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GEARBOX PERFORMANCE ANALYSIS COMPARISON FOR SYNTHETIC AND MINERAL OIL

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ABSTRACT: The correct choice of lubricants is of fundamental importance for the operation of contacting moving part systems, providing minimal wear of the parts. However, given the viscosity characteristics of different oils, a secondary but also important objective is the energy savings that may be a factor in the choice of lubricants. This work aims to quantify and compare the electrical and mechanical performance of a helical gearbox using two different types of lubricants: ISO VG 150 gear mineral oil and ISO VG 150 gear synthetic oil. From the results, should be able to choose the most energy efficient lubricant. The tests were performed on a bench with a 0.33 hp MANUFACTURER I gearbox motor coupled to a 0.67 hp MANUFACTURER II gearbox motor. To ensure that minimal mechanical energy was lost between the input of the two gearbox motors, the system was aligned using the FixturLASER XA Pro laser aligner. The oil change was performed using the flushing technique to mitigate the possibility of system contamination from the change of the two oils. For the analysis of electrical consumption and mechanical torque, as well as the "lifetime" of the two gearbox motors, the BAKER EXPLORER 4000 equipment was used.

KEYWORDS: Lubrication, Energy Efficiency, Gearbox, Industrial Maintenance

COMPARACIÓN DEL ANÁLISIS DEL DESEMPEÑO DE LA CAJA DE ENGRANAJES PARA SINTÉTICO Y MINERAL LUBRICANTES

RESUMEN: La elección correcta de lubricantes es de suma importancia para la operación de sistemas de partes móviles de contacto, proporcionando un desgaste mínimo de las partes. Sin embargo, dadas las características de viscosidad de los diferentes aceites, un objetivo secundario, pero también igualmente importante es el ahorro de energía que puede ser un factor en la elección de los lubricantes. Este artículo presenta un estudio que tiene como objetivo cuantificar y comparar el rendimiento eléctrico y mecánico de un reductor de engranajes helicoidales utilizando dos tipos diferentes de lubricantes: aceite mineral para engranajes ISO VG 150 e aceite sintético para engranajes ISO VG 150. De los resultados, puede elegir el lubricante con mayor eficiencia energética. Las pruebas se realizaron en un banco con un motorreductor FABRICANTE I de 0,33 hp acoplado a un motorreductor FABRICANTE II de 0,67 hp. Para garantizar que se perdiera una energía mecánica mínima entre la entrada de los dos motorreductores, el sistema se alineó utilizando el alineador láser FixturLASER XA Pro. El cambio de aceite se realizó utilizando la técnica de flusing para mitigar la posibilidad de contaminación del sistema por el cambio de los dos aceites lubricantes. Para el análisis del consumo eléctrico y el par mecánico, así como la "vida útil" de los dos motorreductores, se utilizó el equipo BAKER EXPLORER 4000.

PALABRAS CLAVE: Lubricación, Eficiencia Energética, Reductores, Mantenimiento Industrial

1. INTRODUCTION

Contact moving parts of all equipment are subject to wear, which leads to the appearance of defects that affect continuity and quality of the machine. An unforeseen breakdown translates into a sudden stop, which can lead to large losses and loss of time and production (LAGO and GONÇALVES, 2006). In order to avoid a downtime in a production line the predictive maintenance expense is small compared to the financial expense due to breakdown or failure. For gear units, in particular, oil analysis and vibration analysis are of paramount importance to ensure uninterrupted operation.

The main functions of the gear units are to restrict speed, maximize torque and transfer motion. They are essentially formed by a welded or cast structure, shafts, gears, pinions, bearings and retainers. The elements of its interior that most deteriorate with its operation are the gears, bearings and seals. Through the use of a suitable lubricating oil, these damages caused by friction can be lessened (ARAÚJO, 2011).

In order to minimize friction and deterioration, remove heat and particles formed by friction between the moving parts, it is necessary to insert a lubricant (LAGO, 2007). According to CPM (1997), lubricants can be pasty, solid and even gaseous depending on their physical state. These are determined by viscosity. Among the lubricant branches, there are synthetic oils, pure mineral oils, fatty oils, additives and compounds.

The first lubricants were of animal origin, but over time, man was perfecting and creating new inventions and, by necessity, the lubricants were also evolving, having bases of plant, mineral and synthetic origin. Today's high performance, modern lubricants are far more important than simply reducing friction and wear. The latest generation lubricants can also control the formation of deposits, suspended contaminants, protect against corrosion, clean components and maintain the correct operating temperature (AZEVEDO, FONSECA and CARVALHO, 2005).

Mineral oils are obtained through the distillation of petroleum, their properties are directly linked to the nature of crude oil, from which the diverse composition is formed by hydrocarbons that belong to paraffinic, naphthenic and aromatic classes. It is important to note that this type of oil is the most used and important in lubrication. Synthetic oils, come from a laboratory polymerization process, which seeks to offer special viscosity and resistance characteristics in order to meet special industries applications (SOUZA, BRITO, SILVA and SILVA, 2017).

Fluids, in general, vary viscosity with temperature, and therefore the resistance they exert to movement during machine operation also diverges. Dynamic viscosity is the property that determines the fluid resistance to a shear force. Studies demonstrate that this magnitude is highly influenced by changes in temperature. (OLIVEIRA, BARROS and ROSSI, 2009). The behavior of the viscosity

according to the temperature (T) is patterned by the Arrhenius, equation 1, E_a which corresponds to viscous flow activation energy; R is the universal gas constant and μ_∞ corresponds to the dynamic viscosity when the temperature tends to infinity.

$$\mu = \mu_\infty \times \exp\left(\frac{E_a}{R \times T}\right) \quad (1)$$

The objective of this study is to analyze and compare the energy performance of the mineral and synthetic lubricant oil, both for ISO VG 150 gears, which although having the same rated viscosity, exhibit different viscosity curves as a function of the operating temperature.

2. MATERIALS AND METHODS

Experimental tests have been developed in the Dynamic Systems Laboratory (LASID), Mechanical Engineering Department (DEMEC) of the Federal University of São João del - Rei (UFSJ).

For this research a setup was preperade with a MANUFACTURER I gearbox motor acting as a drive system and a MANUFACTURER II gearbox motor acting as a load. The goal is to simulate the most common industries working conditions. The gearbox motor oil was changed for comparison, while the load gearmotor remained with the same oil throughout the test.

In Figure 1 is shown the setup test and the equipment used to perform this study , in which [1] is the AC voltage regulator for load control; [2] is the MANUFACTURER II gearbox motor used as a load; [3] is the MANUFACTURER I gearbox motor used as the system driver and [4] Baker Explorer 4000 equipment used for data acquisition and diagnostics.

FIGURE 1. Test bench. Source: Author (2019).

To ensure minimum energy loss in the coupling between the two gearbox motors and thereby obtain more accurate results, the system was aligned using a laser aligner Fixturlaser XA Pro. The results of the vertical and horizontal alignment are shown in Figure 2.

FIGURE 2. Vertical (left) and horizontal (right) alignment. Source: Author (2019).

For the energy results, the equipment used was the Baker Explorer 4000, Figure 3, which consists of an analysis and monitoring device of electric motors where data is presented through a graphical user interface as seen in Figure 4. Through this equipment it is possible to obtain the voltage and current of each gearbox motor phase, as well as its consumed power and torque. Monitoring was performed on the gear boxmotor, which it is working with 100% load.

FIGURE 3 . Baker Explorer 4000. Source: Author (2019).

Firstly, the gear box motor was filled with mineral oil and thereafter with the synthetic oil, while the load remains unchanged. In the oil change procedure, the flushing method was used, which consists of draining the oil from the gear unit, inserting the new oil to be used and starting the system. The purpose is to allow the old oil residue to dilute into the new oil. Finally, the oil is drained again and is added the amount of new oil advised by the equipment manufacturer.

FIGURE 4. Baker Explorer 4000 graphical interface. Source: Author (2019).

The tests for each oil lasted 36 hours, with measurements every 30 minutes. The operation temperature was recorded by the SKF thermography camera TKTi 10. After acquisition, the data were plotted on a graph and the results were compared, as presented in item 3.

3. RESULTS

The Baker Explorer 4000 provides results and important information about the operating condition of the system, as shown in Figures 4 and 5.

According to the data presented in Figure 5 it can be stated that the system does not present phase unbalance, current unbalance or broken bars, also confirmed by Figure 6.

With the data obtained by the Baker Explorer 4000 it is also possible to highlight other characteristics of the gear box motor under study. As shown in Figure 6 the 0.35 hp gearbox motor output power; gearbox input speed is 1695.04 RPM; the energy efficiency is 82.83% and the gearbox motor load is 105.33%.

FIGURE 5. System operating condition. Source: Author (2019).

	Name Plate	Measured
Output Power [Hp]	0.34	0.35
Speed [RPM]	1700	1695.04
RMS [V]	220	225.25
RMS [A]	1.40	1.07
pf [p.u.]	N/A	0.76
Nema Derating [p.u.]	1.0	1.00
Torque [ft-lbs]	1.04	1.09
Efficiency	N/A	82.83
Percent Load	N/A	105.33

Test	Value	Status	Caut. Level	Warn. Level
Voltage Level (Over) [%]	102.39	Good	110.00	120.00
Voltage Level (Under) [%]	102.39	Good	95.00	90.00
Voltage Unbalance [%]	0.48	Good	2.00	3.50
THD [% of fund.]	1.35	Good	7.00	9.00
Total Distortion [% of fund.]	1.54	Good	10.00	12.00
Current Level [%]	77.09	Good	110.00	120.00
Current Unbalance [%]	1.58	Good	10.00	20.00
Load [%]	105.33	Good	110.00	125.00
Ef. Service Factor [p.u.]	1.05	Good	1.10	1.25
Rotor Bar [db]	-51.94	Good	-45.00	-36.00
Op. Point [%]	0.00	Good	20.00	30.00
Loss Difference [%]	N/A	N/A	25.00	50.00
Payback [Months]	N/A	N/A	60.00	24.00

FIGURE 6. Operating data of the gearbox motor MANUFACTURER I. Source: Author (2019).

In Figures 7, 8 and 9 there are the graphic plots of the current measurements, power and load from the 36 hours data acquisition for each oil.

FIGURE 7 . Current (RMS) . Source: Author (2019).

FIGURE 8. Power consumed by the gear unit. Source: Author (2019)

FIGURE 9. Gearbox load (%). Source: Author (2019)

Based on the results obtained in Figures 7, 8 and 9, there is a lower energy consumption by the gearbox motor when operating with mineral oil.

It is also possible to note from Figures 8 and 9, current and power, respectively, that there was stability after the twentieth measurement. This is due to the entry set in the steady operation where the temperature of operation has stabilized, not having most significant changes in the lubricant viscosity.

4. FINAL CONSIDERATIONS

The energy consumption is directly related to the oil viscosity, since the higher its viscosity, the greater the resistance imposed to the gears movement.

Although both oils have the same viscosity rating, the variation in viscosity with temperature over time is different for each oil. Synthetic oils, in general, have higher viscosity index, their viscosity has a smaller variation with increasing temperature.

However, this does not mean that mineral oil is more efficient than synthetic oil. The great benefit of synthetic oil is its ability to maintain its properties over a much longer period. According to the manufacturer of the oils used in the test, synthetic oil can have twice the life of mineral oil.

The small energy savings achieved in the first instance using mineral oil can turn into early wear of equipment components and, consequently, the need for shorter changeover periods.

For future work, it is desirable an increase in test time, followed by analysis are the oil's lubricant, in order to detect a possible difference in the gear lifetime wear and physicochemical properties of lubricants. Another point of improvement is the testing of higher wattage gear boxes, where the energy differences are likely to be more significant, thus approaching actual application conditions in the industry.

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