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LUBRICANT LIFESPAN OF A DIESEL ENGINE FUELED WITH PREHEATED CRAMBE OIL

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Abstract. *The non-transformed vegetable oil applications as fuel on Diesel engines are frequent. However, the utilization of these oils without criterion causes damages to engine. The literature shows that has a great variability of results, which are directly related with the vegetable oil quality, production and purification processes, utilization criteria and engine technology in which the oils were tested. In this work, an essay was performed with a diesel engine fueled with crambe oil preheated at 100°C, with application of an average load of 51% of the rated power, aiming to evaluate the lubricant. At time zero and each 15 hours of engine working, the lubricant was sampled for physico-chemical analysis, and it was completely replacement after 50 hours, according to manufacturer's recommendation. The essay had duration of 100 hours, totalizing 7 samples. The physico-chemical analyses of the lubricant indicate that the fuel combustion was adequate, because there are not indications of lubricant contamination by the fuel. However, on first 50 hours, was observed high iron contamination. It should be noted that important properties of the lubricant were not significantly altered.*

Keywords: *vegetable oil, fuel, contamination.*

1. INTRODUCTION

With a view to sustainable development, the search for energy alternatives occupies an important place on the world agenda. Energy from biomass becomes prominent as a renewable energy source. Examples are the use of ethanol and biodiesel, which are alternatives fuels to gasoline and petrodiesel, and whose main raw materials are renewable and less polluting.

The use of vegetable oils in diesel engines also has been studied due to its heating value and similar characteristics to petrodiesel. Its utilization as fuel without transformation into biodiesel is more beneficial, since the transesterification implies on higher costs and energy consumption, contamination and co-product generation (ESTEBAN et al., 2011). However, the straight use of vegetable oils as fuel, without any type of treatment, is harmful to the engine due mainly to its high viscosity and low volatility. These promote pumping and atomization problems, leading to incomplete combustion and, consequently, deposits of carbon in the internal parts of the engine, higher smoke emissions, lubricant contamination and engine durability problems (RYAN III et al., 1984; BALAKRISHNA, 2012).

The preheating of vegetable oil before the injection system is one of the solutions for these problems, because it decreases the oil viscosity, improving the injection and favoring the combustion, avoiding premature engine aging and improving thermal efficiency (ESTEBAN et al., 2012; SONAR et al., 2014). Studies comparing the performance of

diesel engines fueled with unheated and preheated vegetable oils indicate that preheating reduces fuel consumption, emissions of pollutants, carbonization and lubricant contamination (DELALIBERA, 2009; JAIN et al., 2017).

The lubricant conditions analysis may be a good indicative of combustion efficiency. The lubricant contamination can occur through the fuel dilution, due to incomplete combustion or clearances, resulting in lubricant viscosity reduction (ALMEIDA et al., 2002; HASANNUDDIN et al., 2016), or by the presence of combustion residues and soot, causing increase of the lubricant viscosity and lubricant pumpability problems (GEORGE et al., 2007; MAZIERO et al., 2007), also can occur contamination by water, metals, sourced from engine wear and corrosion, and sediments or dust, such as silicon (CÔRREA et al., 2011; PINHEIRO et al., 2017). According to studies of Inoue et al. (2009) and Almeida et al. (2002), the contamination caused by vegetable oils used as fuel decreases the lubricant lifespan reducing the time interval between the lubricant changes.

In this context, the aim of this work was to evaluate the contamination and the lifespan of the lubricant used in a diesel engine fueled with preheated crambe oil (*Crambe abyssinica* Hochst) in a long-term test, in order to infer about the technical feasibility of the application of this oil as fuel.

2. MATERIALS AND METHODS

The study was performed at the Machinery Testing Laboratory of Agronomic Institute of Paraná (Instituto Agronômico do Paraná - IAPAR), in Londrina city. A Diesel engine was used (Tab. 1), coupled to an electric generator with capacity of 4 kVA connected to a resistive load bank, composed of halogen lamps, with capacity to absorb 3.0 and 3.9 kW. These loads correspond to 51 and 66% of the rated engine power at 1,800 rpm.

Table 1. Engine specifications according to manufacturer's manual.

| | | | |
|---------------------|---------------------|-----------------------------|--------------------|
| Manufacturer/model | YANMAR/B9C | Aspiration | Natural |
| Number of cylinders | 1 | Injection/combustion system | Mechanic/Indirect |
| Bore x stroke | 90 x 100 mm | Lubrication | Forced by pump |
| Total displacement | 636 cm ³ | Lubricant pressure | 0.049 a 0.49 MPa |
| Cycle | Diesel – 4 strokes | Lubricant capacity | 1.5 a 2 L |
| Power rating | 5.88kW@1,800rpm | Cooling system | Condensation water |

Pure crambe oil (*Crambe abyssinica* Hochst), preheated at 100°C and obtained by simple pressing followed by filtration, was used as fuel. It was chosen based on the study conducted by Delalibera et al. (2017), in which crambe oil, when compared to three other vegetable oils (rapeseed, linseed and jatropha), presented the best results. Petrodiesel S500, with 5% of biodiesel, was used during the engine start, until its warming up, and before turning off, to remove vegetable oil residues from internal engine parts, because these residues can cause problems with cold engine start.

The test procedures were performed as described by Delalibera et al. (2017), with the fuel alternation between petrodiesel and crambe oil made through a manual three-way valve and utilization of an electric resistance to preheat the vegetable oil.

A long-term test, mainly characterized by test time exceeding the lubricant lifespan (DELALIBERA, 2015), was carried out. The essay had a total duration of 100 hours and the lubricant was exchanged with 50 hours, based on manufacturer's indication. The engine operated uninterrupted from 8 to 10 hours a day, at 1,800 rpm and with an average of 3.0 kW of power absorption by the generator/load bank set.

To evaluate the lubricant conditions, it was added to the reservoir of the engine at its maximum volume (2.0 L) and each 15 hours of operation, 0.2 L samples were taken, without replacing the volume removed until the lubricant exchange. The samples were taken with the engine warm, right after it turning off. An unused lubricant sample was also taken, as control, totalizing seven samples, at times 0, 15, 30, 45, 65, 80 e 95 hours. The lubricant used was 15W40.

The samples were sent to Laboroil Ltda, in Belo Horizonte – MG, to analyze some parameters, such as contamination by combustion products, metals from wear of engine moving parts, and properties, as viscosity, total base number, among others (DELALIBERA, 2015).

3. RESULTS AND DISCUSSION

The results of the analyses performed on the lubricant samples are shown in Tab. 2.

Table 2. Results of lubricant oil analysis used in Diesel Cycle engine running on preheated vegetable oil from crambe (*Crambe abyssinica* Hochst) and petrodiesel

| Time of engine operation | 0 h | 15 h | 30 h | 45 h | 65 h | 80 h | 95 h |
|---|---------|--------|--------|--------|--------|--------|--------|
| Time of lubricant sample | Control | 15 h | 30 h | 45 h | 15 h | 30 h | 45 h |
| Soot ¹ (%) | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 |
| Viscosity 40°C ² (cSt) | 102,0 | 105,4 | 103,1 | 103,7 | 106,2 | 104,4 | 101,7 |
| Dilution ³ (%) | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Water ⁴ (%) | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Precipitation index ⁵ (%) | 0,05 | 0,10 | 0,10 | 0,15 | 0,05 | 0,10 | 0,10 |
| TBN ⁶ (mgKOH g ⁻¹) | 8,23 | 8,27 | 8,50 | 8,95 | 8,63 | 8,60 | 8,03 |
| Insoluble Pentans ⁷ | 0,04 | 0,01 | 0,02 | 0,03 | 0,00 | 0,03 | 0,02 |
| Dispersivity ⁸ | 100 | 77 | 75 | 83 | 76 | 75 | 74 |
| Contamination index ⁹ | 0,1 | 0,1 | 0,3 | 0,2 | 0,1 | 0,2 | 0,3 |
| Weighted loss ¹⁰ | 0 | 2 | 8 | 3 | 2 | 5 | 8 |
| Aluminum ¹¹ (ppm) | 0,10 | 3,80 | 7,62 | 12,13 | 4,96 | 7,67 | 11,99 |
| Copper ¹¹ (ppm) | 0,10 | 3,50 | 6,24 | 8,71 | 3,40 | 6,21 | 8,86 |
| Chromium ¹¹ (ppm) | 0,10 | 2,50 | 4,32 | 6,56 | 1,92 | 3,47 | 5,97 |
| Iron ¹¹ (ppm) | 0,73 | 150,0 | 202,9 | 256,4 | 105,2 | 145,6 | 182,8 |
| Silicon ¹¹ (ppm) | 7,47 | 8,43 | 10,04 | 12,60 | 8,88 | 9,88 | 12,38 |
| Lead ¹¹ (ppm) | 0,10 | 14,28 | 19,92 | 22,79 | 10,80 | 14,62 | 16,68 |
| Zinc ¹¹ (ppm) | 1385 | 1379 | 1375 | 1376 | 1427 | 1373 | 1396 |
| Tin ¹¹ (ppm) | 0,10 | 0,44 | 1,70 | 3,19 | 0,13 | 1,26 | 2,54 |
| Calcium ¹¹ (ppm) | 1288 | 1300 | 1316 | 1350 | 1356 | 1326 | 1378 |
| Sodium ¹¹ (ppm) | 0,10 | 0,25 | 0,58 | 1,15 | 0,60 | 0,78 | 0,97 |
| Boron ¹¹ (ppm) | 0,51 | 0,69 | 0,75 | 0,84 | 0,62 | 0,63 | 0,71 |
| Magnesium ¹¹ (ppm) | 1067 | 1076 | 1087 | 1106 | 1118 | 1088 | 1118 |
| Manganese ¹¹ (ppm) | 0,10 | 0,10 | 0,37 | 0,87 | 0,10 | 0,08 | 0,50 |
| Phosphorus ¹¹ (ppm) | 1191 | 1180 | 1178 | 1189 | 1224 | 1171 | 1204 |
| Oxidation ¹² (Abs) | 5,861 | 7,054 | 8,366 | 9,746 | 7,177 | 8,684 | 10,110 |
| Nitration ¹² (Abs) | 5,185 | 5,647 | 6,074 | 6,489 | 5,660 | 6,132 | 6,448 |
| Sulfatation ¹² (Abs) | 12,461 | 13,701 | 14,388 | 15,421 | 15,693 | 14,656 | 16,086 |

STANDARDS: 1-ASTM D7686; 2-ASTM D445; 3-ASTM D3524; 4-Laboroil; 5-ASTM D91; 6-ASTM D4739; 7-ASTM D4055; 8-ASTM D7899; 9-ASTM D7900; 10-ASTM D7901; 11-ASTM D5185; 12-ASTM D7889.

According to Tab. 2, the highest variation of viscosity observed was 4% superior than control; a relevant fact, because Maziero et al. (2007) observed that, with 63 hours of diesel engine operation with crude sunflower oil without preheating, the viscosity of the lubricant had a marked increase, as a result of contamination by substances originated from irregular combustion, causing damage and clogging in lubrication system. According to Sidibé et al. (2010), the dilution of vegetable oil in lubricants can lead to polymerization and consequent lubricant thickening, forming suspended solids and damaging the lubrication (DELALIBERA, 2009; PAULSEN et al., 2011). In contrast, Inoue et al. (2009) and Delalibera et al. (2012) observed a reduction of lubricant viscosity when using preheated blends of vegetable oil and petrodiesel; similar results were noticed by Almeida et al. (2002) with use of preheated palm oil as fuel. The lubricant oil dilution is caused by improper injection and combustion problems, due to poor atomization and low volatility of vegetable oils (RYAN III et al., 1984; ALMEIDA et al., 2002).

Therefore, the low viscosity variation obtained in the lubricant oil analysis is an indicative of better combustion of the fuel used, consistent with the results obtained in soot content analysis, which remained constant. Soot is a product of

incomplete combustion and, consequently, an indicator of combustion efficiency (HASANNUDIN et al., 2016) and whose presence in the lubricant can cause increased viscosity and abrasive engine wear (GEORGE et al., 2007; HASANNUDIN et al., 2016). The good results obtained can be attributed to the use of an indirect combustion engine, since this type of engine presents lower tendency to carbonization and lubricant contamination, compared to those of direct injection (RYAN III et al., 1984).

TBN (total base number) indicates the reserve alkalinity present in the lubricant, indicating its ability to neutralize the acids formed during combustion; the lubricant must be rejected when its value is 50% of the initial value (MATHAI et al., 2012). The result obtained indicates a good condition of the lubricant in relation to this aspect. The reduction of TBN results in an increase of viscosity and oxidation of the lubricant and is a good indicator of its lifespan remaining time (PEREIRA, 2015).

No contamination by water was observed and the precipitation index, that indicates the presence of insoluble components in the lubricant with an allowed maximum value of 1% (MAZIERO et al., 2007), is within acceptable values.

The contaminants elements analysis in the lubricant indicated an increase in the contents for most of the observed ones. The increase of iron, copper, chromium, aluminum, lead and tin contents is a consequence of the wear of moving parts of the engine (SILVA, 2006; HASANNUDDIN et al., 2016). Iron and aluminum also can be originated in external contaminants, as well as silicon, present in the environment in high concentrations (SILVA, 2006; RAPOSO JR et al., 2011; HASANNUDDIN et al., 2016); these contaminants are resulting of the input of sediments (dust) through the intake system.

The elements zinc, calcium, magnesium and phosphorus, which appear in larger quantities in the analyses, are added to lubricants as additives, to improve their properties, acting mainly as metal surfaces protectors against wear and corrosion and as antioxidants (GEORGE et al., 2007; HASANNUDDIN et al., 2016; PINHEIRO et al., 2017). These elements, together with sodium, can also come from external contaminants, as they may be present in the fuel composition and pass from the combustion chamber to the crankcase (SILVA, 2006; DELALIBERA, 2009).

The concentrations of all analyzed elements are normal in all samples, except for iron, that presented highly elevated content with only 15 hours of essay. These values may indicate an abnormal engine wear process or can be attributed to external contaminants, since the soil in the region of Londrina is rich in iron ore. According to Pereira (2015), the metal particles can catalyze the oxidation process and the lubricant aging. Thus, due to the high presence of metallic materials and ferrous alloys, it would be recommended the exchange of the lubricant.

4. CONCLUSIONS

The results obtained in the lubricant analysis referring to viscosity and soot content indicate complete combustion of crambe oil used as fuel, which did not degrade the lubricant during the evaluated period.

Lubricant lifespan has been reduced due to iron contamination, sourced from abnormal engine wear or dust entering through the intake system.

As a suggestion for future works, it is proposed to continue the study with longer test time to evaluate if the good results will be maintained.

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