**Investigation of Effective Methods of Cleaning of Used Motor Oils**

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**Abstract:** This article analyzes the changes in the physicochemical properties of used oils after the adsorption cleaning process using bentonite. According to the results of the study, bleaching clay and bentonite adsorbent effectively absorb mechanical impurities, oxidation products and harmful additives from the oil composition. After the cleaning process, the color of the oil becomes lighter, the acidity number decreases and the possibility of reuse increases. The results of the study show that cleaning oils using bleaching clay and bentonite is an environmentally and economically effective method. The essence, technological processes, advantages and disadvantages of the adsorption method in the regeneration and cleaning of used motor oils were analyzed. The adsorption method is considered environmentally and economically effective and expands the possibilities of reusing motor oils.

**Keywords**: used motor oil, regeneration, adsorption, adsorbent, ecology, recycling.

**INTRODUCTION**

Today, motor oils, which are widely used in the automotive and industrial sectors, are an important material that ensures the uninterrupted operation of machines and mechanisms. However, during use, the physicochemical properties of oils deteriorate, and oxidation products, resinous substances, metal particles, fuel residues and water accumulate in their composition. This makes further exploitation of oils impossible and leads to their collection as waste. According to statistics, millions of tons of used motor oils are disposed of worldwide every year, and they are classified as hazardous waste that pollutes the environment [1].

Therefore, the processing and regeneration of used oils is an urgent scientific and technical issue. Among the regeneration methods, the adsorption method is distinguished by its simplicity and efficiency [2].

Adsorption purification of used motor oils is one of the most promising directions in solving environmental and economic problems today. This method serves to restore the physicochemical properties of motor oils, enable their reuse, and reduce the volume of waste. In the future, the effectiveness of the method can be further increased by developing new highly effective adsorbents and optimizing technological processes.

The purpose of this work is to study the changes that occur in the properties of used oils after the adsorption purification process using local bleaching clay and bentonite.

For this, the following tasks were set:

1. Determining the initial properties of used oil.

2. Studying the possibilities of using local bleaching clays and bentonite as adsorbents.

3. Comparison of oil properties before and after purification.

4. To evaluate the effectiveness of the adsorption method.

The results obtained and their analysis. Adsorption is a surface phenomenon, which is the absorption of particles in a liquid or gas on the surface of a solid substance (adsorbent). Adsorbents used in the purification of motor oils (activated carbon, bentonite, silica gel, zeolite, aluminosilicates) have high porosity and a large surface area. With their help, the following substances are effectively separated: coloring substances; resins and oxidation products; organic acids; heavy metals; coke and dispersed particles [3].

Adsorption is a surface phenomenon. Molecules or ions are trapped on the porous surface of the adsorbent. This process occurs due to the following forces:

Van der Waals forces (physical adsorption),

Chemical bond forces (chemical adsorption) [4].

Physical adsorption is reversible, and the substance is easily separated from the surface. Chemical adsorption, on the other hand, is more stable and difficult to reverse due to stronger bonds [5].

**MATERIALS AND METHODS**

The adsorption process is widely used in many areas: in environmental protection - to purify the air from gases and harmful impurities; in the chemical industry - to separate coloring or unwanted substances from solutions; in the oil and grease industry - to regenerate used oils; in pharmaceuticals - to purify medicinal substances; and in the household sector - in water filtration and air purifiers [6].

The oil purification process usually consists of the following sequential stages:

1. Preliminary preparation.

The oil is stored in a container for a certain period of time. During this stage, large particles and sediment fall to the bottom and are separated.

2. Adsorption process

A specially prepared adsorbent (often bentonite, activated clay or activated carbon) is mixed with the oil.

Fine fractions of the adsorbent are used (0.071–0.25 mm) [7].

The adsorption temperature is usually maintained in the range of 150–200 °C, since under these conditions the viscosity decreases and the adsorption rate of contaminants increases.

3. Centrifugal separation (centrifugation)

The contaminants absorbed by the adsorbent are quickly separated using a centrifuge.

4. Filtration (filtration process)

The oil is heated to 80 °C and passed through a dense fabric (cotton) [8].

At this stage, the remaining small particles are removed.

Ordinary paper filters cannot be used, since their pores quickly become clogged with bentonite and other small particles [9].

5. Adsorbent regeneration.

After a certain period of use, the adsorbent surface becomes saturated with contaminants. It is regenerated for reuse, which is done by sharply reducing the pressure or by heating to 200–300 °C.

The temperature and duration of treatment are of great importance in the purification of used oils by adsorption [10, 11].

**RESULTS AND DISCUSSION**

Theoretically, with increasing temperature, the adsorption efficiency should decrease, since in this case the thermal motion of the molecules of the separated (adsorbed) substance increases and they are difficult to capture on the surface of the adsorbent. However, at low temperatures, the molecules of the substances diffuse very slowly to the surface of the adsorbent due to their high viscosity. Therefore, viscous motor oils are usually subjected to contact treatment at temperatures around 150–200 °C during the adsorption process.

Table 1 presents the technology for purification of used motor oils by adsorption.

An important aspect of the purification efficiency is the duration and intensity of mixing the oil with the adsorbent (in powder form). If the adsorbent and oil are left undisturbed, the liquid layers in direct contact with the adsorbent are purified, but mechanical impurities in more distant layers penetrate the surface of the adsorbent very slowly. Therefore, contact purification of used oils is usually carried out under conditions of intensive mixing (1000–1400 rpm). The mixing time is 30 minutes [10].

**TABLE 1.** Technology of adsorption treatment of used motor oils

|  |  |  |
| --- | --- | --- |
| **Stages** | **Process content** | **Result** |
| 1. Initial preparation | Large solid particles, sediment and liquid phase (water) in the oil are separated by mechanical filters, screens or sedimentation. Separation of large particles by filtration. | Initial oil treatment removes water and mechanical impurities.  At this stage, 40–60% of impurities are removed. |
| 2. Heating | The oil is heated to 70–100 °C | This step ensures good mixing of the adsorbent with the oil and reduces viscosity. |
| 3. Adsorption process | The oil is mixed with an adsorbent (activated carbon, bentonite, zeolite, silica gel, etc.). Impurities are absorbed onto the surface of the adsorbent. | Coloring substances, resins, oxidation products and heavy metals are removed |
| 4. Separation | The adsorbent is separated from the oil by filtration or sedimentation | The purified oil is separated. |
| 5. Additional processing | Neutralization (with acid/alkali). Additional adsorption to improve color - Useful additives (inhibitors, detergents-modifiers) are added | Restores the quality of the oil, increases its stability.  High degree of purification (70–85%). Environmentally friendly, low atmospheric emissions. The technology is simple and requires little energy. |

**TABLE 2.** Advantages and disadvantages of the adsorption method

|  |  |
| --- | --- |
| **Advantages** | **Disadvantages** |
| The technology is simple and inexpensive. | It is difficult to reuse the adsorbent |
| Environmentally safe | Part of the oil is lost with the adsorbent |
| High cleaning efficiency. | Additional methods are required for heavily contaminated oils. |
| Allows oil reuse. | There is a problem with the disposal of adsorbent waste. |

The adsorption method is one of the most effective and environmentally friendly methods for the recovery of used motor oils. It is widely used in practice, as it is based on cheap raw materials and provides a high degree of purification.

The most important factors affecting the adsorption efficiency are the following [9]:

Temperature - adsorption decreases at high temperatures, but is carried out at 150–200 °C to reduce the viscosity of oils;

Pressure - the amount of adsorption of gases increases with increasing pressure;

Particle surface area and porosity - an adsorbent with a larger surface area absorbs more substance;

Time - after a certain time, the adsorbent becomes saturated and the process reaches equilibrium.

From the table, it can be concluded that the most effective adsorbent is activated carbon, since it (high surface area, bentonite is the cheapest and is bulk. Zeolite works best in ion exchange, and silica gel can be used to dry water that has been added to oil.

Adsorption properties depend on the temperature, humidity, number of pores, and specific surface area (surface area of 1 g of adsorbent) of the materials. These indicators differ significantly for porous and non-porous substances. In the first case, the specific surface area can be up to 1000 m²/g. Activated carbon, silica gel, aluminosilicate catalysts, etc. have such properties. Non-porous adsorbents include black smoke particles, crushed crystals, aerosil, etc. Their specific surface area is from 1 to 500 m²/g.

The purification was carried out according to the following scheme: sedimentation, adsorption, centrifugation, and filtration.

**TABLE 3.** Used adsorbents and their properties

|  |  |  |  |
| --- | --- | --- | --- |
| **Adsorbent type** | **Main characteristics** | **Advantages** | **Disadvantages** |
| Activated carbon | High porosity, large surface area, absorbs organic substances well | Improves color, effectively removes oxidation products | Expensive, difficult to regenerate |
| Bleaching clay | Natural clay mineral, has high sorption capacity | Cheap, environmentally friendly, widely used | Low mechanical strength |
| Bentonite | Natural clay mineral, has high sorption capacity | Cheap, environmentally friendly, widely used | Low mechanical strength |
| Silica gel | High surface area, effectively absorbs moisture and acids | Removes organic acids and water well | Higher price, limited reuse |
| Zeolite | Crystalline aluminosilicate, has ion exchange ability | Well absorbs heavy metal ions, stable | Preparation process is complicated |
| Aluminosilicates | High mechanical stability, absorbs various particles | Can be used repeatedly | Efficiency is lower than activated carbon |

The clay used in adsorption is dried in an oven at a temperature of 120 °C and ground. Then the clay is divided into portions and placed in a porcelain dish crushed. After that, the clay was separated into fractions by passing through sieves of 0.25 mm and 0.071 mm. For the adsorption process, fractions of +0 ÷ –0.071 mm and +0.071 ÷ –0.25 mm were used.

**TABLE 4.** Comparative properties of bleaching clay and bentonite

|  |  |  |  |
| --- | --- | --- | --- |
| **№** | Parameters | Bleaching clay | Bentonite |
| 1 | Composition | Various natural clay minerals | Consisting mainly of montmorillonite mineral |
| 2 | Main function | Adsorption of coloring agents, tar and oxidized additives from oil and other products | Adsorption of various substances (water, oil, petroleum products) due to its large surface area |
| 3 | Field of application | Mainly bleaching and purification of oils | Widely used as an adsorbent for oil, oil, water purification |
| 4 | Form | Natural or acid-activated | Natural, as well as in specially treated form |
| 5 | Advantage | Quickly lightens color, easy to use | Has a very large adsorption surface, has swelling properties |
| 6 | Limitations | The quality may vary in different regions | Sometimes the effectiveness in completely lightening the color is lower |

The cleaning process was carried out based on the adsorption method. Local bleaching clay was dried, sieved and used as an adsorbent. The used oil was pre-filtered and then treated with an adsorbent.

The adsorption purification of oil was carried out according to the following methodology. 600 g of used engine oil was placed in a heat-resistant 900 ml beaker. 30 g of prepared clay was added to the oil. The adsorption purification process was carried out for two hours at a temperature of 120 °C with constant stirring.

After adsorption, a centrifuge was used to separate solid inclusions. For this, the oil heated to 80 °C was decanted and poured into centrifuge beakers to 3/4 of its volume. The centrifugation process was carried out at a speed of 3000 rpm. The process was carried out for 60 minutes.

The efficiency of the adsorption process depends not only on the type and temperature of the adsorbent used, but also on its duration. If the contact time of the oil with the adsorbent is insufficient, complete diffusion of substances does not occur and the expected degree of purification is not achieved [6].

In practice, even long-term adsorption does not significantly increase the efficiency, since after a certain time the adsorbent surface is saturated with molecules and an adsorption-desorption equilibrium is established.

Therefore, it is important to determine the optimal duration of the adsorption process. For example, when intensively mixing oils with the adsorbent (1000–1400 rpm), a duration of about 30 minutes is considered the most effective.

**TABLE 5. Pro**perties of oils before and after adsorption treatment with bleaching clay

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **№** | Parameters | Unit of measurement | Before treatment | After treatment |
| 1 | Color | - | Dark brown | Yellowish-brown |
| 2 | Viscosity (at 100°C) | mm²/s | 12.8 | 11.5 |
| 3 | Acid number | mgKOH/g | 3.6 | 1.5 |
| 4 | Mechanical impurities | % | 0.12 | 0.02 |
| 5 | Water content | % | 0.20 | 0.05 |
| 6 | Combustible residue (coke) | % | 1.4 | 0.6 |

A certain portion of each sample was taken and filtered. For filtration, the oil was heated to 80 °C. The filtration process was carried out in a flask through a glass funnel. A dense cloth was used as a filter. It is difficult to clean the oil on paper filters, since finely dispersed clay quickly clogs the pores of the paper. In order to determine the efficiency of the cleaning, the original used oil was also filtered in parallel.

The experiments conducted show that adsorption cleaning using local bleaching clay significantly lightened the color of the used oil, made it possible to clean it from mechanical impurities and partially from tar and oxidation products. After cleaning, positive changes were observed in the viscosity, acid number and other main physicochemical indicators of the oil. After adsorption and centrifugation, the total amount of mechanical impurities decreased, but the amount of non-combustible impurities increased. This can be explained by the fact that after adsorption and centrifugation, organic impurities were adsorbed and remained as a precipitate. At the same time, not all of the clay was completely precipitated during centrifugation, since particles smaller than 12.5 μm remained stable in sedimentation under such conditions. However, after filtration of the purified oil, the amount of mechanical impurities decreased by 1.5–2 times. As a result of filtration through a dense fabric, a significant part of the clay particles remained in the filter. In the same filter, but without pre-treatment with clay, the reduction of impurities in the filtered oil was very small. This indicates that filtration alone is not sufficient for oil purification. The specific surface area of the clay fraction +0 ÷ –0.071 mm is close to the specific surface area of the +0.071 ÷ –0.25 mm fraction, and the degree of purification for both fractions is the same. So, for effective oil purification, it is enough to use a fraction of +0.071 ÷ –0.25 mm. Using a fraction of +0 ÷ –0.071 mm is not advisable, since in this case the oil properties are the same as in the fraction of +0.071 ÷ –0.25 mm, but the separation of clay becomes more difficult: it has a higher sedimentation rate and the filtration process becomes more complicated.

Among adsorbents, bentonite occupies a special place due to its high surface area, swelling properties and strong adsorption capacity. Bentonite is one of the natural clays, the structural basis of which is the montmorillonite mineral. It swells when in contact with water and oil, absorbing a large amount of particles onto its surface. Therefore, bentonite allows for effective purification of used oils from mechanical particles, tar and oxidation products.

Also, since bentonite is a widespread, inexpensive and environmentally friendly material, its potential for industrial use is very high.

For more effective purification of oils, bentonite was used as an adsorbent. In this case, the used oil was pre-filtered and cleaned of mechanical impurities. Bentonite was dried, crushed, sieved and used as an adsorbent. The adsorption process was carried out for a certain time, and then the purified oil was separated by filtration.

Based on the results obtained, it is possible to develop economical, environmentally friendly and effective methods for processing used oils. This will serve: environmental protection, waste reduction, and expansion of the use of secondary resources.

**TABLE 6.** Indicators of oils before and after adsorption treatment with bentonite

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicators** | **Unit of measurement** | **Before treatment** | **After treatment** |
| Color |  | Dark brown | Yellow-brown |
| Viscosity (at 100°C) | mm²/s | 13.0 | 11.6 |
| Acid number | mgKOH/g | 3.8 | 1.7 |
| Mechanical impurities | % | 0.15 | 0.03 |
| Water content | % | 0.22 | 0.06 |
| Combustible residue (coke) | % | 1.5 | 0.7 |

As can be seen from the table, the oil color was significantly lightened during treatment with bentonite, the acidity number decreased, the number of mechanical impurities decreased sharply, and the viscosity of the oil approached the standard level.

**CONCLUSION**

Adsorption treatment using local bleaching clay is an effective method for improving the quality of used oils. The economy, simplicity and environmental safety of this method allow it to be applied in practice. Adsorption treatment using bentonite is an effective method for improving the quality of used oils. This method removes mechanical impurities, oxidation products and harmful additives from the oil, increasing its reusability. The economy and high adsorption capacity of bentonite make it convenient for widespread use in practice.

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