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PIN ON DISK TESTS TO VERIFY THE USE OF ADDITIVATED VEGETABLE OILS AS LUBRICANTS

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Abstract. *New environmental trends point to the need of the productive sector to turn to alternative solutions when it comes to automotive lubricants. From 2002 to 2011, the total production of assembled motor vehicles (cars, light commercial vehicles, trucks and buses) increased from 1.63 million to 3.41 million units. That represents an increase of 108.5% . This work was performed in search of finding a biolubricant that meets the needs of cars used today. It was evaluated samples of vegetable oil (soybean and sunflower), with specific additives and aging methods. For that, parameters like Viscosity and PQ index were performed. After being subject to wear in a simulation equipment (Pin-on-Disk), samples were evaluated. It was concluded that the use of those kind of biolubricants is feasible and it is necessary to pay attention to the amount and type of additives required and the to correct aging.*

Keywords: *biolubricants, vegetable oils, pin-on-disk, antioxidant*

1. INTRODUCTION

The first lubricants used by the men were that of animal origin. Over time, man has been perfecting and creating new inventions and, by necessity, the lubricants have evolved also starting to have bases of plant, mineral and synthetic origin. Currently, modern lubricants of high-performance have a very performance beyond simply reduce friction and wear. The latest generation of lubricants can also provide: the control of the formation of deposits and suspended contaminants, corrosion protection, cleaning of the components and ensure the correct operating temperature (Azevedo, et al, 2005, p.2.).

It is known that minerals lubricants can cause permanent damage to the environment, since they are not biodegradable and have some degree of toxicity (Gonçalves and Padovese, 2012). Therefore, during the last two decades, the concern with the use of petroleum-based lubricants and their impact on the environment has been great, which has resulted in research of various biodegradables vegetable oils as was done before the discovery of the petroleum.

Vegetable lubricants, also classified as biolubricants are being widely studied in order to replace the lubricants of mineral origin to meet environmental regulations and conservation of nature, since they are biodegradable (Gonçalves and Campos-Silva, 2011).

Vegetable with essential oils assumes a leading position, as a raw material for new sources of energy without environmental pollution risk (BIODIESELBR, 2007). Fatty esters present in vegetable oils are commonly used as lubricants with favorable environmental characteristics and good performance on the machines (Quintero Perez, 2009, p.1).

2. BACKGROUND

In the last six decades, the research about synthetic and mineral lubricants, brought an improvement on the quality in terms of various properties, like viscosity, dispersancy, detergency, etc. Parallel to the development of these lubricants it has increased concerns over toxicity, biodegradability and low availability of oil. In this sense the study and development of biodegradable lubricants has been prioritized in the industry of lubricants (Norrbuy, 2003).

Green Lubricants or EFL (Environmentally Friendly Lubricant) are renewable and usually made from vegetable oils (sunflower, canola, corn, coconut, palm, peanuts or soybeans) or synthetic esters (polyalkylene glycols - PAGs), or the petroleum base oils severely hydro treated (Wilson, 1998).

The presence of long chain acids in vegetable oils has increased interest as an alternative source of these to commercial lubricants based on mineral oil (Goyan, et al., 1998). When compared with mineral and synthetic oils, vegetable oils have some advantages such as increased viscosity and lubricity, low volatility, higher detergency and dispersion. With best properties of biodegradability and toxicity, these lubricants have great potential to be used in industry (Kabir, et al., 2008).

Castor and jojoba oils have very good properties relative to other vegetable oils, presenting interesting variants. Castor oil is a triglyceride, but the fatty acids are predominantly monounsaturated hydroxyl and ricinoleic acid having a chain of 18 carbons (Asadauskas, et al., 1997). Most of the research being conducted in the US and in the Europe are based on soybean oil and rapeseed oil (Krzan, et al., 2003). Peanut and palm oils are abundant in countries like India, Malaysia, Indonesia and the Philippines, what brought much interest in such oils in recent years.

The performance of palm oil in terms of friction, wear, viscosity degradation and emission of gases compared to commercial mineral lubricating was conducted in two-stroke gasoline engines, followed by a test in a four balls machine. The results showed that palm grease exhibited better performance in terms of wear, while the mineral oil showed better performance in terms of friction, and that palm oil was more effective in reducing carbon monoxide and hydrocarbons emissions (Masjuki, et al., 1999).

Canola oil additivated with 5% boric acid powder (average particle size equal to 100 micrometers) had their performance investigated in its use in metal forming. The tests indicated that the mixture has obtained an superior performance to pure boric acid, pure rapeseed oil and mineral lubricating oil used in the conformation (Lovell et al., 2006).

Green lubricant powder additived with boric acid powder in various concentrations and particle sizes was tested in pin-on-disk equipment, creating several works on analysis of lubricants with this type of equipment, including automotive lubricants (Kabir et al., 2008).

3. MATERIALS AND METHODS

The accelerated aging of the test lubricating oil was conducted using a muffle furnace. The preparation procedure of each of the samples used was made by the procedure described below.

In three beakers of 1000 ml, 1000 ml of soybean oil were placed. In one of the beakers it was kept pure oil. In the other two beakers it was added 5.0% and 10.0%, respectively, by weight of an antioxidant additive. The same procedure was applied for the preparation of sunflower oil samples.

The additive used was Liovac 3355 donated by Miracema-Nuodex company. According to data provided by the company, the additive is composed of zinc dialkyldithiophosphate with 15.0% sulfur, 6.5% phosphorus and 7.0% zinc. It has a pale yellow color, being soluble in all types of mineral oils. It is suitable as input for formulating multifunctional package for lubrication of internal combustion engines powered with gasoline, GNV, alcohol and diesel, and its main function is to prevent wear of metal parts of the engine, in addition to acting as an antioxidant and anti-corrosive.

From the six prepared beakers, it was withdrawn 250 ml of each and labeled these taken samples as having 0 days of aging. The recipients, containing the remaining oil, were taken to the aging process in a muffle oven at 60 ° C, following the AOCS (American Oil Chemist's Society) recommendations, so as to obtain an acceleration of aging of the oils. Every 15 days, it was withdrawn from each beaker a new sample of 250 ml, generating aged samples of 15, 30 and 45 days, properly labeled according to type of oil, amount of additive and aging time. Labeling of samples obtained oil is brought in Fig. 1.

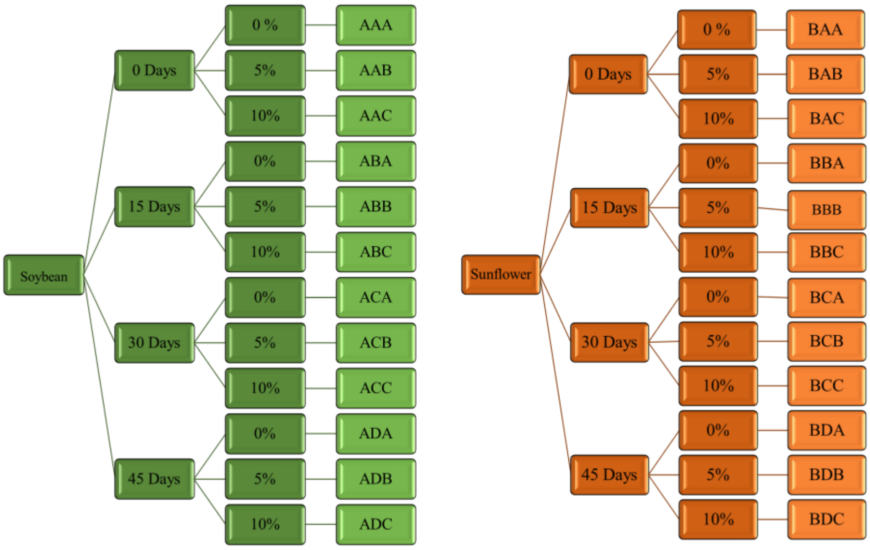

Figure 1. Nomenclature used in the labeling of the biolubricants samples produced.

The measurement of viscosity of each sample was performed using a Saybolt viscometer type. All samples were tested as the viscosity at 40°C and 100°C according to ASTM D445. The tests on pin-on-disk equipment were performed only for samples without aging and with those which passed through aging period of 45 days.

The pin-on-disk equipment used belongs to the Laboratory of Particle Analysis on Lubricant Oils, located at Universidade Estadual Paulista "Julio de Mesquita Filho", located in the city of Ilha Solteira, São Paulo, Brazil.

The rotations used has simulated a distance equal to 100 km, and the pin route radius on the disk equal to 15.75 mm. Analyses were performed with tangential speed constant drive and equal to 0.49455 m / s under an also constant load 5.0 kg. Monitoring of rotations was conducted through a tachometer, model Pet-2000 DX, brand Oppama. The pin and the disc were used made of 4340 steel and bronze, respectively, both being shown in Fig. 2.

Figure 2. Disk and pin used in the tests in pin-on-dink equipment.

The duration of each test was approximately 56 hours, and the frequency used in the frequency inverter equipment corresponding to 15 Hz. At the end of each test, before beginning the following test, it was performed the cleaning of the disc and of the pin with use of deodorized kerosene PA, so that contamination be avoided by another lubricant.

The characterization of the quantity of ferromagnetic particles present in each sample after testing performed pin-on-disk equipment was made in a PQA device. This device is a magnetometer which has two coils arranged so that the sample coil (sensor) and the reference coil are in equilibrium when there is no sample in the sensor. The system is designed to carefully ensure that both coils also respond to changes in ambient temperature. When a sample of oil containing ferromagnetic particles is placed on the sensor, the balance between the coils is changed. The resulting signal due to this change is amplified, filtered and displayed to the user equipment as an "index" of PQ (Particle Quantifier), relating directly the mass of ferromagnetic particles present in the sample.

Before measurement, was made the calibration of PQA equipment. Calibration is performed through a known standard, following recommendations of the manufacturer's manual. 2 ml samples were collected in a small plastic container using a syringe. To collect this sample, a homogenization of the oil was performed, so that there was no risk of the collected sample not be framed like valid. After the measurement made, the container is extruded through an array of trough located on the side of the machine.

Five measurements for each sample and performed arithmetic averages of the results to means of comparison were made. Then we it was selected three different automotive lubricating oils, according to Tab. 1, and the physical and chemical properties with the prepared bio-lubricants were compared.

Table 1. Physical and chemical properties of three automotive lubricants used for comparison with of the prepared biolubricants in the study.

Trademark	PETROBRÁS	PETROBRÁS		PETROBRÁS
Type of Lubricant	LUBRAZ VALORA	LUBRAX ESSENCIAL SF		LUBRAX ADVENTO
Technical Description	Lubricating oil multi viscosity 100% synthetic technology for modern gasoline, ethanol, flex and CNG	Mineral oil lubricant for use in motors gasoline, etanol, flex and CNG		Mineral oil lubricant multi viscosity of high performance for use in turbocharged diesel engines to low-emission, operating in severe conditions
SAE Degree	5W-30	40	20W-40	15W-40
Density at 20/4ºC	0,8508	0,8948	0,8889	0,873
Flash Point (VA) (ºC)	232	252	252	230
Total Base Number (TBN) (mgKOH/g)	---	---	---	10
Viscosity at 40ºC	311,1	672,3	593,9	482,6
Viscosity at 100ºC	58,8	74,9	74,9	72,1

4. RESULTS AND DISCUSSION

4.1 Saybolt Viscosity

The results obtained for Saybolt viscosity test are shown in Fig. 3.

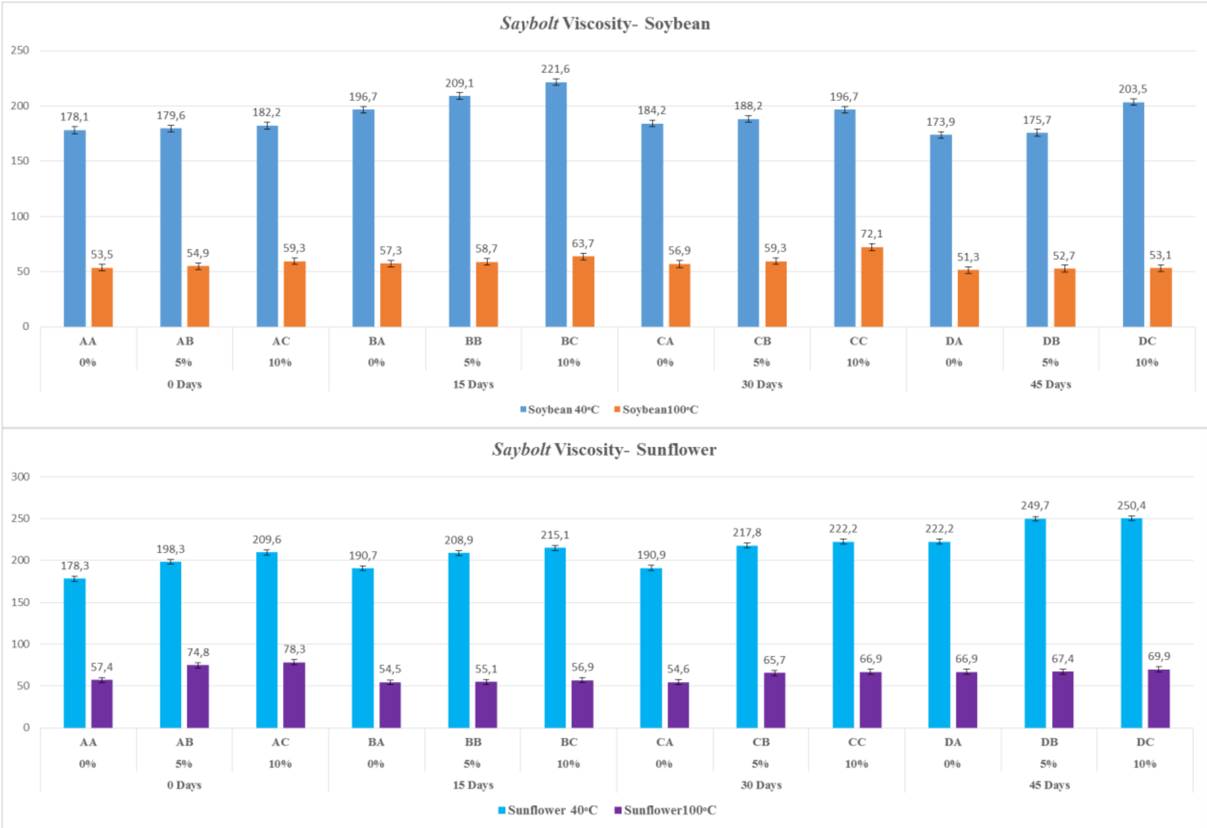

Figure 3. Saybolt Viscosity obtained for the samples of biolubricants prepared with oils of soybean and sunflower.

Through the figure it is possible to see a variation in viscosity between the samples and observe that the viscosity at 40°C increases with aging for the biolubricant based in sunflower oil. Oxidation occurs after a certain period of time, when the antioxidant additive is consumed and the oil oxidizes rapidly. Oxidation is responsable for cause, among others, the increased viscosity, a fact which is confirmed in the experiment where the viscosity increases with age, which was higher for biolubricant based in sunflower oil. The control of oxidation is a major step in the attempt to extend the life of the lubricant.

4.2 Particle Quantifier Analise (PQA)

Values obtained in the test with PQA equipment are shown in Fig. 4.

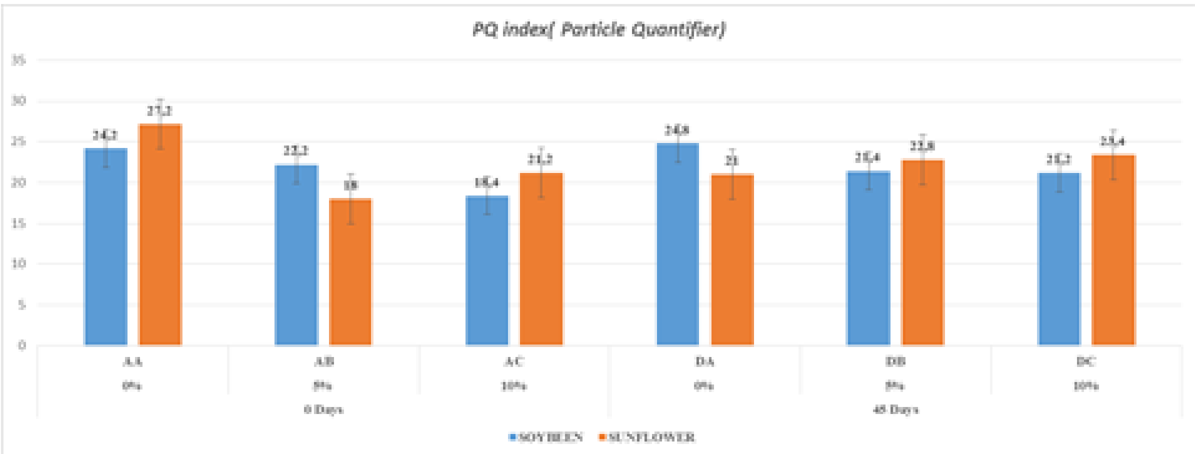

Figure 4. Values obtained for the PQ index for samples of the biolubricants prepared with soybean oil and sunflower oil.

It was found that for samples of the biolubricants based in soybean oil, for a greater amount of additive inserted, lowest values for the PQ index were obtained. At PQ index were obtained that, for biolubricant based in soybean oil, the additive addition caused an improvement of the antiwear properties of the lubricant for both the case without aging, as for the case where the biolubricant was aged. For biolubricant based in sunflower oil, additive addition improved antiwear properties only in the case where the biolubricant had not suffered aging.

4.3 Comparison of Physical and Chemical Properties with Commercial Lubricants

Comparisons were made between commercial lubricants and biolubricants for Saybolt viscosity values measured at 40°C and 100°C. This comparison is brought in Fig. 5. Looking for the figure it can be seen that the viscosity of lubricants, at 40°C, was close to the commercial lubricant LUBRAX VALORA. It also verifies, that at the 100°C temperature, the values for biolubricants and commercial lubricants are close to each other.

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Figure 5. Comparison of Saybolt viscosities measured at 40 ° C and 100 ° C between the prepared biolubricants and commercial lubricants.

5. CONCLUSIONS

From the results, it can be determined that the vegetable biolubricant has high potential to be used as substitute to mineral lubricant. However, it should be noted that some adjustments are necessary in relation to additives.

The results also displayed that the biolubricants, based in soybean oil and sunflower oil, are alternatives strong in replacing to the mineral lubricants, besides the fact that they are biodegradable and be made from renewable sources.

For the sample of biolubricants based in soybean oil, it was found that the antiwear properties are shown proportional to the amount of additive used, until the proportion used. For biolubricants based in sunflower oil, the addition of the additive used proved beneficial only for the state where the biolubricant wasn't aged.

The presented wear were consistent and at the same rate of wear obtained in other jobs to commercial lubricants. However, it is needed a larger chemical study, for that a higher oxidation stability can be given for biolubricants with basis of vegetable oils.

The study of other friction couples, as well as other types of oils and additives, it is desired, in a future work. The additive concentrations and combinations are also envisioned as a target for future studies in order to obtain a statement about which the mixture proportion of the additive and the vegetable oil is the most advisable, comparing it to mineral lubricants.

6. REFERENCES

Azevedo, J. B. et all., 2005. Efeito da Degradação em Motor Automotivo nas Propriedades Termogavimétricas de Óleos Lubrificantes Minerais e Sintéticos. 3º Congresso Brasileiro de P&D em Petróleo e Gás, Salvador, BA.

BIODIESELBR; Biolubrificante Verde. Editorial Diário do Nordeste, 19 Ago. 2007. <http:/www.biodiselbr.com/noticias/em-foco/biolubrificante-verde-19-08-07.htm>.

Gonçalves, A. C., Campos-Silva, J. B., 2011. Predictive Maintenance of a Reducer with Contaminated Oil under an Excentrical Load through Vibration and Oil Analysis. *Journal of the Brazilian Society of Mechanical Sciences and Engineering* (Printed), v. 33, p. 1 -7.

Gonçalves, A. C., Padovese, L.R., 2012. Identification of Lubricant Contamination by Biodiesel using Vibration Analysis and Neural Network. *Industrial Lubrication and Tribology*, v. 64, p. 104-110.

Quintero Perez, H. I., 2009. Produção de Biolubrificante para Usos Especiais. Dissertação de Mestrado, UNICAMP – Faculdade de Engenharia Química, Campinas, SP.

Azadukas, S., Perez, J. M., Larru, D. J., 1997. "Lubrication Properties of Castor Oil-Potental Basestock for Biodegradable Lubricant". Lubrication Engineering, 53, 12, 35-40.

Goyan, R. L., Melley, R. E., Wissner, P. A., Ong, W. C., 1988. "Biodegradable Lubricantes". Lubrication Engineering, 54, 7, 10-17.

Kabir, M. A., Lovell, C. M., Higgs III, F., 2008. "A Pin-on-disk Experimental Study on a Green Particulate-Fluid Lubricant". Journal of Tribology, Octuber, v. 130, p 1-5.

Krzan, B., Vizintin, J., 2003. "Tribological Properties of an Environmentally Adopted Universal Tractor Transmission Oil Based on Vegetable Oil". Tribology International, 36, 827-833.

Lovell, M., Higgs, C. F., Deshmukh, P. and Mobley, A., 2006. "Increasing Formability in Sheet Metal Stamping Operations Using Environmentally Friendly Lubricants". J. Mater. Process. Technol., 1771-3, pp. 87-90.

Masjuki, H. H., Maleque, M. A., 1996. "Wear, Performance and Emissions of a Two-Stroke Engine Running on Palm Oil Methyl Ester Blended Lubricant", Proc. Inst. Mech. Eng., Part J: Journal of Engineering Tribology, 210, 213-219.

Norrby, T., 2003. "Environmentally Adapted Lubricants – Where are the Opportunities?". Industrial Lubrication and Tribology, 55, 6, 268-274.

Willson, B., 1998. "Lubricants and Functional Fluids from Renawable Sources". Industrial Lubrication and Tribology, 50, 1, 6-15.

7. RESPONSIBILITY NOTICE