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Abstract

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V. M. KORBUT, S. Ya. VEILER, and N. V. PETROVA

THE INFLUENCE OF THE PHYSICOCHEMICAL NATURE OF A LUBRICANT
ON ITS EFFECTIVENESS IN METAL FORMING ===================================

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In the forming of metals without lubrication, as a result of adhesion of the metal to the tool, preferential deformation of the surface layers occurs and, consequently, the deformation of the metal over the cross section is nonuniform. If a liquid surface-active lubricant is applied to the metal, or if a solid lubricating layer is formed with a shear stress τ considerably lower than that of the metal being worked, then the distribution of deformation over the cross section proves to be more uniform, and all additional deformation of the surface layer of the metal being worked, caused by friction, will be concentrated in the lubricating layer ([1]).

Thus, in studying the mechanism of action of lubricants under conditions of metal forming, the immediate object becomes the lubricating layer in the metal—tool contact zone, the conditions of its formation, and its behavior during processing. As a characteristic of the lubricating action we adopted the shear stress τ ([1,2]) of the lubricating layer formed on the metal surface (a plasticized layer in the case of liquid lubricants, or a solid coating in the case of solid lubricants). Hydrocarbons, alcohols, and acids served as lubricant models. The method of deformation was wire drawing of rods.

The influence on the lubricating effect of the physicochemical interaction of the lubricant substance with the metallic surface can be traced by comparing the results obtained in drawing aluminum with hydrocarbons, organic alcohols, and acids above their melting points. Alcohols, owing to their ability to adsorb on the metallic surface, proved to be incomparably more effective lubricants than adsorption-inactive hydrocarbons: whereas in the presence of liquid alcohols it is possible to deform the metal to a high degree of deformation (up to 36%), in the presence of liquid hydrocarbons this possibility is limited to 7% reduction at a value of $\tau = 8 \div 10$ kg/mm^2. Such a high value of τ directly indicates that liquid hydrocarbons are squeezed out of the metal—tool contact zone, and that the additional shear deformation occurs in the surface layer of the metal itself ($\tau_{\mathrm{Al}} = 9$ kg/mm^2). The relatively low values of τ when liquid alcohols are used as lubricants are due to the comparatively high plasticity of the lubricating layer formed as a result of adsorption plasticization of the metallic surface.

An increase in temperature in the case of using a liquid alcohol as lubricant leads to a certain increase in the values of τ. The same increase in temperature in the case of using stearic acid leads to a decrease in the values of τ, which is associated with the formation on the metal of a film of solid soap which, apparently, has a lower value-

···than a layer of metal plasticized by a liquid adsorption-active lubricant. As is known, alcohols do not form chemical compounds with the metal and are adsorbed reversibly; therefore an increase in temperature causes a deterioration of the effect as a result of the shift of equilibrium, with increasing temperature, toward desorption.

A fluid lubricant is effective only if it is capable, by interacting with the metal, of forming on its surface a plastic layer that plays the role of a lubricant in the processing operation. If the lubricating substance is in a solid-plastic state and, consequently, possesses sufficiently high structural-mechanical properties, then its adsorption activity in forming the lubricating layer recedes into the background, and the principal role begins to be played by the structural-mechanical properties of the lubricant itself ([1,3]).

Table 1

Influence of temperature on the drawing force for aluminum with transformer oil. $\varepsilon = 7\%$

t, °C	150	100	50	20	0	−15	−60
F, kg	293	296	273	286	190	94	60

A decrease in temperature causes an increase in the shear stress τ in the solid lubricating layer (deterioration of the lubricating effect) in the case of drawing with solid lubricants of different physicochemical nature (paraffin, cetyl alcohol, and stearic acid). A corresponding change in mechanical properties with a change in temperature is also observed in the bulk of these lubricants ([4]).

On the other hand, lowering the temperature may be a favorable and even decisive factor in the case of liquid adsorption-inactive lubricants. Thus, the lubricating efficiency of hydrocarbons upon freezing increases very substantially (the maximum possible degree of reduction increases from 7 to 32% with a sharp drop in the values of τ, owing to the transfer of an additional deformation surface from the surface layer of the metal into the layer of solid lubricant). The same influence is exerted by lowering the temperature on the lubricating properties of the technical product—transformer oil (Table 1).

Fig. 1. Dependence of the shear resistance in the lubricating layer τ on temperature during drawing of aluminum ($\varepsilon = 7\%$) with paraffin (1), cetyl alcohol (2), and stearic acid (3)

In Fig. 1 the general picture is shown of the influence of temperature in the range from −15 to +100° on the properties of the lubricating layer during drawing

Fig. 1. Dependence of the shear resistance in the lubricating layer τ on temperature during drawing of aluminum ($\varepsilon = 7\%$) with paraffin (1), cetyl alcohol (2), and stearic acid (3)

Figure 1: Fig. 1. Dependence of the shear resistance in the lubricating layer τ on temperature during drawing of aluminum ($\varepsilon = 7\%$) with paraffin (1), cetyl alcohol (2), and stearic acid (3)

of aluminum with three model lubricants: paraffin, cetyl alcohol, and stearic acid. Up to the softening temperatures, the character of the dependences is the same for all three lubricants, since in the solid state these substances have approximately equal shear resistances, while their different adsorption activity cannot manifest itself as a result of solidification. Raising the temperature to melting leads to a sharp increase in the resistance to shear (to a decrease in the lubricating effect) in the case of surface-inactive paraffin. Liquid alcohol and acid continue to remain effective, but already by virtue of a different mechanism than in the case of solid lubricants, namely through adsorption modification of the metal surface and the creation of a plastic lubricating layer in the metal itself. The divergence of the curves for cetyl alcohol and stearic acid with a further increase in temperature is associated with chemical fixation of the acid molecules, whereas the alcohol molecules are partially desorbed.

Under conditions of pressure working, the structure of the lubricating layer is destroyed under the action of the tangential component of the compressive force. This is manifested as a decrease in the resistance to shear in the lubricating layer (under processing conditions) with increasing deformation.

Table 2

Dependence of the shear resistance in the lubricant layer (τ, kg/mm^2) on the degree of deformation (ε, %) during drawing of aluminum coated with stearic acid and a phase film of polyisobutylene

ε, %	7.0	11.4	15.2	24.4	31.0	36.0
Stearic acid	2.0	1.5	1.1	0.78	0.60	0.51
Polyisobutylene film	1.6	1.0	0.94	0.62	0.53	0.31

The study of the rheological properties of metals (^{5}) made it possible to find that, as the shear stress increases, the effective viscosity decreases, i.e., the fluidity increases. The same occurs on the metal surface in the lubricant layer under pressure-working conditions; moreover, this result does not depend on how the lubricant layer is formed. A regular decrease in shear resistance in the lubricant layer with increasing degree of deformation (with increasing compressive forces) is observed both in the layer of a solid lubricant and in the layer that is the product of the physicochemical interaction of the lubricant with the metal surface, i.e., in the plasticized layer. The exception is liquid, fluid adsorption-inactive lubricating media, which are in general incapable of forming a strong lubricant layer.

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Institute of Physical Chemistry
Academy of Sciences of the USSR

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