

Research Results on Coagulant Impact on the Used Motor Oil Re-Refining

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Abstract—The issue of used motor oil re-refining and disposal is considered in this paper. Several methods for oil refining are presented. Used motor oil re-refining by the coagulation method is justified. In order to determine the rational parameters of used motor oils settling, a mathematical model of dependence of optical density of settled oil after treatment with a coagulant was obtained. This model made it possible to establish the dependences of optical density on settling time, settling temperature and coagulant ratio. After comparative tests, a rational coagulant was chosen – the M1 (solution of sulfuric acid and urea). This is justified by its high coagulating effect and high yield of refined oil. Based on these dependencies, a rational amount of coagulant M1 was determined in a ratio of 3%, the settling time – of 3-5 hours and the settling temperature of 80 °C.

Keywords—coagulant, settling time, settling temperature, optical density, used motor oil.

I. INTRODUCTION

Various researches show that almost all oils at the time of replacement did not exhaust their resources and did not change their chemical nature. At the same time, they cannot be operated on further, as they are contaminated with mechanical, abrasive impurities from the outside and wear products that are the result of wear of engine parts. These products are removed from oils and reused in units and mechanisms that allow operating conditions for these oils, will significantly solve the problem of reducing oil consumption and to reduce the environmental harm. Today, there is an acute problem of the disposal of used motor oil. Used motor oil has a 2–3 hazard class. Improper disposal of this oil poses a huge threat to the environment and human health [1–3]. According to various studies, one liter of used motor oil that was drained into a reservoir pollutes one million liters of water. There is no established system for the reception and further disposal of used oil. Disposal methods are directly dependent on the initial composition of the oil and its impact on the environment. The choice of the method for used motor oil re-refining primarily depends on the physicochemical properties of the oil basis, transportation conditions on physicochemical oil changes depending on the operating conditions in the engine and also on the engine design. Analysis of existing methods for used oil re-refining shows that they are divided into physical, physico-chemical, chemical and combined methods, depending on what impurities and how they will be removed from the used oil. [4–6]. Physical methods are

simpler to use and cheaper than the other. Physical methods are used at the initial stage of purification. The largest easily removable particles are removed at the settling stage and they are from 50 to 110 microns. This stage of refining does not allow obtaining purified oil that should meet the requirements of GOST for fresh oils. Removing of particle sizes that do not exceed 7–5 microns are already a difficult task. To remove such impurities, it is necessary to use physical and chemical refining methods. In particular, the coagulation process [7–8]. The essence of the method is to strengthen the impurity particles in a colloidal or finely dispersed state. The choice of coagulant affects the refining efficiency of used motor oil and the performance of the process. The chemical refining method is based on the chemical reaction of the used oil and the reagents introduced into it by additives.

II. METHODS

Comparative tests were carried out with the following coagulants: acetic acid, sulfuric acid and M1 coagulant (urea and sulfuric acid solution). The estimated amount of coagulant is chosen equal to 5%. The refining efficiency of the coagulant was determined by settling in measuring flasks with a ground stopper and determining the optical density of the oil. The refining coefficient of used motor oil after coagulation was also calculated. When determining the optical density of the oil, the sample of used oil was heated to a temperature of 110–120 °C. After that, M1 coagulant was introduced into it in an amount of 5%. Then this sample was mixed for 5 minutes. Monitoring of optical density was determined after 1, 3 and 5 hours. The optical density was determined using an FEK-56M photo colorimeter [9]. The refining coefficient was determined by settling a portion of the used oil at a temperature of 110–120 °C followed by filtration on a “blue ribbon” filter and determining the mass of sediment on the filter. The coagulant ratio varied at the levels of 1%, 3% and 5%. Settling of the oil was carried out for 5 hours. The refining coefficient was determined by the formula 1:

$$\varphi = \frac{m_1 - m_2}{m_1} 100\%, \quad (1)$$

Where m_1 is the mass of deposits in the original oil, kg; m_2 is the mass of deposits in oil after coagulation, kg.

III. RESULTS

Table I presents the results of comparative tests to determine the optical density of the oil after processing it with coagulants.

TABLE I. THE RESULTS OF COMPARATIVE TESTS OF USED MOTOR OIL SETTLING UNDER THE IMPACT OF COAGULANTS

Coagulant	Settling time, hours						Oil yield, %	
	I		3		5			
	D	τ	D	τ	D	T		
H ₂ SO ₄	1.03	43.16	0.299	12.56	0.043	1.806	55-60	
CH ₃ COOH	1.24	52.08	0.312	13.10	0.067	0.055	77-82	
M1	1.13	47.46	0.303	12.73	0.055	2.310	85-90	

Based on the obtained data in table 1 it is obvious that the best coagulating ability has the sulfuric acid coagulant. The optical density decreased to 1.03. However, the yield of refined oil using sulfuric acid is only 55-60%. M1 coagulant has the highest yield of refined oil. The curves in Figure 1 characterize the impact of the ratio and type of coagulators on the refining coefficient.

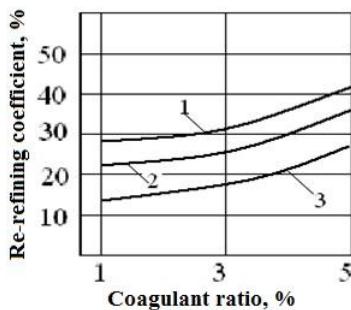


Fig. 1. Comparative tests of coagulants according to the re-refining coefficient: 1 - sulfuric acid coagulant; 2 - M1 coagulant; 3 - acetic acid coagulant

Analyses of the data presented in table 1 and figure 1 show that sulfuric acid is the best coagulant for clarification and purification. The second place goes to M1 coagulant. Acetic acid showed the worst results. The refining coefficient of sulfuric acid is 1.2-1.4 times higher than of M1 coagulant.

However, as a coagulant, sulfuric acid has disadvantages. The yield of refined oil is only 55-60%. The M1 coagulant has refined oil yield at 85-90% [10].

Based on the obtained data, we recommend the use of M1coagulant for the technological process of used motor oils re-refining.

Table II presents test results of the used motor oil refining with the M1 coagulant.

TABLE II. TESTS OF MOTOR OIL REFINING WITH M1COAGULANT

Defined parameter	Coagulant ratio, %					
	0	2	4	6	8	10
D	1.62	1.21	0.6	0.5	0.4	0.45
τ, cm^{-1}	26.04	8.4	2.52	2.11	1.68	1.52

From table II it can be seen that the best coagulating ability of the M1coagulant shows when its content does not exceed 5%. If you increase the content of M1coagulant, then its intensity decreases.

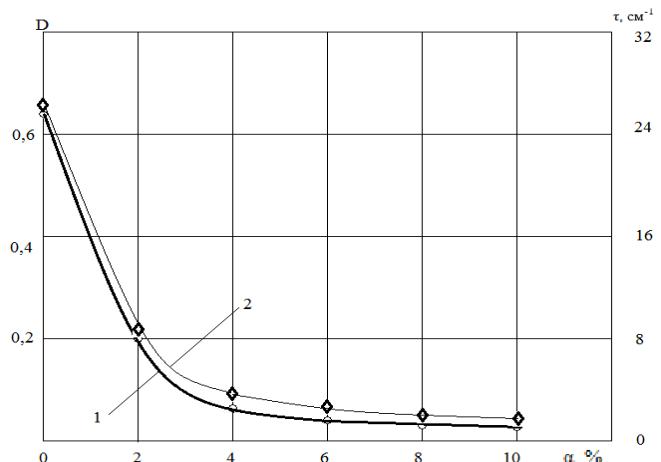


Fig. 2. Dependence of the optical density D (curve 1) and the photometric impurity coefficient τ (curve 2) on the M1 coagulant content in the re-refined oil.

Figure 2 shows that the optical density D of the re-refined motor oil decreases from 1.62 to 0.055, and the photometric impurity coefficient τ decreases from 26.04 to 2.31. With a further increase in the M1coagulant ratio will not lead to a significant decrease in optical density and photometric impurity coefficient. In the range from 5% to 10%, the optical density decreases from 0.05 to 0.045, and the photometric impurity coefficient – from 2.31 to 1.52 [10].

Analyzing table II and figure 2, we can conclude that the optimal amount of M1coagulant is in the range from 3% to 5%.

The results involved the preparation of a mathematical model of the dependence of the optical density of used motor oil after adding coagulant to determine the rational parameters of the used motor oil settling.

When modeling a mathematical model, the following factors were used to assess the effect of various factors on the degree of oil refining during coagulation:

- M1 coagulant ratio, %;
- oil settling time with a coagulator, hours;
- oil temperature during settling, t °C.

The optical density of the oil was taken as a response function, since it is one of the characteristics of oil impurity.

TABLE III. FACTORS AND THEIR LEVELS OF VARIATION

Factor level	Natural values			Coded values		
	M1, %	τ , hours	t , °C	X ₁	X ₂	X ₃
Low	1	0	20	-1	-1	-1
Null	3	2.5	50	0	0	0
High	5	5	80	+1	+1	+1

The resulting mathematical model has the following form:

$$D = 1,5025 - 0,151M1 - 0,099\tau - 0,00246t \quad (2)$$

The coefficient of variation is 22.3%, which is acceptable for these studies.

Figure 3 shows the dependence of optical density on settling time and on the coagulant ratio.

The analysis of the dependences shows that in the range of changes in the coagulant ratio from 1% to 5% and the settling time from 0 to 5 hours, the optical density of the refined oil is reduced, while both factors contribute to a decrease in optical density and, as a consequence, a decrease in oil impurity. The intensity of changes in optical density with this combination of factors depending on the coagulant ratio is higher than on the settling time [11].

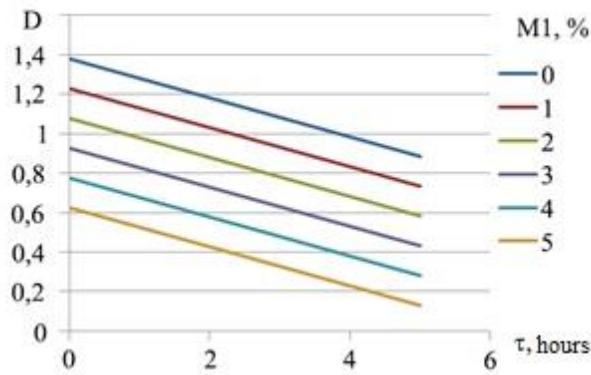


Fig. 3. Dependence of the optical density D on the settling time τ , hours and on the M1 coagulant ratio, %

The dependence presented in figure 3 shows that, with a constant settling time of 2.5 hours in the range of change in the M1 coagulant ratio from 1% to 5%, the optical density of the refined oil decreases from 1.104 to 0.5, i.e. by 0.604 units; and at a constant 3% of M1 and when the settling time changes from 0 to 5 hours, the optical density decreases from 0.9257 to 0.5545, i.e. by 0.3712 units. The time of settling and the coagulant ratio contribute to increased clarification and, as a result, reduced impurity of the oil.

The curves in figure 4 represent the dependence of optical density on settling temperature and coagulant ratio.

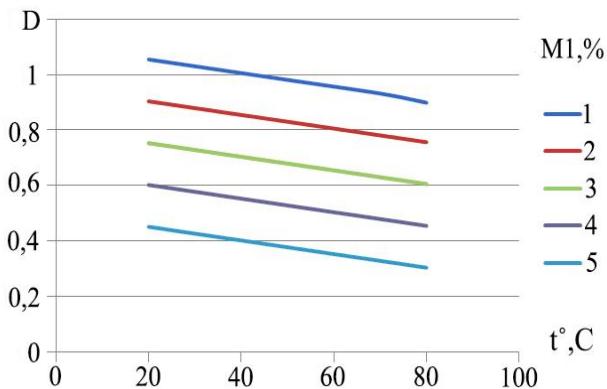


Fig. 4. Dependence of the optical density D of re-refined motor oil on settling temperature t °C and the M1 coagulant ratio, %

The settling temperature and the coagulant ratio contribute to an increasing of used oil clarification, which reduces the optical density of the refined oil. The impact gradation of these factors is different: the optical density decreases by about 50% (depending on the ratio) at a temperature of 50 °C; the optical density decreases only by 20%, when the sediment temperature changes from 20 to 80 °C with a constant M1 ratio equal to 3%. However, for any M1 ratio, the intensity, depending on the temperature, remains constant [12]. When refining used motor oil, it is

recommended that the settling be applied at a temperature of 80 °C after the coagulant is added to it.

Figure 5 shows the dependence of optical density on settling temperature and time.

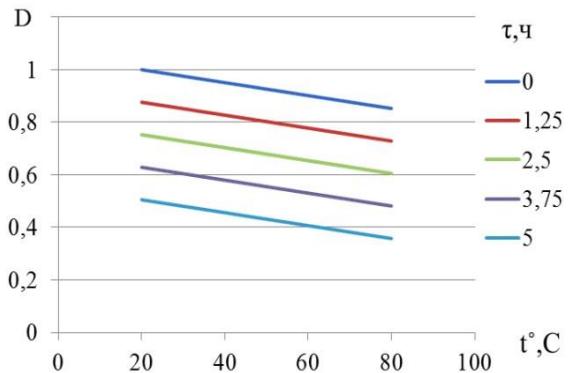


Fig. 5. Dependence of optical density D of re-refined motor oil on settling temperature t °C and time τ, hours

The dependence of the optical density of the refined used motor oil on the settling temperature and time, presented in Figure 5, shows that with an increase in the oil settling time and with an increase in the settling temperature, the optical density of the refined oil decreases, which indicates a decrease in the contamination of the oil with impurities. From the graphs it follows that the temperature has a less noticeable effect on the clarification of the oil than the settling time. During the oil refining process, the oil settling time is recommended to vary from 3 to 5 hours.

IV. CONCLUSION

These comparative experiments allowed us to determine the rational M1 coagulant to improve the purification of used motor oils. This is justified by its high coagulating effect and high yield of refined oil. Studies of the effectiveness of M1 coagulant made it possible to obtain a mathematical model of the dependence of the optical density on the coagulant ratio, settling time and temperature. The calculations carried out according to the model and their analysis made it possible to establish rational parameters for the settling of used motor oil: coagulant ratio at 3%; settling temperature at 80 °C; settling time at 3-5 hours.

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