SELECTION OF THE CONDITIONS FOR THE OPTIMUM EFFECT OF METAL-CONTAINING ADDITIVES IN OILS

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The antifriction properties of lubricating oils can be significantly improved by additives containing organic substances and metal salts [1-4]. The elevated efficiency of an additive prepared by dissolving copper sulfate in glycerin was demonstrated in [3]; good results were also obtained with additives based on tin, silver, gold, and some other metal salts soluble in ethers and polyhydric alcohols. The friction coefficient decreased by 10-16 times and wear decreased by 8-10 times when these additives were used [2, 3].

Despite the efficiency of metal-containing additives demonstrated in laboratory conditions, their wide introduction in practice is lagging behind, due to the lack of information on the optimum conditions for manifestation of their antifriction properties. The problems of the best ratio of concentrations of the components of the additive and the optimum concentration of the additive in the lubricant must be solved first. The problem of optimizing the tribological processes includes a large number of interrelated parameters [5]. It is recommended that methods of systems analysis [5, 6], consisting of identifying the fundamental subproblems in the problem investigated, be used to solve this problem.

Such subproblems for liquid lubricants (LL) of complex composition (with additives, for example) include [5]: I) determination of the physicochemical processes in LL during preparation; II) study of the compositions of LL which guarantee minimum resistance to movement on standard friction pairs; III) study of the evolution of the system parameters during the operation of real friction units (oxidation and heat resistance of LL, resistance of friction pairs to abrasion and corrosion, etc.).

A tin-containing additive (TCA) prepared by dissolving stannic chloride in dihydric alcohol was selected as the metal-containing additive for conducting such complex studies. The results of the solution of subproblem I are reported in [4]. It was found that surface-active molecular complexes which tend to self-associate (both in the additive itself and in the base oil) are formed in the TCA during preparation. Association of the complexes in micelles causes them to lose surface activity, but oil-filled gels which should improve the antifriction properties can be formed in LL of a certain composition.

The results of solving subproblem II using the same additive are reported below. Some preliminary results of studies conducted to solve more voluminous subproblem III are also reported. The antifriction effect of TCA in a steel—steel friction pair using I-40A base lubricating oil was investigated in the present study. The measurements were made on a SMTs-2 friction machine with a roller (40X steel, HRC 59-61)—plate (ShKh15 steel, HRC 56-58) scheme with a sliding speed of 1 m/sec. The effect of the additive was evaluated with the relative friction coefficient f_{rel} (ratio of the friction coefficients in oil with and without the additive) to exclude the difference in the properties of the samples.

The dependences of f_{rel} on the concentration c of the additive in oil with a concentration x of the tin salt of 110 and 210 g/liter are presented in Fig. 1. In both cases, an increase in the concentration of additive in the oil causes an uneven decrease in f_{rel}. The improvement in the antifriction properties of the additive with a lower concentration of the active agent (tin salt) for a lower concentration of additive in the oil ($c \approx 2$ vol. %) is surprising. For the additive more saturated with the active agent, f_{rel} only decreases when the concentration in the oil is greater than 10 vol. %. This finding can be explained by micellization in the additive with a high concentration of tin salt based on the data obtained concerning the properties of LL in [4].

The effect of the composition of TCA on f_{rel} with a 0.5 and 2.5 vol. % concentration c in the oil is shown in Fig. 2. In both cases, f_{rel} only decreases in a narrow range of x:

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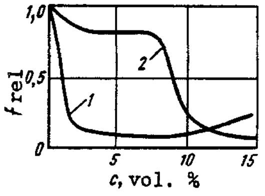

Fig. 1

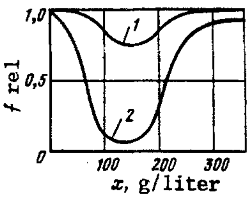

Fig. 2

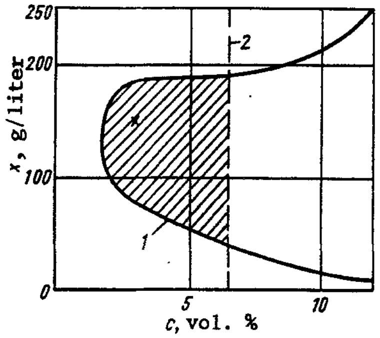

Fig. 3

Fig. 1. Dependence of the relative friction coefficient f_{rel} on the concentration c of additive in I-40A oil with a concentration x of stannic chloride of: 1) 110 g/liter; 2) 210 g/liter.

Fig. 2. Dependence of the relative friction coefficient f_{rel} on the concentration x of stannic chloride in the additive with a concentration of additive c in I-40A oil of: 1) 0.5 vol. %; 2) 2.5 vol. %.

Fig. 3. Region of the optimum concentrations of additive in the oil (c) and stannic chloride in the additive (x): 1) restrictions for the friction coefficient; 2) restrictions for the corrosion resistance; hatched area of minimum wear.

80-130 g/liter. In consideration of the data in [4], the increase in f_{rel} for small x is due to the insufficient number of active molecular complexes in TCA for the formation of a continuous coating on the working friction surface. The increase in f_{rel} for large x is due to loss of the surface activity of TCA for the critical micelle concentration [4].

Metal-containing additives thus have an efficient antifriction effect only when relatively rigorous requirements for both their composition and their concentration in LL are respected. The region of the optimum concentrations of TCA which guarantee its active effect is shown in Fig. 3. A diagram was plotted with the results of measurements in coordinates of x and c, and the hatched region corresponds to a decrease in f_{rel} to 0.1 and lower. The antifriction effect of the additive is virtually not manifested outside of this region, which has the shape of a narrow "tongue."

The distinctly delimited region of the optimum composition of the LL studied is the solution to subproblem II that explains the occasionally observed inefficiency of metal-containing additives without rigorous monitoring of their composition and concentration in the base oil. Further restrictions of this region could be found in solving subproblem III; determining the conditions of prolonged work of LL in real friction units. The preliminary studies in this direction showed that "excess" (not reacting with the friction surfaces) active components of TCA during operation of a friction unit can decompose with the formation of corrosive-aggressive acid residues.

The upper boundary of the concentration of TCA in the oil for which corrosion is not observed is indicated by the broken line in Fig. 3. Studies of the wear resistance showed that the optimum region of the composition of LL for this parameter corresponds to the hatched region in Fig. 3. The degree of wear was $12.2 \cdot 10^{-5}$ kg/($m^2 \cdot m$) in LL with a composition outside of the hatched region. LL with a composition corresponding to the center of this region (point ×) guarantees a multiple reduction in wear: the degree of wear does not exceed the precision of the measurement ($\sim 0.7 \cdot 10^{-6}$ kg/m^2·m).

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