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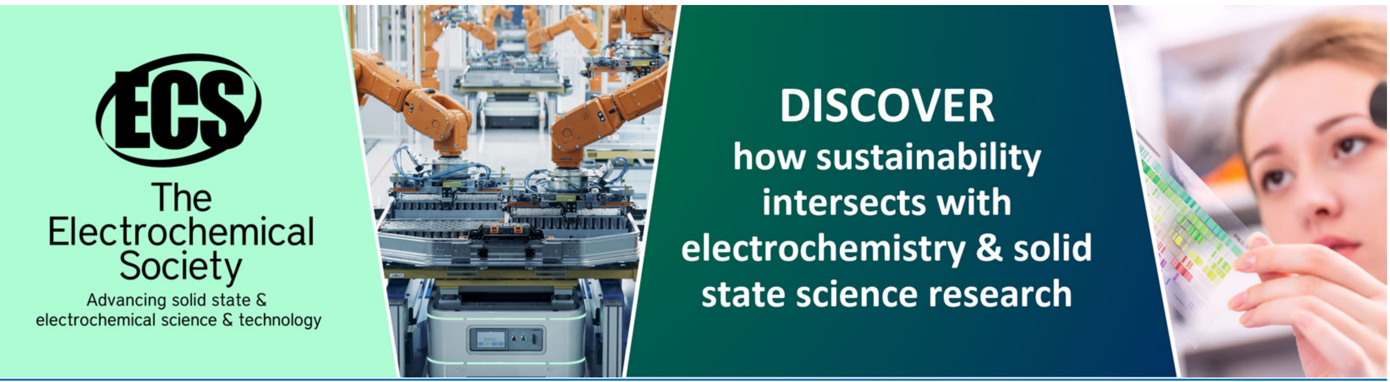

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Investigation of wear in a 3D printed Shaft – Bearing mechanism using different Lubricants

Devanshu Jain*[1], Akash Jain[1] and Prof. RC Singh[1]

[1]Delhi Technological University, India

Abstract. Wear is the damaging, gradual removal or deformation of material at solid surfaces. The material loss due to wearing of interacting surfaces is a major concern. This not only decreases the life of the components that are interacting but also lead to various hazards. A lubricant is a substance, usually organic, introduced to reduce friction between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces interact. The experiment has been carried to study the wear rates of the tribopair and effect of lubricants on it. The shaft was fabricated by using an inhouse built 3-D printer. It is performed using a shaft-bearing mechanism. This research article discusses the study of measurement of the reduction in wear in the materials Polylactic Acid and an MDF board using HP grease AP3 and Loctite Maintain as two different lubricants.

1. Introduction

In the modern-day world, efficiency has become the major aspect of any products performance. Professionals in various industries, like, automotive, mechanical, electrical, and computer etc, are working towards improving the efficiency of the product being manufactured. In this high competent time, every company tries to improve their product's performance to the maximum level.

In the mechanical and automotive industry wear is the major killer of the product's performance. Wear is the progressive elimination of material from either of the two surfaces in relative movement (sliding, rolling or impact) [1]. This not only hampers the life of the product but also reduces its efficiency. The number of cycles completed by an internal combustion engine's piston during its operation determines how efficient it is. Due to constant operation, gradual wear occurs and it is not able to provide the required torque due to energy loss. This hampers the engine performance.

Wear is caused as a consequence of friction. When two surfaces are in relative motion then friction is created, as a resisting force, between them due to their roughness. Rougher a surface is, more is the friction created. The frictional force tends to oppose the relative motion of the surfaces and thus leads to surface wear.

Lubricants are substances that are applied between the interacting surfaces so that the relative rubbing is hindered. This process is thus termed as lubrication. Lubrication helps in lowering the frictional force built up and reduces wear by enabling the surfaces to slide smoothly. Lubricants can be of three major types: solid, aqueous and gas. The aqueous lubricants further classified on the basis of the base oils used in their production.

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Viscosity of lubricants plays a major role in the movement of surfaces and thus the efficiency. As the viscosity of the liquid lubricant increases, the coefficient of friction decreases making the surface interaction smoother.[4]

2. Design

The shaft used for the experiment was designed on SolidWorks v2018.

A key is mounted on the shaft to connect it with the rotating machine elements like pulleys, gears etc [2]. In the design, the key is mounted in order to easily detect the wear on the contact surface.

The specifications of the design are tabulated as follows:

Table 1: Specification of Shaft Design

Length	25 mm
Outer Diameter	12.5 mm
Inner Diameter	6.5 mm
Key Width	1 mm

The different views of the shaft are shown in Figure 1 and Figure 2.

Figure 1: Front View of Shaft

Figure 2: Design of the Shaft

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3. 3-D PRINTER SPECIFICATIONS

The shaft was printed using the CREALITY3D CR-10 3D printer. The forming technology adopted by the printer is Fused Deposition Modelling (FDM), which is also termed as Melt Manufacturing. It is the most widely used method of 3D printing.

The nozzle diameter of the machine is 0.4 mm and the filament diameter are 1.75 mm. The printer works at a speed of 60mm/s when a power of 270W is delivered to it [3]. The 3-D printer used for the experiment is shown in Figure 3.

Figure 3: CREALITY3D CR-10 3-D Printer

4. Lubricants Used

In this study, the lubricants used are HP grease AP3 and Loctite Maintain. These two lubricants are chosen because they belong to the different classifications of lubricants. HP grease AP3 is a semi-solid lubricant whereas Loctite Maintain is a liquid lubricant. These are different in terms of their viscosities. The varying properties makes it easy for the investigation to give measurable results.

HP grease AP3 is an NLGI grade 3 grease manufactured by HP Lubricants. It is light yellow, smooth and uniform in appearance with a mild petroleum odour. The kinematic viscosity of the lubricant is 90 – 110 cSt. It has a vapor density greater than air and the flash point is around 200°C. Its main advantage is that it is insoluble with water.[5]

Loctite Maintain is a light, semi-drying oil type shower that infiltrates, greases up, expels water, counteracts rust and cleans. It is clear liquid with specific gravity of 0.8 and flash point of -142°F. The viscosity is similar to SAE 10 Motor Oil (~ 481.9125 cSt). [6]

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(a) (b)

Figure 4: (a) HP Grease AP3 (b) Loctite Maintain

5. Experimental setup

For the purpose of carrying out the experiment we need the given materials, MDF board, drilling machine, 3D printed shafts, High torque 500 RPM DC motor, 1200mAh LiPo battery, Vernier Calliper, HP grease AP3 and Loctite Maintain, as shown in Figure 5.

Figure 5: Apparatus Used in the Experiment

A hollow shaft was 3D printed using PLA (Polylactic Acid), as shown in Figure 6. One end was fixed to a high torque 500 RPM motor and the other end was free.

The shaft of the motor was D-shaped and hence a corresponding hole was given in the 3D printed shaft to ensure positive drive. Holes were drilled corresponding to the outer diameter of the 3D printed shaft in MDF board to make the bearing. The MDF board was clamped to a vice, and the shaft was inserted in the hole drilled, as depicted in Figure 3. The motor was then powered by a 12V Lithium Polymer (LiPo) battery for 2 minutes and the time was noted for three different cases - no lubrication, NLGI 3 grease and Loctite Maintain.

Initial measurement of the shaft and hole were taken using a Vernier calliper. The shaft was inserted into the bearing to complete the shaft and bearing setup without applying any

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lubrication. The batterys was connected to the motor and a timer was started for 2 minutes. After 2 minutes, the battery was disconnected and the final measurement of the shaft and bearing were noted using a Vernier calliper. The procedure was repeated with and without the application of lubricants. First NGLI 3 grease was used to carry out the experiment and then Loctite Maintain was used.

Figure 6: Shaft being 3-D Printed

Figure 7: Experimental Setup

6. Observations and Analysis

PLA and MDF were used as the materials for shaft and bearing respectively because of the high wear rate. This was desirable as values for wear could be easily measured in small operation time and the effect of lubricant could be observed easily.

Table 2: Observations

S.No.	Case	Time (min)	Initial Shaft (mm)	Final Shaft (mm)	Initial Bearing (mm)	Final Bearing (mm)	Reduction in shaft (mm)	Increase in bearing (mm)
1	No Lubrication	2	12.95	12.75	12.4	13.4	0.20	1.0
2	HP Grease AP3	2	12.95	12.90	13.4	13.6	0.05	0.2
3	Loctite Maintain	2	12.95	12.70	13.5	13.6	0.25	0.1

As seen from the observation table, it can be seen that application of grease significantly reduces the wear in the shaft and bearing. The application of Loctite however leads to a greater wear in shaft and less wear in the bearing. This is due to the fact that Loctite got absorbed into the MDF causing the hole to swell and applying greater pressure onto the shaft hence leading to greater wear. The wear in the shaft was offset due to the swelling and hence a lower value was registered. This phenomenon did not occur with the grease as it wasn't absorbed by the MDF. It could therefore be inferred that lubrication in the bearing leads to lower wear.

7. Conclusions

Lubrication with grease leads to significantly lower wear in the shaft and bearing mechanism compared to no lubrication. Application of Loctite should lead to lower wear rates in metals however the values for the current setup were offset due to absorption by the MDF.

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