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Recycling of waste engine oil for diesel production

R. Maceiras [a,*], V. Alfonsín [a], F.J. Morales [b]

[a] Defense University Center, Escuela Naval Militar, Plaza de España 2, 36920 Marín, Spain
[b] Escuela Naval Militar, Plaza de España 2, 36920 Marín, Spain

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ABSTRACT

The aim of this work was to recycle waste engine oil until converting it into reusable product, diesel fuel. The waste oil was treated using pyrolytic distillation. The effect of two additives (sodium hydroxide and sodium carbonate) in the purification of the obtained fuel was also studied. Moreover, the influence of the number of distillations were analysed. Some thermal and physicochemical properties (density, viscosity, colour, turbidity, acidity value, distillation curves, cetane number, corrosiveness to Cu, water content, flash point and hydrocarbons) were determined to analyse the quality of the obtained fuel. The best results were obtained with 2% of sodium carbonate and two successive distillations. The obtained results showed that pyrolytic distillation of waste engine oil is an excellent way to produce diesel fuel to be used in engines.

1. Introduction

In the last years, alternative fuel technologies have been investigated to replace the fossil fuel, due to the decrease of this source and the increment of its demand and cost. The use of waste engine oil for diesel production seems to be a good way for producing alternative fuels.

Waste oil is generated from a wide variety of sectors: industrial, automotive, aviation and marine. Fig. 1 shows the global consumption of lubricating oil in different sectors (IETC, 2013). It is estimated that 45 million tons per year are generated in the world (IETC, 2013), being only the 40% of this oil collected and disposed properly and about the 8% of this is recycled into new lubricant oils. Waste oil has severe adverse environmental and health impacts due to its content on metals and other contaminants (Nerín et al., 2000) remaining from the additives, such as phenols polycyclic aromatic hydrocarbons and compounds containing zinc, chlorine or phosphorous (Fuentes et al., 2007). Then, the recycling and reuse of waste oil have received special attention in the last years. Production of alternative fuels from waste oils not only decreases the consumption of petroleum based fuels, but also protects the environment from toxic and hazardous chemicals (Bhaskar et al., 2004) and reduces greenhouse gas emissions (Naima and Liazid, 2013).

Many researches have worked on different technologies to convert waste oil on into diesel: pyrolysis (Arpa et al., 2010; Van de Beld et al., 2013), vacuum distillation (Hamawand et al., 2013), hydrogenation (Tóth et al., 2015). Pyrolysis is a thermochemical process that involves the decomposition of organic material at elevated temperatures in absence of oxygen. This process produces organic gases, oiled liquids and carbonaceous residue that can be used as fuel (Kim and Kim, 2000). The pyrolysis can be conducted in a distillation apparatus to obtain volatile compounds (Demirbas et al., 2015). For that reason, this paper reports the recycling of waste engine oil by pyrolytic distillation. This process breaks up large molecules of waste engine oil and allows to obtain diesel. Some experiences were done directly with the waste engine oil and other experiences were carried out in presence of additives with the aim of purifying the obtained diesel. In all cases, the properties of the obtained diesel were determined to analyse the possibility of using it in a diesel engine.

2. Experimental

2.1. Equipment

The waste engine oil used in this research was collected from the Spanish Navy Patrol boat "Tabarca". Prior to the experiments, it was necessary to purify the waste engine by filtration with a qualitative filter.

The experiments were carried out in a distillation equipment (Fig. 2). In each test, 100 mL of waste engine oil were placed into a boiling flask of 250 mL. The flask was introduced in an electrical heating mantle (LBX Instruments, HM01 series) that reaches a maximum temperature of 450 °C at the surface. Then, the waste

* Corresponding author.
E-mail address: rmaceiras@uvigo.es (R. Maceiras).

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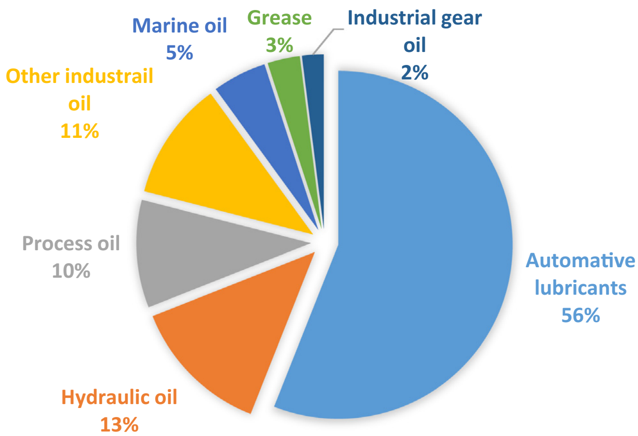

Fig. 1. Percentage of global use of different lubricants.

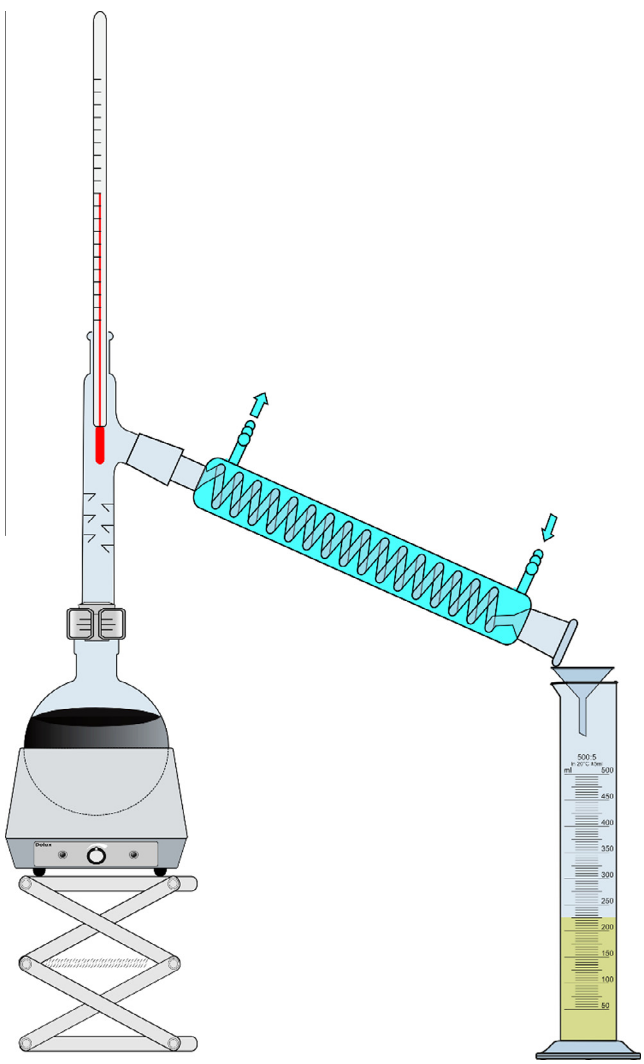

Fig. 2. Scheme of the distillation system.

sample was heated and a fuel vapor was obtained. The temperature of the fuel vapor was monitored with a thermometer. Finally, a water-cooled condenser was used to condense the fuel vapor.

With the aim to purify and improve the quality of the obtained fuel, some experiences were carried out in presence of two additives: NaOH and Na_2CO_3 (2 wt.%). These additives were chosen due to the fact that it has been observed that they can reduce the amount of sulphur compounds in the obtained diesel (Shakirullah et al., 2010). Moreover, the influence of a second distillation of the obtained fuel was investigated. To summarize, the detailed conditions of the each experiment are shown in Table 1.

2.2. Analysis

Some physicochemical properties of the obtained fuel were determined using standard procedures with the aim to check its quality and compare the values with the specifications established in RD 61/2006 (BOE, 2006), where the Spanish Government determined the requisites of petrol, diesel and liquid petroleum gasses, and with UNE-EN 590 (2013), that describes the physical properties that automotive diesel fuel must meet if it is to be sold in many European countries. The analysed properties were: density, viscosity, colour, turbidity, acidity value, distillation curves, cetane number, corrosiveness to Cu, water content, flash point and hydrocarbons (total, polycyclic aromatic and benzene). All experiments were carried out by triplicate.

2.2.1. Density

The density (D) was determined according to UNE-EN ISO 3838 (2004). The value was obtained at 15 °C using a pycnometer type Gay-Lussac of 10 mL with an uncertainty of ±0.0015. Measurements for each sample were taken twice with the aim to ensure repeatability.

2.2.2. Viscosity

The kinematic viscosity (υ) was obtained according to ASTM D 445 (2015) measuring the necessary time for the volume of liquid to flow under gravity through a standard capillary tube at 40 °C. Then, the dynamic viscosity was obtained by multiplying the kinematic viscosity by the density of the liquid.

2.2.3. Colour

An automatic colorimeter of Grabner Scientific was used to determine the colour (CL) of the samples, according to UNE-EN ISO 51-104 (1978) and compared with the standards of ISO 2049 (1996). The colour is usually determined to establish when the fuel has been refined to the required grade. However, it has been shown that the colour of the diesel varies with the storage time from a clear and transparent tone to a dark brown (Bergeron et al., 1999). Then, the colour is not always a reliable guide to product quality.

2.2.4. Turbidity

It is usually included in fuel specifications of ASTM D 4176 (2014) that the fuel must be clear and bright and free of visible particulate matter. In this paper, the turbidity (TB) was measured with a turbidimeter Butech TN 100.

Table 1
Experimental conditions.

	Additives	No. of distillations	Previous treatment
Sample 1	0	1	No
Sample 1a	0	2	No
Sample 2	0	1	Heated until constant weight
Sample 3	2% Na_2CO_3	1	No
Sample 3a	2% Na_2CO_3	2	No
Sample 4	2% NaOH	1	No
Sample 4a	2% NaOH	2	No

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