just a few of the materials that laser engraving may be utilized on. Permanence: Marks created by laser engraving are unaffected by fading or wear over time. Durability: Products with laser engravings are incredibly robust and resilient to a great deal of wear and tear. The procedure of laser engraving is dependable and safe [4]. However, when utilizing a laser engraver, it's crucial to follow basic safety guidelines. When using a laser engraver, wear safety eyewear should be worn at all times and take care not to breathe-in the laser's vapors.All things considered, laser engraving is a very strong and adaptable technique that has many uses. It is an accurate, quick, and long-lasting procedure that may be applied to produce goods of superior quality.

Equipment for 3D laser engraving is frequently used to manufacture personalized awards, trophies, and other decorative items. They can also be used to create molds for injection molding and other industrial procedures. Some benefits of using a 3D laser engraving machine are as follows: The first advantage is adaptability; a wide variety of materials, such as wood, glass, crystal, metal, and plastic, may be engraved using 3D laser engraving machines. Precision makes up the second category. Such 3D laser engraving machines can produce incredibly precise and intricate patterns. Speed is the third factor since 3D laser engraving machines can quickly engrave designs. Fourth, 3D laser-etched patterns have a long lifespan and are incredibly durable.

Friction will prevent a rolling rod from rolling when it is in a hole [5]. The materials of the rod and the hole, their surface finishes, the normal force between them, and the presence of any lubricants are some of the variables that will affect how much friction there is. Friction is influenced by temperature in several ways. Initially, it may have an impact on the viscosity of any lubricants that are used. Friction will be decreased by a greater temperature because it will cause the lubricant to become less viscous [6].

Second, the materials' elastic modulus [7] for the rod and the hole-containing shaft might be impacted by temperature. Elevated temperature causes the elastic modulus to decrease, resulting in increased deformability of the materials. Friction will rise as a result.Third, the hole and the rod may expand thermally due to temperature. Friction will rise if the rod and hole fit more tightly as a result of this.

In this paper, slots created on a steel rod using laser engraving that is lubricant-saturated will regulate the rod's rotation within the hole.

2. EXPERIMENTALSETUP

One type of laser engraving apparatus that can create three-dimensional designs on materials including wood, glass, and crystal is the 3D laser engraving machine depicted in Fig. 1. The material's surface is targeted by a laser beam, which evaporates it at the focal point. The desired pattern is then created by moving the laser beam over the material`s surface.

The laser engraving machine used for the experiment is GL-FMC100 from Qingdao YanconBaoshengda Industry Co., Ltd as shown in Fig.1 witha rigid table and rotarychunk with laser power 100W and power supply 220V 50HZ 10A. The Machine specifications for 3D laser engraving is listed in Table 1 [8] as listed in its catalog.

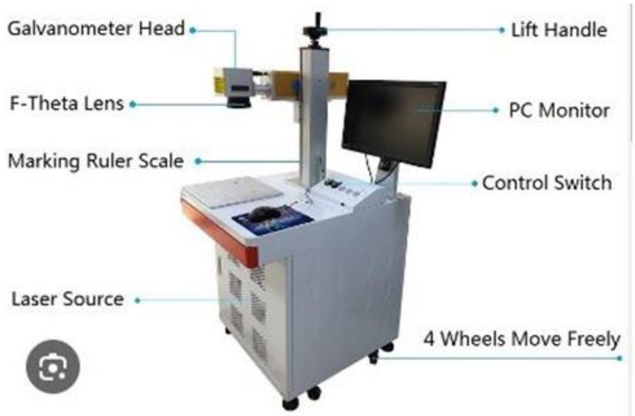

FIGURE 1. 3D Laser engraving machine used for the experiment

TABLE 1. Machine specifications of Laser engraving

Parameters	Power (W)	Frequency (kHZ)	Speed (mm/sec.)	Number of paths	Hatching
Range	0 - 100	0 - 100	20 - 1000	5	constant

2.1 Workpiece Materials

Steel 37 (Fe 99.43-99.75%, C 0.08%, Mn 0.25-0.4%, S 0.05%, P 0.04%) was selected for the experimental work. The workpiece had a thickness of 20 mm, holes with a diameter of ø14 j6, and a Brinell hardness of approximately 100 HB [9]. The diameter of the rod was 14 mm. Table 2 displays the characteristics of these materials.

2.2 Design of Experiments

It's critical to take action to stop rotation-related temperature increases from becoming problematic. For instance, to lower friction, bearings should be greased regularly. To lessen vibration, rotating machinery should be balanced.

In this work, average temperature readings are obtained after rods rotate inside holes with an average time taken from 3 to 8 minutes with varying speeds on a drilling machine, and the experiment was repeated with slotted rods engraved on a laser machine filled with hydraulic oil with the same conditions, and the average temperatures are recorded.

Following this experiment, a laser engraving machine was used to create several slits in the rods; a total of 36 trials needed to be carried out. Table 3 lists the input elements and their corresponding levels. The experiment was run three times for each level during rotation.

TABLE 2. Properties of Material used

Property	Steel 37
Equivalent Grades	AISI 1006
Composition	(Fe 99.43-99.75, C 0.08, Mn 0.25-0.4, S 0.05, P 0.04)
Elongation %	22
Tensile Strength MPa	370
Yield Strength (0.2%) MPa	300
Shear Strength MPa	230
Hardness Brinell	100
Density g/cm3	7.8
Melting Point (±50) °C	1470
Thermal Conductivity W/mK	53
Electrical Conductivity % IACS	6.9

The temperature measured by a spinning rod within a hole made by a drilling machine using variable speeds (280-540-1600) r.p.m taking approximate time from 3 to 8 minutes for measuring and the result of the corresponding temperature listed in Table 4. The average output temperature was calculated in Table 5 that is resulted from table 4.

2.3 Preparation of Specimens

A close-up of the plate with three holes drilled is shown in Fig. 2, and the rotating Φ14 H7 j6 rods were used in the experiment to rotate the rods inside the hole using a drilling machine as shown in Fig. 3. In Fig. 4, a laser engraving machine is displayed, which is utilized to create slots on the revolving rods.

TABLE 3. Input factors and their levels

Process	Factors, Symbol (units)	Levels		
Laser	Power (W)	100		
	Frequency (MHz)	100		
	Speed (mm/sec)	500		
	Number of Paths	5		
	Hatching	Constant		
Rotating Rods	Speed of rotating rods (R.P.M)	280	540	1600
	Time of rotation (min.)	Approximately from 3 to 8		
	Oil used	NUTO H 68		

TABLE 4. Process variables and their corresponding responses

Speed (R.P.M)	Δ Time (min.)	Temperature (0C)	Temperature with oil (0C)	Temperature with 2 slots (0C)	Temperature with 3 slots (0C)
280	3 to 8 min	50	45	32	26
280	3 to 8 min	55	44	30	27
280	3 to 8 min	53	40	28	25
540	3 to 8 min	58	52	45	28
540	3 to 8 min	60	55	47	30
540	3 to 8 min	59	54	42	29
1600	3 to 8 min	60	52	47	31
1600	3 to 8 min	62	56	40	28
1600	3 to 8 min	61	57	45	27

TABLE 5. Average output Temperature

Speed (R.P.M)	Δ Time (min.)	Δ Temperature (0C)	Δ Temperature with oil (0C)	Δ Temperature with 2 slots (0C)	Δ Temperature with 3 slots (0C)
280	3 to 8 min	53	43	30	24
540	3 to 8 min	56	54	45	29
1600	3 to 8 min	61	55	44	29

FIGURE 2. Plate material blank mounted on Laser machine

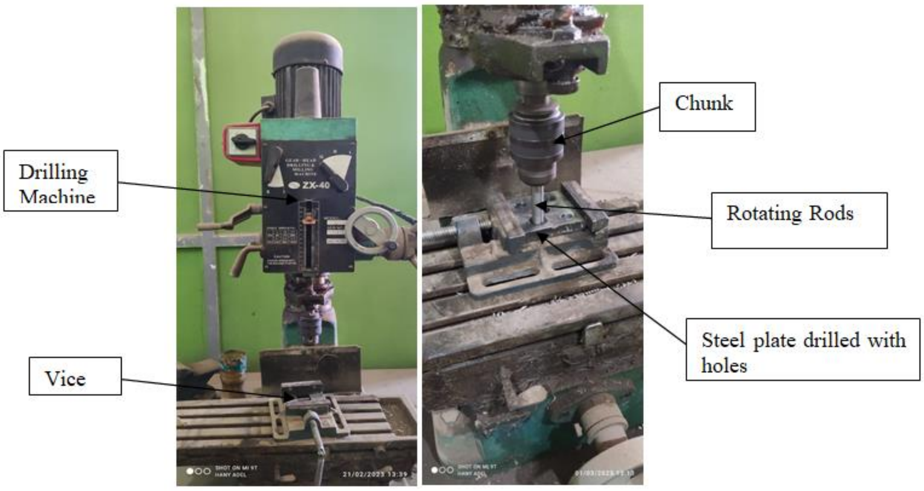

FIGURE 3. The Drilling machine was used in the experiment and the installation of the rod and the plate

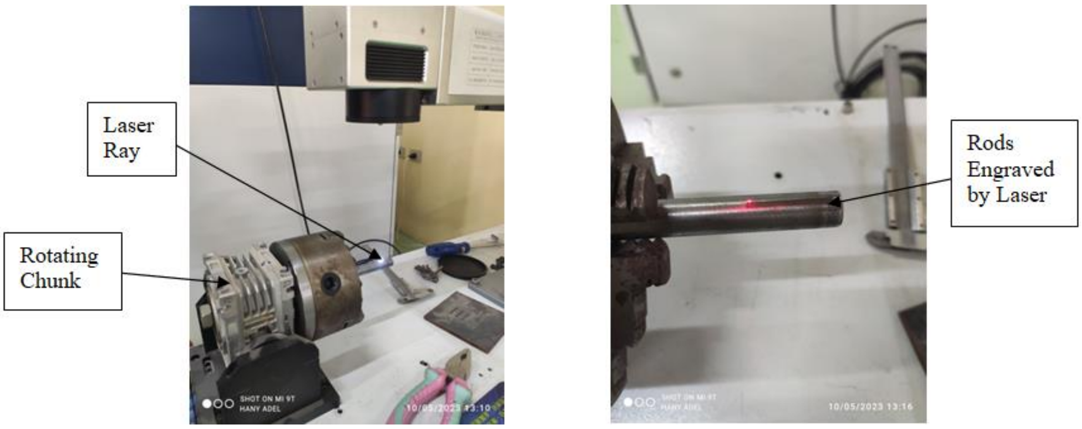

FIGURE 4. The Laser Engraving machine used in the experiment

2.4 Temperature (ΔT)

The Temperature was measured by an infrared thermometer temperature gun as shown in Fig. 5.

FIGURE 5. Infrared thermometer temperature gun tester

2.5 Slots

Slots are formed in the rods by a laser engraving machine with dimensions equal to the thickness of the workpiece which is 20mm length and 2 mm width as shown in Fig. 6

2.6 Oil used [10]

Nuto™ H Series oils are good quality anti-wear hydraulic oils intended for industrial and mobile service applications, subjected to moderate operatingconditions and requiring anti-wear lubricant. Their effective oxidation resistance and chemical stability support good oil life in moderate to severe applications.

FIGURE 6.Slots engraved in Rotating Rods

Features and Benefits

- Good anti-wear performance helps reduce pump wear and prolonging pump life
- Corrosion protection helps reduce the effects of moisture on system components
- Filterability to prevent filter blockage even in the presence of water

Applications

- Systems using gear, vane, radial and axial piston pumps and those containing gears and bearings where mild anti-wear characteristics are required
- Where hydraulic oil contamination or leakage is unavoidable
- Where small amounts of water are unavoidable

3. RESULTS & DISCUSSION

Using a laser to etch three-dimensional patterns on a material is known as 3D laser engraving. Despite being a relatively new technology, it has become highly popular very quickly for a variety of applications, including the creation of jewelry, medical equipment, and industrial parts. Steel 37 and other mild steel are commonly used in structural applications. It is inexpensive and easy to use. But compared to other types of steel, it is not as strong or resistant to corrosion.

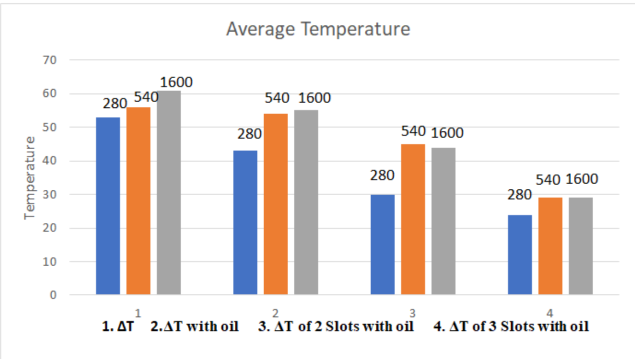

FIGURE 7. Average temperature readings with different speeds

In this experiment, Figure 7 shows the variation of temperature with rotating speeds. The highest temperature was observed at high speeds when the rod rotated inside the hole with transition interference, as shown in Figure 7 (1), which indicates high friction occurred.

When putting hydraulic oil on the rod while rotating inside the hole, the temperature decreased compared to without oil, as shown in figure 7 (2).

Laser engraving machine used to make slots in the rods to be filled with oil used to decrease the friction between the rods and the hole while rotating.

Two and three slots were engraved in two different rods and filled with hydraulic oil, as shown in figure 7 (3, 4). It was observed that the temperature decreased due to the reduction of friction between the rod and the hole. As the number of slots increases, the temperature and friction decrease, which will act as a self-lubricant under rotation.

when the rotational speed increases, the temperature increases which increase the friction between the rod and hole.

The particulars of the situation will determine how temperature and friction affect a rolling rod in a hole overall. But generally speaking, friction will resist the rod rolling and temperature will tend to increase friction; therefore, it was minimized by utilizing laser engraving to create grooves in the rods and hydraulic fluid to lower temperature and friction. The rotating rod will lubricate itself.

4. CONCLUSION

A rolling rod's performance in a hole can be greatly influenced by temperature and friction.

1. It is feasible to design bearings and other systems that minimize friction and maximize performance by knowing how these elements affect friction and how laser engraving helps to achieve this.
2. The rod was engraved with slots using a laser engraving machine so that it could be filled with oil to lower temperature and friction while rotating.
3. With the hole, the rod will act as its lubricant. When the number of slots increases, the temperature and friction decrease, especially in high speeds, compared to without slots.

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