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Selection of a Dispersion Medium for Recycling Plastic Greases According to Fire and Explosion Indicators

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Abstract
The article presents the results of determining fire and explosion hazard indicators for used lubricants, which are supposed to be used as a dispersion medium in the production of recycling plastic greases. Having determined the flash point of the oils, it is possible to calculate the values of the ignition temperature and self-ignition according to linear regression equations, with an error of up to 2 °C. The flash point can be a criterion when choosing raw materials and layout of the technological scheme for the production of recycling plastic greases.
Keywords: grease, used oil, flash point, ignition, self-ignition, boiling fractions, regeneration.

1. Introduction

Indicators characterizing fire and explosion hazard are included in the nomenclature of quality indicators of greases related to safety, the mandatory definition of which is fixed by the requirements of normative and technical documentation. The hardware design and operating parameters of the production technology, storage and transportation of greases to their places of direct application depend on them.

Considering the fact that greases 75-95% (mass.) consist of the dispersion medium, which is both commercial lubricating oils and individual oil fractions, and in the case of recycling plastic greases even used oils [1], then their the explosion hazard will mainly be determined by the fire and explosion hazard of the dispersion medium.

The main indicators used to characterize the fire, explosion hazard and the dispersion medium (lubricating oils), and commercial greases are the flash point in the open (t,°C) and closed (t *,°C) crucible, it is the lowest temperature, at where the vapor of the heated oil forms a mixture with the air that flares up when the flame is brought to it, the ignition temperature (t,°C) is the minimum temperature at which the mixture of oil vapor with the air above its surface flashes up and does not go out within a certain period of time, and the self-ignition temperature (t,°C) is the lowest oil temperature at which it is ignited in the absence of an external ignition source (spark, open flame, etc., due to the excess of the rate of heat generation during the oxidation reaction over the heat removal rate) [2].

The magnitude of $t_{f.p.}$, $t^{*}_{f.p.}$, $t_{ig.}$ and $t_{s-ig.}$ depends on many factors (heating rate, pressure, reaction volume), and first of all, on the fractional composition of oils, i.e. the presence in the oil of low boiling hydrocarbon fractions that evaporate when heated. So, when heating the oil, first of all, vapors of low-boiling fractions are released, which form a mixture with the air that flashes when the flame is brought up. The more such fractions $t_{f.p.}$, $t^{*}_{f.p.}$ и $t_{ig.}$ $t_{s-ig.}$, of oil. Considering t_{s-ig}, we note that the rate of a chemical reaction at a constant temperature

depends on the concentration of reacting substances, which means that oil with a low concentration of boiling fractions, due to the low reaction rate (low heat generation), is characterized by high t_{s-ig}. Under such conditions, a large amount of heat is expended in heating the oil, and the predominance of heat over heat loss occurs only at high temperatures. And, on the contrary, at a high concentration in oils, low boiling fractions, an increase in the reaction rate occurs, and as a result, t_{s-ig} decreases. However, in the future, at too high concentration of low-boiling fractions in the oil, the value t_{s-ig} of the oil will increase due to a decrease in the proportion of oxidizing agent, which leads to a decrease in the reaction rate [3].

The technological operations during the implementation of which the accumulation of low-boiling fractions in oils occurs that worsen the value of the indicators characterizing their fire and explosion hazard, we will present in the form of a structural diagram shown in Fig. 1.

Considering that nowadays, almost all greases are produced on the basis of either commercial oils or oil fractions thickened with metal soaps, the main source of accumulation in base oils, and consequently in greases, low boiling fractions, is a violation in the production process.

Here we can distinguish the superposition of boiling temperatures between adjacent distillates, which can reach 70–130°C [4], and often arises due to a violation in the operation of a distillation column operating under vacuum. This also includes the insufficient separation depth of the selective solvent during the implementation of processes such as dewaxing and deasphalting of oil fractions.
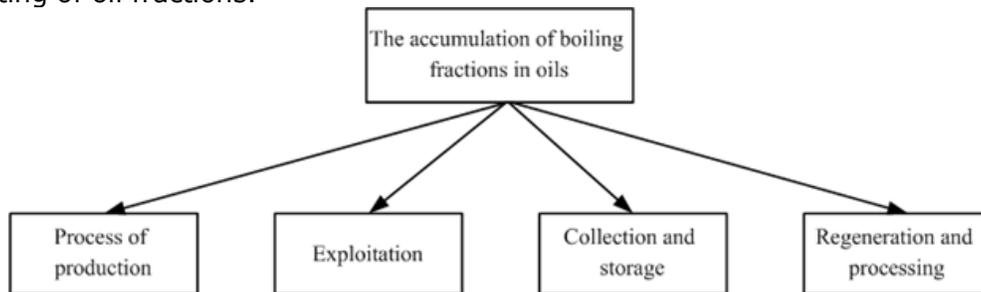

Figure 1. Scheme of accumulation of low-boiling fractions in lubricating oils

In the case when used oils are used in the production of lubricants to expand the raw material base of the process and reduce production costs, the accumulation of low-boiling fractions in them, along with production disruptions, will have a more significant impact on their operation.

It is known that during the operation of lubricating oils in the nodes of various units, their aging occurs - a set of processes leading to a loss in the initial quality of the oils [5]. The main processes causing oil aging are the oxidation of oil hydrocarbons and pollution with various impurities. The study of the influence of these processes on the quality of oil becomes especially relevant when using used lubricating oils as a dispersion medium of greases. In the process of oil oxidation, which is promoted by elevated temperatures, the catalytic effect of the metal and aeration of the oil, the concentration of tar-asphaltene substances in it increases [6]. As a result, the density, viscosity, and values $t_{f.p.}$, $t^*_{f.p.}$, t_{ig} and t_{s-ig} increase in oil. Various impurities entering the oils in the performance of their functions also have deterioration in the initial quality of the oil. In some cases, this especially applies to motor oils, in case of disruption of the operating processes in the engine, high boiling fractions of fuel can accumulate in them, which burst together with the exhaust gases into the crankcase [7]. Also, in case of violation of the load-speed regime, in some cases, thermal (typical for motor oils) and mechanical (typical for gear oils) degradation of additives and oil hydrocarbons can be observed [8]. All these processes, individually or in combination, lead to the accumulation of low boiling fractions in the oils, which contribute to a decrease in the values $t_{f.p.}$, $t^*_{f.p.}$, t_{ig} and t_{s-ig}.

Low boiling fractions can accumulate both in pure and used oils during their collection, pumping and storage, when these operations are carried out using insufficiently clean technological equipment.

As for the regeneration and processing of used oils, at this stage low boiling fractions can accumulate using selective solvents at elevated temperatures at which degradation of hydrocarbons of lubricating oils can be observed [9-10].

Thus, taking into account all of the above, we investigate the fire and explosion hazard indicators of used lubricating oils, which are potentially suitable for use as a raw material - a dispersion medium in the production of recycling plastic greases. For this, in accordance with ASTM D92-05a (2010) and ASTM D93, for the sample out of 20 used oils (industrial, hydraulic, motor and transmission), the values $t_{f.p.}$, $t^*_{f.p.}$ and t_{ig} were determined (see Fig. 2-3).
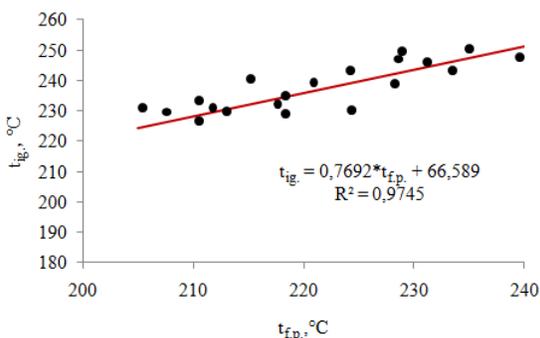

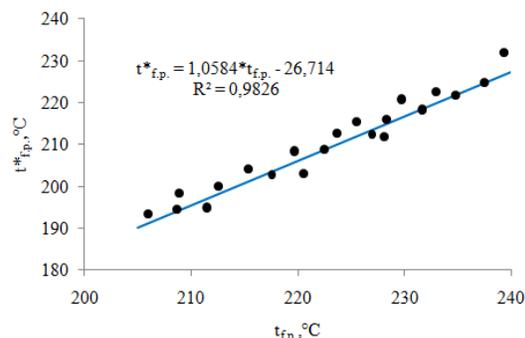Figure 2. Dependence of $t_{ig.}$ on value $t_{f.p.}$ of waste oils

Figure 3. Dependence of the value $t^*_{f.p.}$ on the value $t_{f.p.}$ of waste oils

The obtained dependences showed that the dependences of $t^*_{f.p.}$ and t_{ig} values on values $t_{всп}$ are adequately described by the linear regression equation, as evidenced by the value of the approximation confidence coefficient (0.9745 and 0.9826).

It should be noted that many years of practical experience in the use of lubricating oils shows that under normal operation, the change in the value $t_{f.p.}$ fluctuates in a rather narrow range and usually does not exceed 20 °C, relative to the initial value [11]. In accordance with the data given in the work [12], it can be determined that the average value $t_{f.p.}$ for non-working lubricating oils, regardless of their functional purpose, is 220°C. Then, it can be assumed that the change interval $t_{f.p.}$ of working oils will be in the aisles of 200-240°C, and this, in turn, is fully confirmed by the studies.

Therefore, for any used lubricating oil, provided that its value $t_{f.p.}$ is in the range of 200-240 °C, using the linear regression equation, it is possible to calculate the values $t^*_{f.p.}$ и t_{ig}, while the calculation error is in the aisles 0.5-2.0°C.

Also, with the help of a laboratory setup (see Fig. 4), the value t_{s-ig} was determined and its dependence on the value t_{s-ig} was determined (see Fig. 5).
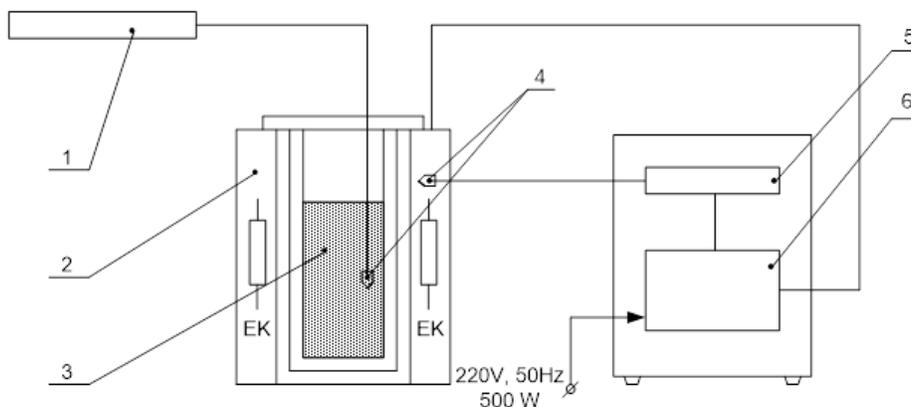

Figure 4. Technological scheme of the installation for determining the value t_{s-ig}:

1 - sample temperature control device; 2-electric furnace; 3-smple; 4-thermocouple «K» ; 5- current regulator; 6- oven temperature control device

The definitions of t_{s-ig} is based on simulating the conditions under which a certain amount of used oil can self-ignite at atmospheric pressure, while gradually heating to high temperatures in technological equipment. For this purpose, a test sample of oil with a volume of 50 cm^3 is placed in a glass, which is placed inside an electric furnace. After that, heating is switched on at a speed of 4°C/min, and 20°C to the expected temperature t_{s-ig}, the heating rate decreases to 1°C/min. After which the temperature is fixed at which self-ignition of the test oil sample occurs.

$$t_{s-ig} = 1,3674 * t_{f.p.} + 45,75$$
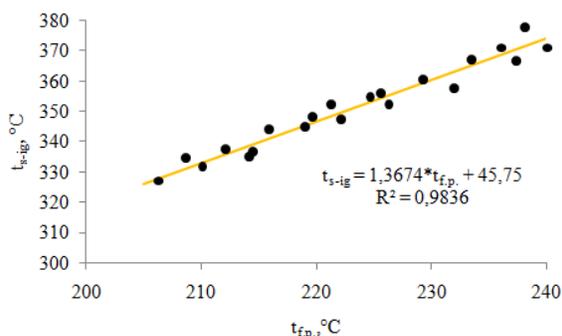$$R^2 = 0,9836$$

Figure 5. Dependence of the value t_{s-ig} on the value $t_{f.p.}$ of waste oils

The dependence shown in Fig. 5 shows that, as in the case of the above $t^{*}_{f.p.}$ and t_{ig} indices, with an increase in $t_{f.p.}$ of used oils, their t_{s-ig} increases, and the dependence itself is also adequately described by the linear regression equation, as evidenced by the value of the confidence coefficient approximations equal to 0.9836.

The technological process for the production of recycling plastic greases involves either the dissolution of the polymer thickener in a dispersion medium (oil) at a temperature of 10-20°C higher than the melting temperature of the thickener, or its dissolution at the boiling point of the dispersion medium.

In the first case, the temperature does not exceed 180°C, which is significantly lower than the values of the considered fire and explosion hazard indicators; it greatly simplifies the production flow chart. Secondly, the process temperature can reach 280°C, which exceeds the index $t^{*}_{f.p.}$, $t_{f.p.}$ and t_{ig}. At the same time, in the technological scheme of production, it is necessary to take into account the possibility of collecting the vapors released during heating of the components, in particular the dispersion medium, their cooling, and condensation with further return to the reaction zone or removal from the installation. In addition, there is a need to use explosion-proof equipment, which in turn leads to increased production costs.

2. Conclusions

The safety of the technological process depends on the indicators of fire and gas hazard which are among the most important ones, it means that they must be determined, especially when new types of hydrocarbon raw materials are used to expand the raw material base.

The results obtained indicate that by determining the flash point of the oil using the obtained regression equations, it is possible to calculate the temperature of its ignition and self-ignition, from which the category of industrial premises for explosive and fire hazard, the evaluation and choice of explosion-proof electrical equipment will be covered. Also, together with the flash point and self-ignition temperature, it is necessary to determine the flash point in a closed crucible according to the method ASTM D93. This is mainly due to the fact that increased pressure (for example, saturated vapor pressure) inside the apparatus reduces the flash point of the oil, compared with the flash point determined at the atmospheric pressure.

If we consider the variation range of the values of the considered fire and explosion hazard indicators, then the narrowest range of values is observed at the ignition temperature (28 °C), the widest one is at the ignition temperature (48°C), and the flash point determined by method ASTM D93 is intermediate (39°C) between the rest. This, in turn, causes a small amount of error (up to 2°C) when calculating these indicators according to the obtained regression equations.

The flash point, along with the content of water and mechanical impurities, can become a criterion in the selection and determination of the required depth of preparation of one or another raw material for use as a dispersion medium in the production of greases.

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