Article **Journal Economic Development**
June 2022, Vol.9 No.27 27-32

Oil characterization from waste used in boiler vapor generator

Caracterización de aceites de desecho utilizados en calderas generadoras de vapor

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DOI: 10.35429/JED.2022.27.9.27.32 Received: January 30, 2022; Accepted: June 30, 2022

Abstract

The following study is part of the firs step of a project exploration to develop technologically a fuel mixing wasted oil, to be used in an air-oil combustión in the vapor generators, a vizcosity análisis was performed and therefore the calorific power was calculated from the samples; during the exploration stage, an analisys is perform from the principal elements that form each and every one of the oils and they are mixed to obtain five different oil samples with the main objective to determine which of them is the best option for the technological development to comply with the stablished standards; for this proecess it was taken as a reference, Diesel, and it was compared with the samples obtained to determine which of these could be a the fuel that replace it. The calorific value of motor oil at 100% reaches a maximum value of 10,619.60 Kcal/Kg and vegetable oil at 100% has the lowest calorific value of 9,321.30 Kcal/Kg. Considering the mayor calorific power from the analized fuels, the mayor efficiency during the combustión process for the use of alternate fuel is motor oil at 100% from sample 1.

Waste, Industrial oil and fuels

Resumen

El presente estudio forma parte de la primera etapa de exploración de un proyecto para desarrollar tecnológicamente un combustible, mezclando aceites de desecho, que se utilice para realizar la combustión aire-aceite en los generadores de vapor. Se realizó un análisis de viscosidad y se calculó el poder calorífico de las muestras; en la etapa de exploración, se realiza un análisis de los principales elementos que forman cada uno de los aceites y se mezclan para obtener cinco muestras de diferentes aceites con el objetivo de determinar cuál de ellos es la mejor opción para el desarrollo tecnológico que cumpla con los estándares establecidos; para este proceso, se tomó como referencia, el Diesel, y se compara con las pruebas obtenidas, para determinar cuál de éstas pudiera ser el combustible que lo sustituye. El poder calorífico del aceite de motor 100% es el que alcanza un valor máximo de 10,619.60 Kcal/Kg y el aceite vegetal 100% es el menor poder calorífico con 9,321.30 Kcal/Kg. Considerando el mayor poder calorífico de los combustibles analizados, la mayor eficiencia en el proceso de combustión para el uso de combustible alternativo es la muestra 1 de Aceite motor 100%.

Residuos, Aceite industrial y combustibles

Citation: SAN MIGUEL-IZA, Sandra Maria, RANGEL-GONZALEZ, Blanca Margarita, ARREOLA-VILLA, Sixtos Antonio and PÉREZ-ALVARADO, Alejandro. Oil characterization from waste used in boiler vapor generator. Journal Economic Development. 2022. 9-27:27-32.

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Introduction

Industrial oil used in vehicle engines or industrial machinery becomes a highly polluting waste. It has been proven that oil is one of the most polluting wastes on the planet, mainly due to its high heavy metal content and its low biodegradability. Its dumping is capable of contaminating the soil as well as surface and groundwater, seriously affecting soil fertility and making cultivation impossible. If waste oils are dumped into the sea, the hydrocarbon compounds can persist for 10 to 15 years floating on the water. However, this polluting power can be avoided if used oil is properly extracted, stored and treated.

Fortunately, new regulations on used oils oblige lubricant manufacturers to take care of the waste generated by their products once they have been used (SIGAGUS, 2017 and Biodiesel, 2022).

Used cooking oil is the waste generated by heating vegetable oils and cooking food in them. Once the total polar content of the vegetable oil has reached a value of 27%, the oil must be discarded, as it is no longer suitable for further cooking. Used vegetable oil waste, burnt vegetable oil, used cooking oil (RAUC), yellow grease or UCO, is currently one of the main causes of urban wastewater pollution, since once used, if discharged into the sewage system, it pollutes the environment, causing blockages and bad smells in the pipes and a large number of environmental problems. These discharges make water treatment extremely costly, as well as hindering the normal operation of wastewater treatment plants. If these oils are not properly managed, when they are returned to the environment mixed with water, they contaminate internal basins, the sea and aquifers, interfering with natural life and degrading the environment. Oil in water facilitates the proliferation of micro-organisms harmful to health.

Refuse Derived Fuels (RDF), also known as Refuse Derived Fuels (RDF), come from the blending of different types of waste and are a fuel used for energy recovery that has good calorific value and low chlorine content. A more precise definition indicates that RDF can be solid, liquid, pasty or gaseous fuels obtained from hazardous, non-hazardous or inert waste for energy recovery in incineration or co-incineration plants and that normally meet specifications established between the fuel producer and the user (Costa Posada et al. 2017). Co-processing in industry is the best way to recover energy and material from waste (Rocha et al. 2011).

In this work, a procedure was proposed and validated to use oils as an alternative fuel to diesel used in a boiler. One of the main elements of the procedure consists of adjusting the viscosity of the oils to be used in the burner. The tests in the boiler were successful as combustion was achieved in the burner of all the samples analysed, thus demonstrating the possibility of substituting conventional fuels for those based on waste oils.

Methodology to be developed

The technological development of the new alternative fuel was conceptualised and designed to have performance characteristics similar to those of existing fuels and with added value because it was made from recycled elements. For the development of the project, five samples of oil mixtures were analysed, which are as follows:

Sample 1.- Motor oil 100%.

Sample 2.- 100% vegetable oil.

Sample 3.- Motor oil 50% - Vegetable oil 50% Sample 4.

Sample 4.- Motor oil 75% - Vegetable oil 25% Sample 5.

Sample 5.- Engine oil 25% - Vegetable oil 75%.

Figure 1 shows the image of the five samples that were prepared for laboratory analysis.

ISSN 2410-4019

Figure 1 Image of samples prepared for analysis

A comprehensive study was carried out to establish the critical variables to be controlled and the development of the following exploration model. Relevant activities carried out at this stage included the following:

1. Collection of oils and lubricants

2. Viscosity profiling

3. Calorific value calculation

The oil and lubricant collection stage includes preparing the sample for analysis by decanting and sieving the fluid, determining its % volume of water and sediment, in accordance with ASTM D 2709-06, which specifies the content of these elements in a fuel.

The determination of the viscosity profile of the fuel in cSt is very important to define the behaviour of the fuel with the atomisation temperature. For this purpose, its behaviour at different temperatures was determined and the dynamic injection viscosity was calculated according to the stipulations of the ASTM 0445-04 standard (Rodríguez Gauna, 2019).

After this, combustion tests were carried out with the five mixtures, comparing them with the reference fuel, which is diesel; the mixture of air and fuel was controlled so that combustion would be as efficient as possible. To achieve this objective with the oils, heat was applied to each of the blends in order to reduce their viscosity index and dilute the fuel so that it flows easily through the absorption pump. The following activities were considered as relevant:

1. Efficient burner design.

2. Burner atomisation injector design.

3. Design of atomised air-fuel pre-mixing chamber.

4. Post-combustion chamber design

To test the efficiency of the development on an industrial scale, the Clayton EO-10 steam generator was used.

In order to achieve the goals set out in this project, its application was validated in the Clayton steam generator, model E0-10, which has the following technical characteristics:

Model	E0-10
Boiler Horsepower	10 BHP
Net Power	98 Kw
Heat Supply	85026.5 Kcal/Hr
Dry Saturated Steam Flow	157 Kg/Hr
Design Pressure	13 Bar
Working Pressure	10 Bar
Steam Temperature	180 °C
Surface Heating	4.5 M^2
Original fuel	Diésel
Calorific value Diesel	10,195 Kcal/Kg
Diesel consumption full load	8.9 Kg/Hr
Combustion efficiency	93 %
Water supply	24 Lts
Water content in operation	9.1 Lts
Engine Fan	1.5 Kw
Engine Feed water pump	0.37 Kw

Table 1 Design data and thermal capacity of steam generator E0-10

The content of the acceptance tests for the application of the non-conventional fuel in the Clayton EO-10 generator included the validation of the following points:

1. Acceptance testing, ignition, flame detection, heat output and products of combustion.

2. Steam generation, pressure, temperature and steam flow.

3. Determination of energy efficiency and heating rate.

4. Extensibility of application of this project.

ISSN 2410-4019

Analysis and discussion of results

Viscosity analysis

Due to the complexity of fuels and for reasons of reproducibility of results and simplicity in carrying out experimental and modelling studies, it is necessary to use substitute fuels, i.e., simpler mixtures of some reference compounds. In the selection of a surrogate fuel, both the fuel they replace and the characteristic they are intended to simulate must be taken into account, and they are usually classified by the latter factor. In this case, the fuel to be substituted is Diesel.

The technological development of a new fuel starts from the basic principle of using waste oils because they have lost their lubricating capacity, for motor vehicle oils, and in the case of vegetable oils because they have lost their calorific value, or simply because they have become contaminated in both cases. Therefore, it is logical to expect results with high contents of particles and sediment, as well as water content.

The reports of the results obtained in the laboratory analysis are shown in Table 2. These contain the viscosity profile; the spectrometry of the mixtures was partially performed due to moisture problems of the samples.

Tests	M1	M2	M3	M4	M5
Viscosity CST 40°C MAX MIN A 40°C	74.04	45.03	48.14	60.78	41.78
Viscosity CST 100°C (ASTM Method D-445)	11.74	8.91	8.85	10.28	8.6
I.V (viscosity index) (Minimum)(Method ASTM D-2270)	153	183	166	158	190
Neutralisation number (TAN) (Mg KOH/gr) (Method ASTM D-974) Máx	0.91	2.84	0.19	0.44	0.07
% of water (MET ASTM D-6304) KARL FISHER (Maximum)	7.50%	0.14%	3.26%	6.49%	1.78%

Table 2 Viscosity analysis results

Water and moisture play an important role in the calorific value and viscosity of the fuel; Figure 2 shows the graph of the percentage of water content for each of the samples. It can be seen that for the vegetable oil the percentage of water is very low with values of 0.14%, while for the motor oil it is 7.50%; when mixing these oils the average water content varies according to the percentages of each of them, as can be seen for sample number three, for which the percentages of oils is Motor 50% - Vegetable 50% and coincides with its average of 3.26% of moisture reported against the 3.68% calculated from the results of each of the percentages of moisture of the oils at 100%.

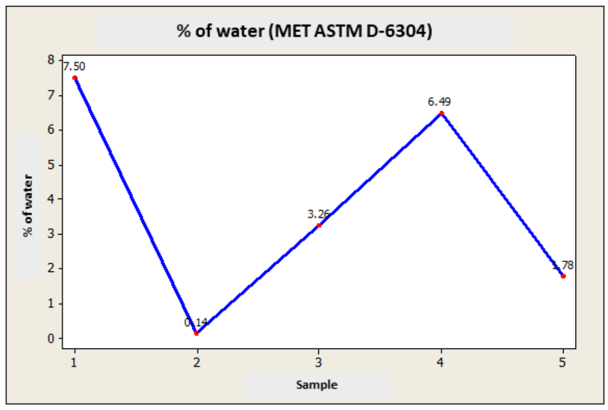

Figure 2 Percentage of water found in each of the samples

Viscosity Control

The viscosity of the oil mixtures varies as a function of temperature, with the results of the stoichiometric analyses the viscosity values were plotted, the results are shown in Figure 3. It can be seen that for all cases the viscosity is higher for lower temperatures and lower viscosity for higher temperatures, which means that for a temperature of 40°C we have an average viscosity of 53.95 cSt, while for a temperature of 100°C the average viscosity is 9.68 cSt.

In Figure 3 it can also be seen that the profile of the curves is very similar for the temperatures of 40°C and 100°C, however, there is a variation in viscosity depending on the percentage of each of the oil blends.

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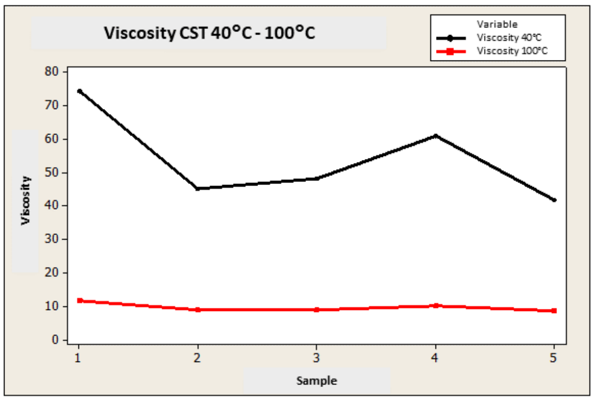

Figure 3 Temperature-dependent viscosity profiles

The induction pump of the steam generator uses diesel as fuel, which has a viscosity of 4 cSt, therefore, it is necessary that the development of the alternative fuel meets the same characteristics so that the fuel can be sucked and injected into the burner; to obtain the same viscosity in each of the samples, each of them has to be heated to different temperatures, which are as follows:

Sample 1.- 121°C

Sample 2.- 112°C

Sample 3.- 107°C

Sample 5.- 110°C

These values are obtained from the graph in Figure 4, which was constructed with the data obtained from the viscosity analysis.

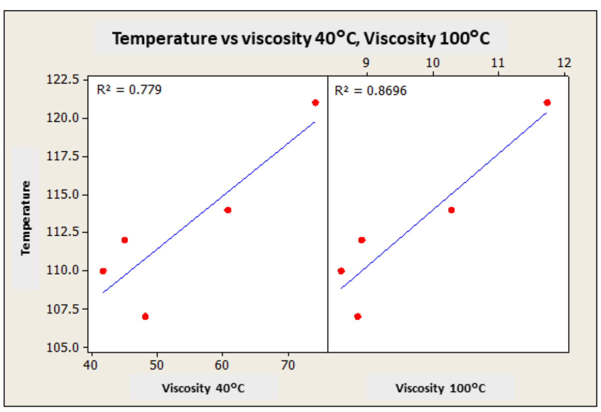

Figure 4 Correlation for viscosity calculation. Reference Diesel 4.0 cSt

The alternate fuel was heated in an electric slow cooker, and the temperature was monitored with an infrared pyrometer until the temperatures specified above were obtained for each of the samples.

Combustion tests

In order to calibrate the injector nozzles and the amount of air, the burner was installed on a workbench and combustion tests were carried out with diesel as the standard fuel and the fuel blends prepared.

With the data obtained from the spectrometry for the percentages of alloying elements and the help of an EXCEL sheet, the calorific value can be calculated for each of the fuel samples analysed, the results are shown in Table 3. It can be seen that the sample with the highest calorific value is number 1, which contains 100% motor oil, which has 10,619.78 Kcal/kg; therefore, the samples containing the highest percentage of motor oil are proportional in the calculation of their calorific value.

Comparing the values of samples 1 and 4 with the calorific value of diesel (10,200 Kcal/kg), it can be seen (Table 3) that these blends slightly exceed the efficiency of conventional fuel (diesel).

	M1	M2	M3	M4	M5
Combustible calorific value	10,619.78 Kcal/kg	9, 321.12 Kcal/kg	10,072.14 Kcal/kg	10, 280.51 Kcal/kg	9,771.26 Kcal/kg

Table 3 Calorific value calculation results

Funding

Funding: The present work has been funded by COECYT (Project key COAH-2019-C13-C063), call C13-2019.

Conclusions

The calorific value of 100% motor oil is the one that reaches a maximum value of 10,619.60 Kcal/Kg and 100% vegetable oil is the lowest calorific value with 9,321.30 Kcal/Kg. The calorific value of the mixtures of both oils varies in proportion to the percentage of each of them. Considering the higher calorific value of the analysed fuels, the highest efficiency in the combustion process for the use of alternative fuel is sample 1 of 100% motor oil.

Co-processing offers a safe and healthy solution for society, the environment and industry in general by substituting non-renewable resources. Co-processing of alternative fuels provides a solution in terms of reducing dependency on fossil fuels as well as a contribution to reducing emissions. Importantly, by using waste oils in other processes, it helps the environment.

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