The European Journal of Technical and Natural Sciences 2025, No 4–5
ISSN 2414-2352

PREMIER Publishing
ppublishing.org

DOI:10.29013/EJHSS-25-4.5-39-48

RESULTS OF RESEARCH OF THE MAIN PROPERTIES OF MULTI-FUNCTIONAL LUBRICANTS

Shaabidov Shorakhmat Askarovich [1], ***Mirzaev Kakhramon Karshiboevich*** [1], ***Mamasobirov Umid Mamazokirovich*** [1], ***Xusanboev Azizbek Gulomovich*** [1]

[1] Tashkent State Techical University Named After Islam Karimov

Cite: *Shaabidov Sh.A., Mirzaev K.K., Mamasobirov U.M., Xusanboev A. G. (2025). Results of Research of the Main Properties of Multi-Functional Lubricants. European Journal of Technical and Natural Sciences 2025, No 1.* https://doi.org/10.29013/EJHSS-25-4.5-39-48

Abstract

The article is devoted to the study of the main properties of polymer-containing multifunctional lubricants based on tars of vegetable oils and technical animal fats. The compositions and results of studies on the determination of adhesion, lubricating, anti-friction and anti-wear properties, as well as the degree of washability from metal surfaces, are presented. The mechanism of lubricating action is revealed, and the process of applying these lubricants is modeled. The wear of spur gears of bevel gear reducers was studied when using lubricants based on tars of vegetable oils and technical animal fats. It was found that they increase the service life of reducers. The multifunctionality of the developed lubricants is expressed in the possibility of their use in the manufacture of agricultural machinery parts and their assemblies, in machining processes with increased pressure, in corrosion protection of parts, in inter-operational storage, and in friction units of machines.

Keywords: *multifunctional lubricant, properties, tar, polymer filler, adhesion, lubrication, wear resistance, friction coefficient, washability, service life*

Introduction

Various lubricants are used in friction units of technological machines. Therefore, much attention is paid to the creation of new lubricants with improved lubricating properties that reduce wear of friction surfaces.

Research and development work is being carried out to increase the wear resistance of friction units using multifunctional lubricants based on vegetable oil tars and industrial animal fats. The introduction of polymer additives into the composition of these multifunctional lubricants allows for an increase in the wear resistance of friction units due to the formation of a polymer film on the friction surface and, to some extent, makes it possible to regulate the tribotechnical properties of friction pairs (Shaabidov, Sh. A., Irgashev, A., & Mirzaev, K. K., 2012; Huang, Y., Chen, Q., Yang, J., Guo, P., Liu, X., Feng, K., ... & Zhou, F., 2025; Mikhnevich, N. N., & Smurugov, V. A., 1985; Chichinadze, A. V., Braun, E. D., Bushe, N. A., et al., 2001).

This article presents the results of studies of the main properties of multifunctional lubricants based on vegetable oil tars and industrial animal fats.

Method

Table 1 presents the physicochemical parameters of technological lubricants based on vegetable oil tars and industrial animal fats, and table 2 presents the formulations of these lubricants, protected by copyright certificates (Garkunov, D. N., 2001; Mirzaev, K. K., & Shoobidov, Sh. A., 2022; Liang, B., Zhao, J., Li, G., Huang, Y., Yang, Z., & Yuan, T., 2019; Shaabidov, Sh. A., 1998).

Table 1. *Physicochemical properties of technological lubricants*

№	Indicator name	Standard	Test method
1.	Appearance	Homogeneous pasty mass from light brown to black	According to GOST 6243–75 Section I
2.	Smell	Specific, non-irritating	Organoleptic
3.	Viscosity, kinematic, at +50 °C, mm^2/s	45–150	According to GOST 33–82
4.	Density at 20 °C, g/sm^3	0,92–1,3	According to GOST 3900–85
5.	Acid number, mgKOH/g of lubricant	60–120	According to GOST 6243–75 Section 7
6.	Flash point in an open crucible, °C	not lower than 250	According to GOST 4333–87
7.	Corrosion tests on steel plates according to GOST 9045–80	Passes	According to GOST 9.080–77
8.	Removability with aqueous solutions of detergents, s	15–30	According to TU 37.066.211–89
9.	Water content, % no more than	5	According to GOST 11812–66

Table 2. *Lubricant recipe*

Components	Mass fraction of components, mass.%									
	1	2	3	4	5	6	7	8	9	10
Recipe for TE based on tars according to A.s. No. 1570285										
1. LMWPE	10	–	–	–	–	–	–	–	–	–
2. MEA	–	–	3	0,5	0,5	3	3	3	0,5	0,5
3. Oxyphos B-1	–	–	0,3	0,3	5	0,3	5	5	5	0,3
4. LMWPE production waste	–	10	15	3	15	3	3	15	3	15
Recipe for TE lubricant according to A.s. № 1626676										
1. Copper oxide	3	5	10	12,5	5	20	–	–	–	–
2. Aerosil	5	10	10	7,5	10	10	–	–	–	–

Components	Mass fraction of components, mass.%									
	1	2	3	4	5	6	7	8	9	10
3. Sunflower oil	5	15	15	10	5	15	–	–	–	–
4. Liquid soap	8	8	10	9	8	10	–	–	–	–
5. Mixture of vegetable oil tars and technical fats in a mass ratio of 1:1, the rest up to 100%.										

When manufacturing parts using the drawing method without lubrication, the bottom of the workpiece broke off, and the drawing force was 1.3...1.4 times higher than when drawing with TE (fig. 1). Thus, when drawing 12X18H10T steel with a drawing degree of 2.0, TE ensures the production of high-quality parts, and Ukrinol 16u, machine oil + MoS_2 lead to the bottom breaking off and metal sticking to the matrix (Shaabidov, Sh. A., 1996; Shabidov, Sh. A., 1996; Reeves, C. J., Menezes, P. L., Lovell, M. R., & Jen, T. C., 2015; Mirzaev, K. K., & Mustaeva, B. U., 2019).

Figure 1. *Dependence of the drawing force on the punch stroke: 1-Ukrinool 16u; 2-machine oil + MoS_2; 3-chalk; 4-graphite; 5-TE*

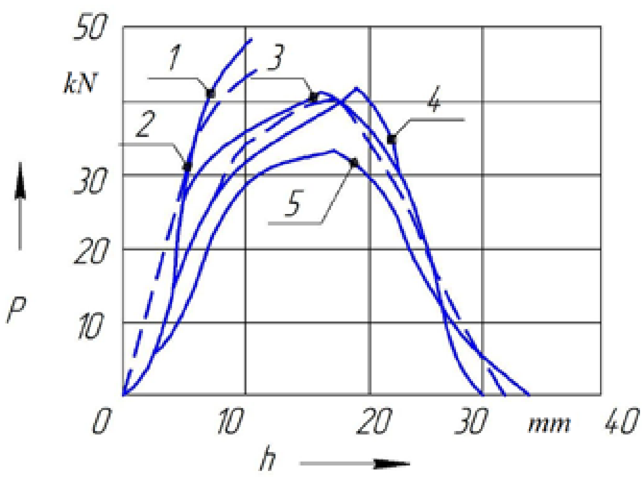
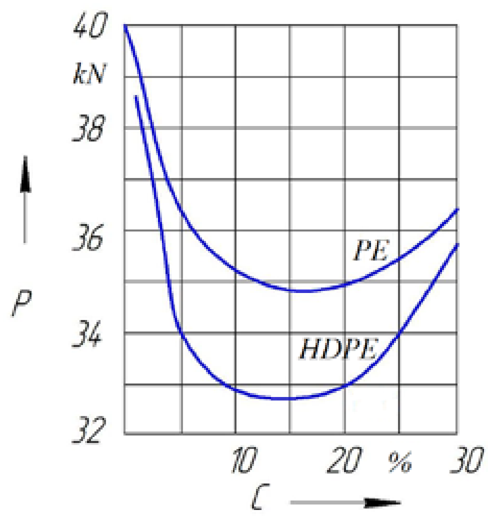


Figure 2. *Dependence of the change in the drawing force on the concentration of the filler in the tar*



A mandatory requirement for the polymer filler TE for stamping-drawing are high friction and film-forming properties. Polymers with a glass transition temperature and flow rate below 250...300 °C, i.e. the stamping temperature, are capable of forming adsorption-plasticized layers on friction surfaces. This ensures a reduction in the drawing force to a filler concentration of 15% (fig. 2). With an increase in the concentration of the polymer filler above 15%, the viscosity of the TE increases, the shear resistance between the monolayers of the lubricant and its components adsorbed on the metal surface increases. Measurement of wear of parts made of 5XHM steel showed that its value when using the developed TE was 0,4...0,6% and was at the level of oil lubricants and is explained by the possibility of hydrogenation of the surface layers of the metal due to mechanochemical reactions in the contact zone.

As the research results have shown, the developed TE based on tars have lower friction coefficients than traditional compositions, but their penetrating ability, which is of particular importance under the conditions implemented during mechanical processing, in friction units, during conservation of ACM, where the adhesion of the TE to the working surfaces is important, has practically not been studied. Fig. 3 shows the dependencies reflecting the influence of the concentration of monoethanolamine (MEA or triethanolamine TEA) on the adhesive properties, and fig. 4 shows the friction force from the load for tars containing PE (polyethylene) as a filler.

The increase in the force and coefficient of friction with increasing polymer concentration is explained by the following mechanism. The surface-active TE, adsorbed on the surfaces of the metal being processed, plasticizes its surface layer, reduces its yield point and facilitates shear formation. The formation of the thinnest, easily deformable layer occurs during the chemical interaction of metal atoms with the polar groups of molecules of the active components of the TE, and this leads to the formation of layers of chemoadsorption metal soaps, sulfur- and phosphorus-containing compounds on the metal surface, firmly bound to the metal surface and reducing the force and coefficient of friction. Adhesive properties and the coefficient of friction are described by the equations:

$$A = 0,5 + 0,3563\,C - 0,0007776\,C^4 \quad (1)$$

$$f = 0,0429 - 0,00628\,C + 0,00139\,C^2 \quad (2)$$

Figure 3. *Effect of filler concentration in tar on adhesion: 1-PE; 2-HDPE; 3- LMWPE*

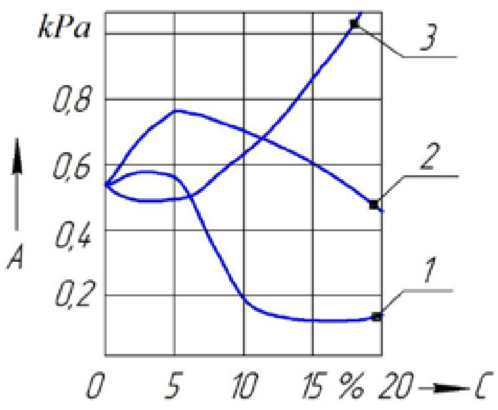


Figure 4. *Dependence of friction force on load for tars: 1–5%; 2–10%; 3–15%; 4–20%*

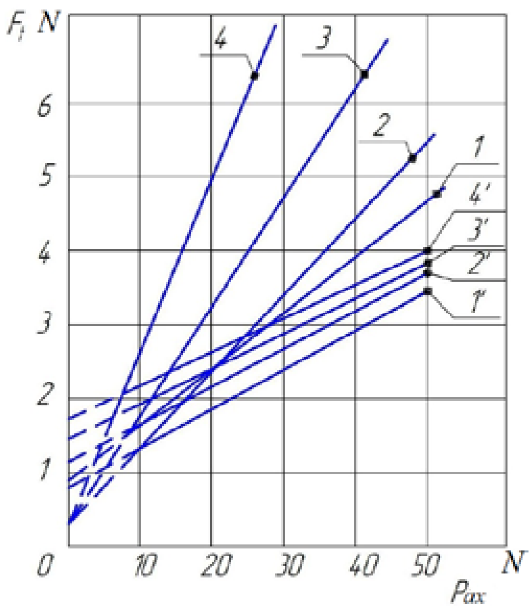


Table 3 shows the results of determining the adhesive properties of tar-based lubricants. Table 3 shows that lubricant compositions according to A.s.1570285 No. 3, No. 5, No. 8 and No. 10 have higher adhesive properties than the other compositions. In these compositions, the concentration of PE waste was 15%.

Table 3. *Adhesive properties of tar-based lubricants*

Composition of TE A.s. No. 1570285	Adhesion, kPa	Composition of TE A.s. No. 1626676	Adhesion, kPa
1	0,58	1	2,36
2	0,15	2	2,53
3	2,41	3	2,71
4	1,54	4	2,87
5	1,98	5	2,49
6	1,44	6	2,41
7	1,73	–	–
8	2,26	–	–

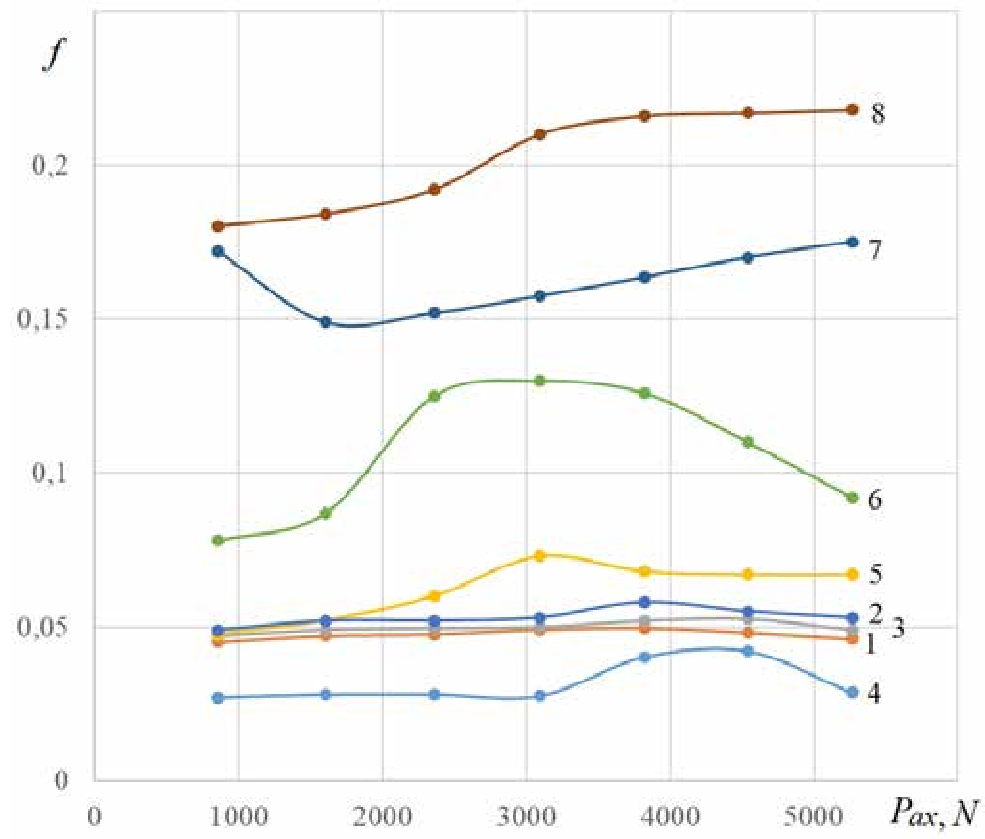
Composition of TE A.s. No. 1570285	Adhesion, kPa	Composition of TE A.s. No. 1626676	Adhesion, kPa
9	1,68	–	–
10	2,56	–	–

Compositions according to A.s.1626676 had adhesion within 2.34...2.87 kPa, which shows more stable adhesive properties of these lubricants.

Fig. 5 shows the change in the friction coefficient from the axial load at the concentration of PE and LMWPE. As can be seen from the graphs, the use of high-pressure PE production waste – liquid LMWPE in all concentrations has a low friction coefficient within 0,027...0,054 in comparison with powdered PE – 0,051...0,175. Based on the research results, it can be stated that TE lubricants are characterized by a low friction coefficient and high adhesive properties.

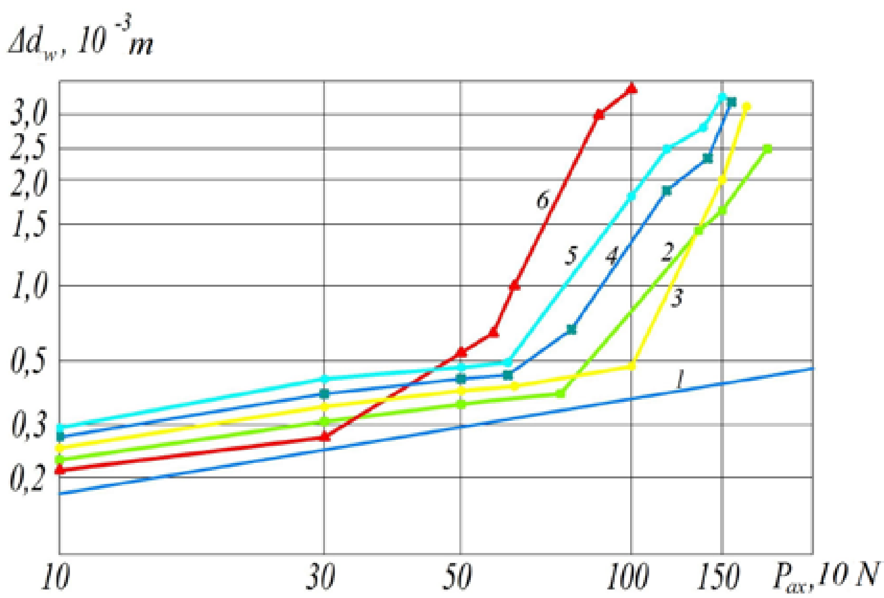
When studying the influence of polymer fillers on the lubricating properties of tar-based lubricants, polymeric materials with different molecular weight and dispersion were used: finely dispersed PE with a particle diameter of 0,2 ... 0,3 mm and its production waste LMWPE with a molecular weight of 800 ... 2000 conventional units. Fig. 6 and fig. 7 illustrate the influence of the concentration of polymer fillers on the extreme pressure and antiwear properties of tars. The introduction of PE into tar up to 10% leads to some improvement in the lubricating properties, an increase in the critical load from 800 ... 850 N to 900 ... 960 N (fig. 6).

Figure 5. *Change in the friction coefficient from the axial load for tars with polymer fillers: 1...4 – LMWPE; 5...8 – PE (respectively 5; 10; 15 and 20%)*



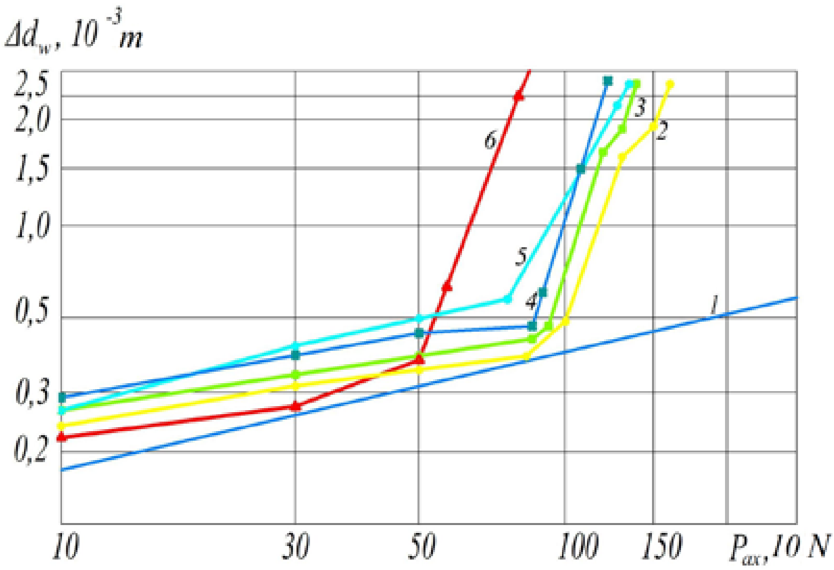
A further increase in the PE concentration leads to an increase in the diameter of the ball wear spot, the force and coefficient of friction, and a decrease in the loads P_k and P_s (respectively, the critical load and the welding load of the balls). The use of LMWPE as a filler (fig. 7) up to 5% leads to an improvement in the lubricating properties of tar, an increase in the critical load to 950...1000 N, i.e. by 11,1...11,76%. A further increase in its content reduces P_k and P_s, and the diameter of the ball wear spot increases. The results of our studies are presented in detail in (Shaabidov, Sh. A., 1998). Machine oil has good lubricating ability only at low loads not exceeding P_{ax} = 300 N. Increasing the axial load leads to a sharp increase in the wear spot of the balls and their welding at a load of 800 ... 900 N. Tar with LMWPE has a higher lubricating property than industrial oil and graphite lubricants at low and medium loads, despite the fact that the welding load does not exceed 1700 N. In addition, the developed TS lubricant has better performance properties, does not contaminate the surface of parts, and is biodegradable. Thus, the results of the studies made it possible to substantiate and establish that the use of liquid low-molecular PE in tars of vegetable oils and technical animal fats as a filler allows replacing scarce powdered polymeric materials without deteriorating the lubricating properties of TE.

Figure 6. *Dependence of wear scar diameter on axial load: 1 – line of elastic deformation of balls according to Hertz; 2 – tar+5% LMWPE; 3 – tar +10% LMWPE; 4 – tar +15% LMWPE; 5 – tar +20% LMWPE; I–L-A-22 oil*



The method of mathematical planning of the experiment was used to optimize the TS compositions based on tars, which have the best lubricating and technological properties (Shaabidov, Sh. A., 1996; Shabidov, Sh. A., 1996). The developed lubricants underwent extensive production tests in production conditions at the Kalmakir Mining Administration of the Almalyk Mining and Metallurgical Plant. The tests were conducted on heavily loaded open friction units of the EKG-10 excavator with a bucket volume of 10 m^3. The efficiency of the lubricants was determined relative to the SS lubricant – synthetic solid oil GOST 4366–76, used by the plant. The conditions for conducting production tests: air dustiness of 3...8 g/m^3, heating temperature of the tested friction units under direct sunlight 80...92 °C. Comparative tests have shown the following: TE lubricants reduce wear intensity by 20...26%; friction coefficient by 15...20%; increase the operating temperature of the lubricant by 34...41 °C and the seizing onset load by 18...25%. The developed lubricants based on tars with polymer fillers are recommended for heavily loaded open gears, for lubricating rolling and sliding bearings of industrial equipment, friction units of the ACM and mobile machines in order to reduce wear intensity, friction coefficient, increase the operating temperature of the lubricant and the seizing onset load.

Figure 7. *Dependence of wear scar diameter on axial load: 1 – line of elastic deformation of balls according to Hertz; 2 – Gomel MZhK tar; 3 – tar+5% PE; 4 – tar +10% PE; 5 – tar +15% PE; 6 – I–L-A-22 oil*



X-ray structural studies have shown that the use of TE has a positive effect on the technological heredity of parts, reducing their tendency to warping and corrosion during operation, due to a decrease in the level of internal stresses. Table 4 shows the results of determining the internal stresses of the I kind for samples made of 12X18H10T steel. It was not possible to determine the crystallite sizes and microstresses of the II kind, because the samples are two-phase as a result of stamping and the intensity peaks for the |111| (γ-Fe) and (α-Fe) reflections overlap due to the small difference in interplanar distances.

Table 4. *Internal stresses of the I kind for samples made of steel 12X18H10T*

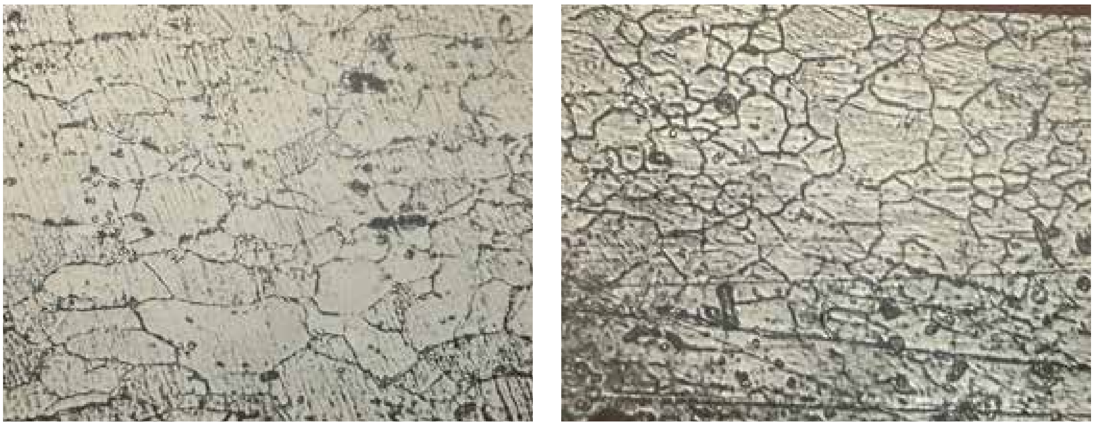
Samples	Change in interplanar distance along lines Δd, Nm				Sum of internal stresses along lines, MPa (σ1+σ2)			
	111	002	202	113	111	002	202	113
No.1 wall	0,00151	–0,0007	–0,00024	–0,0001	6500,1	4041	1839	1001
No.1 coal and wall	–0,0008	–0,0003	–0,0002	–0,00003	3370	1360	1346	250
No.10 wall	–0,0011	–0,0006	–0,0004	–0,0002	4760	3227	3067	148

The parts manufactured by stamping are in a two-phase state on the surface. The texture is weakly manifested, since the corresponding intensities in the diffraction patterns are suitable for austenite (γ-Fe) and pearlite (α-Fe). Internal stresses appear due to the difference in the physical and mechanical properties of these phases.

The results of metallographic and X-ray structural analysis on samples made of 12X18H10T and 08 Yu steel showed (Shaabidov, Sh. A., 1998) that the composition and type of TE significantly affect the nature of the distribution and change in microhardness, grain texture, and the magnitude, direction, and distribution of residual internal stresses of the first kind during the manufacture of parts. Fig. 9 shows the microstructure of 12X18H10T steel samples after stamping using factory (a) and polyfunctional tar-based lubricant (b).

Figure 9. *Microstructures of samples made of 12X18H10T steel (400ˣ)*

a **b**



And this once again gives grounds to assert that, based on a rational choice of the composition and type of TE, it is possible to purposefully influence and, to a certain extent, control the processes of wear of friction units and corrosion during the operation of the ACM and metal structures.

Table 5. *For the gears in gearboxes, the average comparative wear along the length of the tooth, u_q (mm/(N/mm))*

Gearbox number	Section along the tooth length					
	I		II		III	
	H_1	H_2	H_1	H_2	H_1	H_2
Cantilever gear						
1	0,388/0,361	0,656/0,592	0,346/0,313	0,538/0,501	0,088/0,074	0,013/0,012
2	0,212/0,197	0,420/0,393	0,147/0,131	0,322/0,297	–	–
3	0,272/0,261	0,785/0,674	0,191/0,180	0,558/0,503	–	–
4	0,484/0,424	0,329/0,292	0,245/0,202	0,198/0,167	–	–
Intermediate gear						
1	0,345/0,309	0,331/0,295	0,304/0,281	0,304/0,264	0,025/0,021	0,025/0,020
2	0,314/0,279	0,275/0,255	0,177/0,149	0,321/0,286	0,307/0,270	0,297/0,219
3	0,213/0,178	0,300/0,283	0,222/0,199	0,444/0,402	0,260/0,202	0,540/0,495
4	0,430/0,393	0,353/0,309	0,376/0,312	0,340/0,294	0,305/0,268	0,301/0,264
Gear wheel						
1	0,681/0,505	0,476/0,421	0,598/0,532	0,376/0,311	0,292/0,224	0,670/0,516
2	0,632/0,581	0,528/0,469	0,418/0,394	0,484/0,410	0,229/0,201	0,132/0,110

Table 6. *Tooth wear rate, u mkm/hour*

Details	Grease	1	2	3	4
Console gear	Litol (grease)	3,280	1,921	1,721	1,061
Intermediate gear		1,725	1,203	1,184	0,942
Gear wheel		3,405	1,385	1,390	1,037
Console gear	TG based on bitumen	3,052	0,862	1,478	0,875
Intermediate gear		1,545	0,625	1,117	0,825
Gear wheel		3,012	1,230	1,269	0,931

Table 7. *Wear resource of gears for bevel gears [∑t], hours*

Details	Grease	1	2	3	4
Console gear	Litol (grease)	351	530	541	768
Intermediate gear		667	849	787	865
Gear wheel		338	735	670	786
Console gear	TG based on bitumen	377	1182	630	931
Intermediate gear		745	1630	834	988
Gear wheel		382	828	734	875

Conclusions

1. Based on the conducted research, multifunctional technological lubricants based on tars of plant origin have been developed and introduced into production, which in combination provide the required reliability and improve the operational characteristics of the parts and units of the ACM.

2. The mechanism of lubricating action has been established and the TE compositions with the best indicators have been optimized.

3. Based on the rational choice of the composition and type of TE, it is possible to a certain extent to purposefully influence and control the processes of wear of friction units and corrosion during manufacture, during operation of the ACM and metal structures.

References

Shaabidov, Sh. A., Irgashev, A., & Mirzaev, K. K. (2012). *Improving the operational properties of machine parts surface layers: Monograph*. – Tashkent: Tash GTU.

Huang, Y., Chen, Q., Yang, J., Guo, P., Liu, X., Feng, K., ... & Zhou, F. (2025). A Novel Hindered Phenol Based Multi-Functional Lubricant Additive with Enhanced Antioxidant and Tribological Performance. *Tribology International*, – 111136 p.

Mikhnevich, N. N., & Smurugov, V. A. (1985). Study of adhesion interaction in polymer-containing lubricating compositions. *Friction and Wear*, – 6(4). – P. 627–632.

Chichinadze, A. V., Braun, E. D., Bushe, N. A., et al. (2001). *Fundamentals of tribology (friction, wear, lubrication): Textbook for technical universities* (2nd ed., rev. and suppl.; A. V. Chichinadze, Ed.). – Moscow: Mashinostroenie.

Garkunov, D. N. (2001). *Tribotechnics (wear and wearlessness): Textbook* (4th ed., rev. and suppl.). – Moscow: MSHA Publishing.

Mirzaev, K. K., & Shoobidov, Sh. A. (2022). *Improving the wear resistance of rolling bearings*. Tashkent: Innovation rivojlanish nashriyot-matbaa uyi.

Liang, B., Zhao, J., Li, G., Huang, Y., Yang, Z., & Yuan, T. (2019). Facile synthesis and characterization of novel multi-functional bio-based acrylate prepolymers derived from tung oil and its application in UV-curable coatings. *Industrial Crops and Products*, – 138. – 111585 p.

Shaabidov, Sh. A. (1998). *Technological foundations for increasing the preservation of agricultural machinery using multifunctional lubricants based on vegetable-derived bitumen* (Doctoral dissertation). – Tashkent.

Shaabidov, Sh. A. (1996). Modeling the process of applying multifunctional high-viscosity lubricants. *Uzbek Journal "Problems of Mechanics"*, – (3). – P. 32–36.

Shabidov, Sh. A. (1996). Optimization of lubricating and technological properties of multifunctional lubricants based on vegetable-derived bitumen. *Uzbek Journal "Problems of Mechanics"*, – (4). – P. 66–69.

Reeves, C. J., Menezes, P. L., Lovell, M. R., & Jen, T. C. (2015). The influence of surface roughness and particulate size on the tribological performance of bio-based multi-functional hybrid lubricants. *Tribology International*, – 88. – P. 40–55.

Mirzaev, K. K., & Mustaeva, B. U. (2019). Wear resistance of gear drives operating in an abrasive environment. *Universum: Technical Sciences,* – 3(60). – 8 p.

submitted 16.09.2025;
accepted for publication 30.09.2025;
published 30.10.2025

Contact: anvarovichsarvar908@gmail.com