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EFFICIENT USE OF USED LUBRICANTS

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ABSTRACT

In the current context of the deepening energy crisis and the continuous decrease of natural resources, especially crude oil, it is necessary to approach production strategies that are really efficient, both from a technical and economic point of view, in order to reduce energy consumption as much as possible and manage resources as efficiently as possible. In this sense, the experimental study presented in this paper proposes an effective technological solution for the transformation of some waste, such as used lubricants, into useful products, this valorization being realized with minimal processing costs and energy consumption.

Keywords: waste, used oils, valorization, environment impact

INTRODUCTION

Lubricating oils represent approximately 10% by weight of the total amount of the processed crude oil. The range of lubricating oils is very diverse, both due to the functions they perform depending on their specific use, but also due to their physico-chemical and performance characteristics [1].

The global consumption of lubricants varied, from the beginning of the millennium when it was about 40 million metric tons, then it registered a decrease until 2009, to about 32 million metric tons and returned to a value of about 36 million tons in the recent years.[2-5].

Of the total need for lubricants globally, those consumed during their use represent approx. 10-15% (greases, processing fluids, two-stroke engine lubricants, etc.) [1].

Most of the lubricants, approx. 85 – 90%, are quantitatively found at the end of their service life, turning into used oils that are considered waste. That massive amount of waste constitutes a serious environmental problem.

The situation of used oils is still not managed well enough: used oils can be accidentally spilled into the environment, can be incinerated to be destroyed as waste, and only a part ends up being collected in a controlled system [6-8].

The economic value that lubricants present, both from the point of view of the resource of raw materials from which they are obtained, i.e. crude oil, and the costs of the manufacturing chain through which they are obtained, obliges us once again to think about their valorization, after they end the service life.

This concern has existed for at least 40 years, but most technological solutions have focused on the regeneration of used oils, which involves very high costs, even 2 times higher than the basic process for obtaining lubricants [1, 9-12]

A viable and less expensive solution is the conditioning of used oils, which involves the separation of water and impurities, as well as volatile parts, by physical processes of separation and sedimentation, atmospheric distillation, eventually vacuum distillation [13-14]

The present study proposes a technical solution that allows an efficient recovery of used lubricating oils, with even lower costs and significant advantages in terms of environmental impact and resource saving.

EXPERIMENTAL DATA

The main purpose of the experimental study was the transformation of used oils into useful products, by using only simple physical processes, with minimal energy consumption.

For the conditioned used oils obtained in this way, possible solutions of application were sought, so as to realize their direct valorization, without further processing.

In order for the results to be as representative and relevant as possible, used oil samples procured from a well-known used oil collecting company in Prahova county, were used for the study.

The collection system applied by this company, as well as by most companies in the field, is that of collection by categories of oils that have had similar uses, or by categories of oils with relatively close viscosities (which fall into viscosity ranges that include two , maximum three ISO-VG viscosity classes).

For the experimental study, four oil samples were taken, coming from four representative batches of collected used oils.

In the first stage of work, the samples were homogenized and then examined, identifying a significant content of water and impurities.

Next, a separation of water and mechanical impurities was performed for all samples. The separation was achieved by heating the samples under stirring to a temperature of approximately 70 ^{0}C, after which they were transferred to the separation funnels, they were left for 3 hours at rest, then the water and impurities were removed from the oil itself. Thus, a simple conditioning of used oils was achieved.

For the oil fractions thus conditioned, a preliminary characterization was carried out in order to evaluate their quality level. The following features were tested:

- Color, in accordance with the ASTM D 1500 test method;
- Density, according to ASTM D792, SR EN ISO 3675 test method;
- Kinematic viscosity, according to ASTM D445, SR-EN ISO 3104 test method;
- Water and impurities content, according to ASTM D 1796 test method;
- Flash point, according to ASTM D 92 test method.

The results obtained at the end of conditioned oils testing are presented in table 1.

Table 1. Characteristics of the conditioned used oils

Characteristics	**Testing method**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
Color	ASTM D 1500	8	4	8	8
Density	ASTM D792	0.8773	0.8825	0.8809	0.8823
Kinematic viscosity, at 40 ^{0}C, cSt	ASTM D445	40.91	61.2	54.51	37.12
Flash point, ^{0}C	ASTM D 92	98	116	98	108
Water and sediment content:	ASTM D 1796				
- water, % vol.		0.05	0.05	0.05	absent
- sediment, % vol		0.4	absent	0.5	0.6

The results obtained were evaluated in order to identify possible applications, compatible with the quality level of conditioned used oils, without resorting to an additional refining stage.

In this sense, in a first step, the characteristics of the studied samples were compared with the characteristics usually imposed on the base oils, from which the finished lubricants are obtained.

From the evaluation of the obtained results, it can be observed that the conditioned used oils are characterized as follows:

- the color falls within the range 4 – 8, on the ASTM UNION scale;
- the viscosity is specific to the viscosity classes ISO VG 32 – ISO VG 60;
- the density has usual values for oils in these viscosity classes;
- flash points are low values, within the range 98 – 108 ^{0}C;
- water content: 0 - 0.05 % volume;
- content of mechanical impurities is the relatively high, in the range of 0.4 – 0.6 % volume.

These results were analyzed in order to identify possible applications, compatible with the quality level of conditioned used oils, without resorting to an additional refining stage.

In this sense, in a first step, the characteristics of the experimental samples were compared with the characteristics usually imposed on the base oils, from which the finished lubricants are obtained.

From the evaluation of the testing results, it can be observed that the conditioned used oils are characterized as follows:

- the color falls within the range 4 – 8, on the ASTM UNION scale, much darker compared to the usual requirements for base oils;
- the viscosity is specific to the viscosity classes ISO VG 32 – ISO VG 60, but not exactly respecting the specific values of these classes;
- the density has usual values for oils in the above mentioned viscosity classes;
- flash points are significantly lower than those specific to these viscosity classes;
- water content is in the limits of the base oils: 0 - 0.05 % volume;

- the relatively high content of mechanical impurities exceeds the limits imposed on base oils.

Concluding on the analyze of the presented results, the following are highlighted:

- used oils conditioned by the proposed process, could not be used as base oils, in a (potential) lubricant formulation, due to the dark color, low flash points and relatively high impurity content;
- in order to obtain values of the specific characteristics for use as base oils, additional conditioning steps would be necessary;
- a suitable use of these conditioned oils, which would allow their direct utilization at this level of quality, could be that of components for furnace fuels

To verify this assumption, the quality standards for several types of furnace fuels were analyzed. A commercial furnace fuel, heavy furnace fuel type, with representative requirements for this fuel category, was chosen as reference.

The characteristics imposed on the commercial fuel were evaluated against the characteristics of the conditioned used oils. For a concluding evaluation, it was necessary to additionally perform the following characterization tests of conditioned used oils:

- Conventional (Engler) viscosity at 50 ^{0}C, according to ASTM D 1665 test method;
- Freezing point, according to ASTM D 97 test method;
- Density at 15 ^{0}C;
- Lower heating value, calculated according to the carbon and hydrogen content of the fractions.

The calculation method for lower heating value of the conditioned used oils is presented as further. The formula for calculating the lower heating value (LHV) is as follows [14]:

$$LHV = 33915 \text{ x } c + 103000 \text{ x } h, \text{ kJ/kg}$$

c = carbon content expressed in mass fraction:

$$c = 0.15 \text{ x } d_{15}^{15} + 0.74$$

h = hydrogen content expressed in mass fraction:

$$h = 1 - c$$

$$d_{15}^{15} = 0.9952 \text{ x } d_4^{20} + 0.00806$$

The specific lower heating values of the conditioned used oils are shown in the table 2.

Table 2. The calculation of lower heating value of the conditioned used oils

Characteristics	Sample 1	Sample 2	Sample 3	Sample 4
d_4^{20}	0.8773	0.8825	0.809	0.8823
d_{15}^{15}	0.8811	0.8863	0.8132	0.8861
Mass fraction:				
Carbon, c	0.8722	0.8729	0.8620	0.8729
Hydrogen, h	0.1278	0.1271	0.1380	0.1271
LHV, kJ/kg	42744	42693	43450	42695

Table 3 shows the characteristics of the commercial heating fuel, heavy heating fuel type (HHF), taken as a reference, compared to the characteristics of the four selected conditioned used oil samples.

Table 3. Characteristics of conditioned oils and HHF commercial fuel

Characteristics	Test method	HHF admisibility limits	Sample 1	Sample 2	Sample 3	Sample 4
Color		report	8	4	8	8
Density	SR EN ISO 3675	report	0.8773	0.8825	0.8809	0.8823
Kinematic viscosity, at 40 ^{0}C, cSt	SR EN ISO 3104	-	40.91	38.7	35.1	37.12
Engler viscosity at 50^{0}C, E	ASTM D 1665	Max.40	5.4	6.2	4.3	4.9
Water and sediment content: - water, %vol - sediment, %vol	ASTM D 1796	Max.1 Max.1.2	0.05 0.4	0.05 absent	0.05 0.5	absent 0.6
Flash point, ^{0}C	SR EN ISO2592	Min.90	100	116	100	108
Pour Point, ^{0}C	ASTM D 97	-	-20	-21	-23	-15
Punct de congelare, ^{0}C	ISO 3015	Max.45	- 23	-24	-26	- 18
LHV, kj/kg	calculated	Min.39800	42744	42693	43450	42695

Evaluating the results of the characterization of the studied conditioned used oil samples and comparing them with the specific requirements of heavy heating fuel, it can be highlighted that this type of fuel can be obtained from all four types of conditioned oils, without the need for their additional processing.

CONCLUSIONS

The average annual consumption of lubricants between 2000 and 2020 was at the level of 40 million metric tons/year. After their service life, these lubricants turn into an equivalent amount of waste, and this can represent a potential risk to the environment, in case of accidental spills.

The controlled management of these wastes is very important, but even more important is their recovery, because they represent an important source of hydrocarbons, raw materials and energy.

The solution developed within the study is part of this objective because it offers the possibility of transforming some waste, respectively used oils, into a source of raw materials for obtaining useful products, with minimal costs and reduced energy consumption.

Heavy heating furnace fuels, formulated on the basis of conditioned used oils, meet the requirements imposed on these products, have a quality suitable for use and represent an effective way of capitalizing and extending the life of some natural resources.

REFERENCES

[1] Mang, T., Dresel, W., Lubricants and Lubrication, 3rd Completely Revised and Enlarged Edition Edited by Th. Mang and W. Dresel, 2017

[2] Beeton, J., Growing Asian Markets Tough to Enter - Lube Report Asia, Lube & Greases, April 2015.

[3] Sönnichsen, N., Change in global demand for lubricants in 2017 compared to 2016, by region, Statista, 2021, https://www.statista.com/statistics/411637/lubricants-demand-worldwide-change-by-region/#statisticContainer.

[4] Global lubricants market – size, share, Covid-19 impact & forecasts up to 2026, Mordor Intelligence, https://www.mordorintelligence.com/industry-reports/global-lubricants-market-industry

[5] World Lubricants, Industry Study with Forecasts for 2015 & 2020, Study 2771, July 2011.

[6] Boyde, S., Green lubricants. Environmental benefits and impacts of lubrication, Green Chemistry, Issues 4, 2002.

[7] Pinheiro, C.T., Quina, M.J., Gando-Ferreira, L.M., Management of waste lubricant oil in Europe: A circular economy approach, Critical Reviews in Environmental Science and Technology, Vol. 51, Issue 18, 202, pp. 2015 – 2050.

[8] Monier, V., Escalon, V., Cassowitz, L., Etude de la gestion de la filiere de collecte et de valorisation des huiles usagees dans certains pays de l'UE, réalisée pour le compte de l'ADEME par BIO Intelligence Service S.A.S., 2010.

[9] Tănăsescu, C., Tehnologia uleiurilor, Ed. Universităţii din Ploiești, 2002, pp.261-269.

[10] Abdulbari, H.A., Zuhan N., Grease Formulation from Palm Oil Industry Wastes, Waste and Biomass Valorization, Vol. 9, Issue 12, 2018, pp. 2447 – 2457.

[11] Belinskaia I., Kartoshkin A., Recycling of waste lubricants by using low-tonnage technology, Engineering for Rural Development, Vol. 16, 2017, Pp. 378 – 382.

[12] Farias R.B., Pinto D., Goulart M.L., Treatment of residual lubricating oil using rice husk-based material as ecological adsorbent, Waste and Biomass Valorization, Vol. 9, Issue 12, 2018, pp. 2447 – 24571.

[13] Bogatu, L., Onutu, I., Cursaru, D., New alternative for conditioned oils revaluation, Journal of the Balkan Tribological Association, Vol.21, book 1, 2015, pp.222-232.

[14] Rădulescu, A., Bogatu, L., Rădulescu, I., Rheological methods for evaluation of the base oils obtained by conditioning of hydraulic used oils, Journal of the Balkan Tribological Association, vol.22, No.4-IV, 2016, pp.5037-5045.

[15] Dobrinescu D, Procese de transfer termic si utilaje specifice, Editura Didactică şi Pedagogică, Bucureşti, 1983, pp.39-40.

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