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POTENTIAL OF CLEANING SPENT TURBINE OILS USING LOCAL BENTONITE SORBENTS

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Abstract

The article covers the potential of regenerating spent turbine oils and renewal of their physical and chemical properties. Samples of spent Shell Turbo S4 GX46 turbine oil were selected as the object of research. Natural and activated bentonite sorbents were used in their purification process. During the research, the samples were analyzed using the gas chromatography-mass spectrometer (GC–MS) method, and the main components in the oil were qualitatively and quantitatively determined. The analysis results showed that the purification process using activated bentonite was the most effective, as a result of which the amount of useful hydrocarbon components increased and pollutants decreased.

Keywords: *Turbine oil, regeneration, bentonite, activated sorbent, gas chromatography-mass spectrum, adsorption, physical and chemical analysis, ecological safety, industrial waste hydrocarbon components*

Introduction

The persistent and efficient operation of modern industry depends on many complex technological systems. One of these systems is turbines, which play an important role in energy production. The reliable and stable operation of turbines is unthinkable without turbine oils, which are one of their important components. The turbine performs such functions as reducing friction, cooling and protecting turbine parts from corrosion, and extending the service life of mechanisms. In particular, the correct selection and use of these oils in power plants, thermal and hydropower systems directly determines production efficiency.

In addition to that, turbine oils, like any oil product, are contaminated from various sources over time. These contaminants not only worsen the physicochemical properties of the oil, but also increase the risk of equipment failure. The causes of contamination of used turbine oils are associated with dust and moisture entering from the external environment, metal fragments released from the internal system, combustion products, and compounds formed as a result of chemical reactions. This problem poses a serious environmental and technological threat to industrial enterprises, further increasing the need to monitor the quality and service life of the oil.

Assessment of the quality of oil, identification of the contaminating components in it is important for the safe operation of equipment and the prevention of environmental hazards. In this regard, the chromatography method, especially gas and liquid chromatography, is one of the most effective analytical tools for analyzing used turbine oils. This method allows determining the oxidation products, additional chemical compounds, the degree of suitability of additives and contaminants in the oil. Chromatographic analysis not only shows how much oil has been used, but also allows making optimal decisions on oil replacement and cleaning. Therefore, this method is of great scientific and technical importance in working with waste oils in industry.

Materials and methods

A sample of the Shell Turbo S4 GX46 type used turbine oil was taken as the research object. In order to carry out the research, modern physicochemical (gas chromatography-mass spectroscopy) analysis methods, as well as methods for analyzing oil and oil products in accordance with state (GOST) and world standards were used.

The adsorption of used turbine oil was studied in the laboratory using bentonite from the Navbahor mine. Bentonite is a natural aluminosilicate with high sorption activity, and its main active component is the montmorillonite mineral. Due to its porous structure and high surface area, it has the property of effectively absorbing organic and inorganic contaminants contained in the oil.

In the course of the experiment, the used turbine oil was cleaned of mechanical impurities using filter paper and 10 g of bentonite, previously dried, crushed and sieved to a particle size of 0.01 mm, was placed in a burette and 50 ml of used turbine oil was taken and filtered. The filtration process was carried out at a temperature of 30 °C, under normal atmospheric conditions. After passing through the bentonite, the color of the oil changed. In the next stage, bentonite was activated using a muffle furnace at a temperature of 500 °C for 1 hour and the experiment was repeated. During the activation of bentonite at high temperatures, the adsorption level is increased by removing volatile organic compounds and excess bound and unbound water from its content. The oil passed through the activated bentonite was observed to be discolored. One of the modern research methods, gas chromatography-mass spectrometry, was used to separately study the structural components of the obtained samples. The qualitative and quantitative composition of the purified turbine oil was analyzed using Agilent 5975C inert MSD/7890A GC (Agilent Technologies) gas chromatography-mass spectrometer (Tilloyev L. I., Dustov H. B., Murodov M. N., Yuldashev N.Kh., 2022).

Results and discussions

In order to determine the hydrocarbon content of laboratory results obtained from used turbine oils, gas chromatograph-mass spectrometers with an accuracy of 80% or higher were selected. The gas chromatograph-mass spectrum of a sample taken from spent Shell Turbo S4 GX46 turbine oil is shown in (Fig. 2).

The qualitative and quantitative composition of a sample of spent Shell Turbo S4 GX46 turbine oil is presented in Table 1.

The percentages of the four main components in a sample of Turbo S4 GX46 oil are shown. As can be seen, hexatriacontane has the largest share, followed by 17-pentatriacontane and the other two components in much smaller amounts. 1-Naphthalenecarboxamide usually increases the high-temperature resistance of the oil and provides stability. It is added as an acidity reducer and antioxidant.

17-Pentatriacontane is an unsaturated hydrocarbon that controls the viscosity level of the oil and provides high lubricating properties. The main component hexatriacontane is a saturated hydrocarbon and forms the main lubricating part of the oil. It provides high thermal stability, low evaporation rate and good lubricating properties.

According to the analysis results, Shell Turbo S4 GX46 oil has a high content of hexatriacontane, which makes it resistant to high temperatures, stable and effective for long-term use. Other components play an important role in improving the overall quality of the oil by performing additional functions.

The qualitative and quantitative composition of the sample of Shell Turbo S4 GX46 spent turbine oil purified using bentonite is presented in Table 2.

Figure 2. *Gas chromatographic mass spectrum of a sample of spent Shell Turbo S4 GX46 turbine oil*

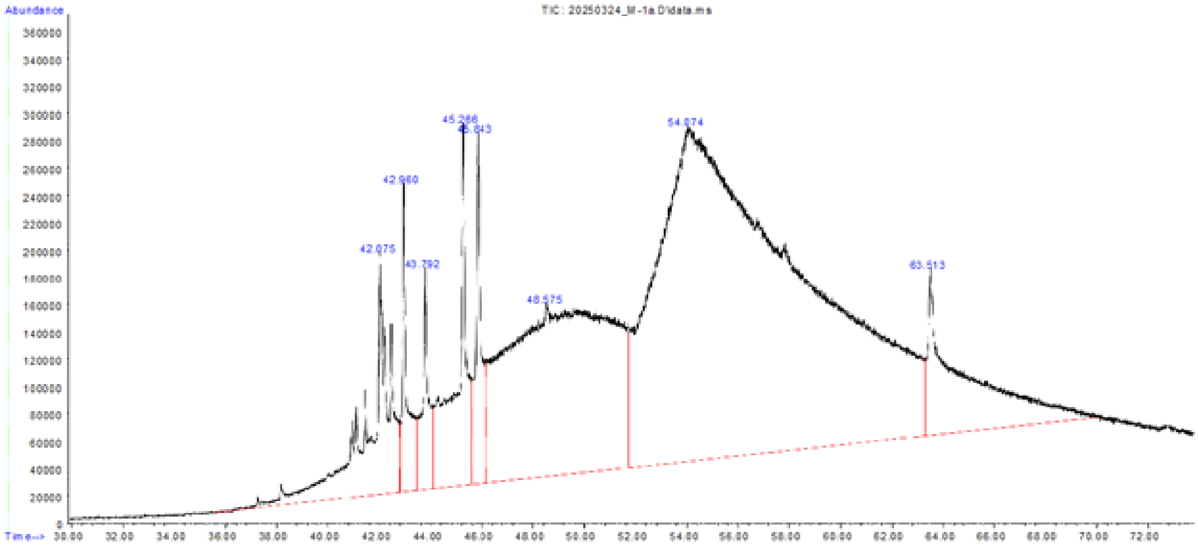
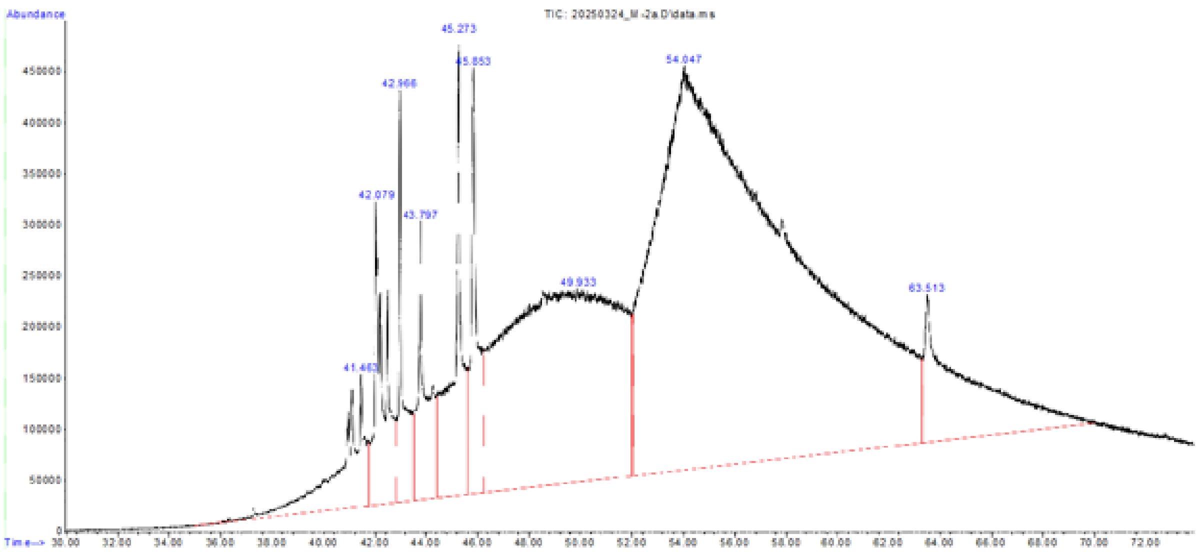


Table 1. *Qualitative and quantitative composition of a sample of spent Shell Turbo S4 GX46 turbine oil*

No.	Components	Rf, min	Content, %
1.	1-naphthalenecarboxamide	45.264	4.75
2.	17-pentatriaconten	48.576	23.94
3.	Hexathriacontane	54.074	63.75
4.	4,4-diamine-p-terphenyl	63.512	7.56

Figure 3. *Gas chromatographic mass spectrum of a sample of Shell Turbo S4 GX46 spent turbine oil purified using bentonite*



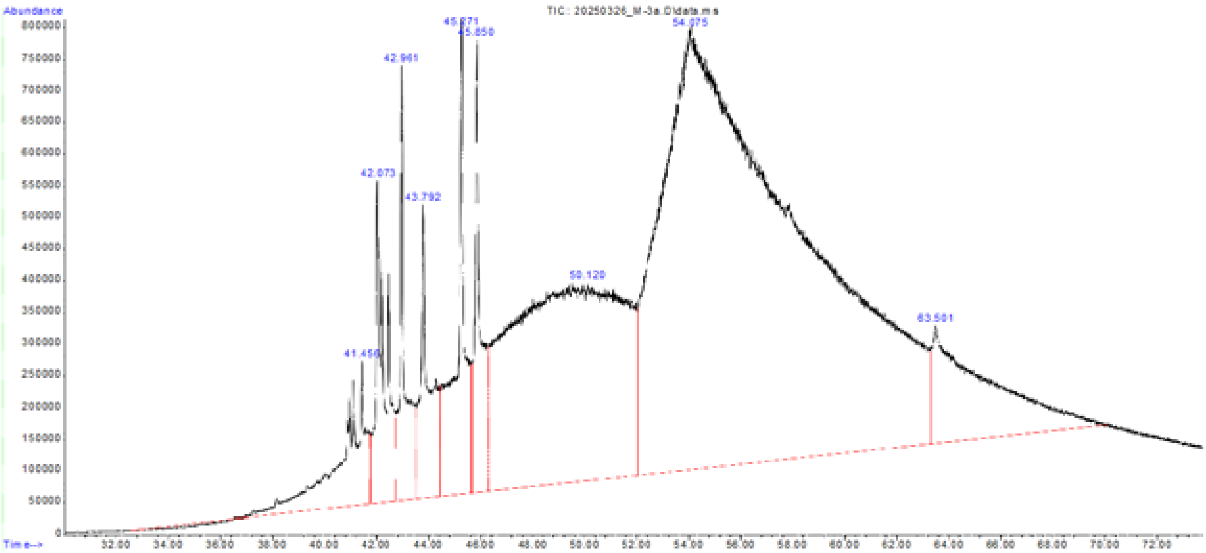
4,4-Diamine-p-terphenyl is added as an antioxidant or stabilizer and also serves to increase thermal stability

Table 2. *The qualitative and quantitative composition of the sample of Shell Turbo S4 GX46 spent turbine oil purified using bentonite*

No.	Components	Rf, min	Content, %
1.	Tricosane	49.934	26.70
2.	Hexatriacontane	54.048	65.95
3.	Benzo[a]anthracene	63.512	7.35

The percentages of the three main components in the sample after purification of Turbo S4 GX46 spent oil with bentonite can be seen to have changed, with hexatriacontane having the largest share, and after purification with bentonite, the composition changed, with the remaining components, tricosane and benzo[a]anthracene, increasing in content.

Figure 4. *Gas chromatographic mass spectrum of a sample of spent Shell Turbo S4 GX46 turbine oil purified using activated bentonite*



Tricosane is a medium-chain alkane that improves cold-weather performance, provides fluidity, and balances viscosity. Benzo[a]anthracene is an aromatic compound that provides stability at high temperatures and, although in small amounts, helps to provide dispersant and detergent properties.

The gas chromatographic-mass-spectrum image of a sample of Shell Turbo S4 GX46 spent turbine oil purified with activated bentonite is shown in (Fig. 4).

The qualitative and quantitative composition of the sample of spent Shell Turbo S4 GX46 turbine oil purified using activated bentonite is presented in (Table 3).

Table 3. *The qualitative and quantitative composition of the sample of spent Shell Turbo S4 GX46 turbine oil purified using activated bentonite*

No.	Components	Rf, min	Content, %
1.	4-methyl-2-mercaptopyridine-1-oxide	43.789	2.91
2.	Tetratriacontane	50.122	26.53
3.	Hexatriacontane	54.074	70.56

After purification of Turbo S4 GX46 oil with activated bentonite, the percentages of the three main components in the sample were observed to change. In this case, after purification with activated bentonite, which has the largest share of hexatriacontane, a change in the composition occurred, and an increase in the amount of Tetratriacontane and 4-methyl-2-mercaptopyridine-1-oxide in the oil was observed.

Tetratriacontane is a high-molecular saturated alkane, which increases the viscosity of the oil and provides anti-friction properties. It also provides thermal and oxidative stability of the oil.

1,4-methyl-2-mercaptopyridine-1-oxide is a pyridine derivative, which contains a mercaptan (–SH) and an N-oxide group. The mercaptan group (–SH) binds well to metal surfaces, therefore this substance is used as an anti-corrosion additive. Due to the N-oxide group, it captures free radicals, therefore protecting oils from oxidation.

The samples of used turbine oils were classified into groups based on the composition of the components determined by gas chromatographic-mass-spectral analysis. The volumetric content of the components determined in the samples according to the hydrocarbon groups is given in Table 4.

Table 4. *Classification of samples of spent turbine oils by hydrocarbon groups*

No.	Unpurified turbine oil (%)	Bentonite-purified turbine oil (%)	Activated bentonite- purified turbine oil (%)
1-naphthalenecarboxamide	4.75	–	–
17-pentatriaconten	23.94	–	–
Hexatriacontane	63.75	65.95	70.56
4,4-diamine-p-terphenyl	7.56	–	–
Tricosane	–	26.70	–
Benzo[a]anthracene	–	7.35	–
4-methyl-2-mercapto-pyridine-1-oxide	–	–	2.91
Tetratriacontane	–	–	26.53

The table above shows the percentage of components in Shell Turbo S4 GX46 turbine oil in unpurified, bentonite-purified and activated bentonite-purified cases. Hexatriacontane is present in all three cases. This indicates that the percentage of this substance increases further with purification.

Conclusion

In conclusion, we can say that according to the research results, each purification stage led to an increase in the amount of the main hydrocarbon components in the oil. The increase in the amount of hexatriacontane ($C_{36}H_{74}$) in the samples purified with activated bentonite to 70.56% indicates a high efficiency of purification. This confirms the possibility of making spent turbine oils technologically reusable by their regeneration.

Scientific research conducted have shown that the use of natural and activated bentonite sorbents in the regeneration of spent turbine oils is an effective technological solution. In particular, the results of gas chromatographic-mass spectrometric analysis proved that stepwise purification processes using sorbents have a significant impact on physicochemical and structural changes.

In the course of the experiments, it was observed that the high adsorption activity of activated bentonite resulted in an increase in the concentration of heavy hydrocarbon components in the oil, while the content of polluting compounds decreased. In particular, a sharp increase in the amount of hexatriacontane indicates the preservation of useful fractions in the oil and the efficiency of processing. This creates an opportunity to repurpose used turbine oils, not just as waste, but as valuable secondary raw materials.

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