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# INVESTIGATION INTO ANTI-WEAR PROPERTIES OF THE WORKING LIQUID LUBRICATION FILM IN HYDRAULIC DRIVES OF HARVESTING MACHINES

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*Influence of carrying capacity of lubricating film in contact of tribounits in a mode of a boundary lubrication on anti-wear properties of lubricating film of the working liquid while in service the hydraulic drive of harvesting machines has been investigated. It has been established, that at increase of loading in contact and operating time of the working liquid the growth of wear of friction surfaces has been observed. Decrease of load carrying capacity of lubricating film of the working liquid of the hydraulic drive is observed at increase in its operating time that leads to wear increase of tribounits. These results from the fact that while in service the hydraulic drive there is a wear of additives and destruction of lubricating film on microasperities.*

**Introduction.** The analysis of reliability index of hydraulic saturated mobile harvesting machine shows that about 30% of failures in operation conditions account for fluid hydrodrives of transmissions (FHT). This leads to unplanned costs associated with downtime of machinery during repair process. This is especially relevant to harvesting machines called as "Forwarder" because reducing process conditions of logging entails to decrease in performance machines and at the same time increases the working cost of products. These machines contain a large number of hydraulic units that are constantly working under unfavorable conditions in a way that facilitates the rapid wear and further failure [1, 2].

**Analysis of publications.** The adjustable axial piston pumps with swash plate and axial piston motors with fixed swash plate have been found in fluid hydrodrives of transmissions of forwarders as the most widely used. Manufacturers of this class of hydraulic machines are leading enterprises such as «Hamilton Sundstrand», «Eaton» (USA), «Danfos» (Denmark), «Sauer-Danfoss» (Denmark), «Rexroth-Bosch» (Germany), «Europarts» (Slovakia) "Hydromash" (Russia), "Hydrosila" (Ukraine) and others.

The analysis of defects of FHT have been evidenced that the main process leading to the loss of their performance should be considered as the wear process of pumping unit and rather the working surfaces of the pistons and cylinder sleeves (piston pair), the distributor and the end surfaces of attached bottom (distributive pair), and surfaces of shoe pair [3,4].

The boundary mode of lubrication is the most dangerous in terms of hydraulic drive surface wear. This lubrication mode runs under high contact loads, low speeds of two sliding surfaces, and increased temperatures of the working liquid. In such conditions the destruction of the lubrication film occurs leading to direct contact of friction surfaces on individual microstructures which results in their increased wear.

From time to time all hydraulic aggregates of harvesting machines perform in such unsteady modes therefore the working liquid should be capable of forming a strong lubricant layer working under various loading conditions on friction surfaces. However, the effect produced by the working liquid composition and loading modes on its anti-wear properties has been explored insufficiently.

The aim of this article is to explore anti-wear properties of the lubricant film layer of the working liquid in hydraulic drives of harvesting machines in the process of their operation in mode of boundary friction.

The task of the investigation is to determine the impact produced by working liquid operating time and load in surface contact under boundary friction on antiwearing properties of a lubricant film layer when the hydraulic drive of harvesting machines while in service.

**Experimental setup.** The most popular hydraulic oil with various operating time was selected as a lubricating liquid for the experiment. The properties of the working liquid are in compliance with the standard DIN 51524 Part 2 (2006), ISO 11158 L-HM (2006).

The subject of research was a pyramid from balls, which is used in four-ball machines of friction. The 7.938 - 60 pyramid balls used were of National Standard 3277-81. The friction pair "ball-to-ball" schematic is shown in Fig. 1.

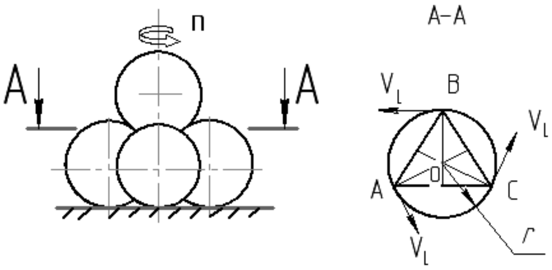

Fig. 1. The schematic diagram of friction pair "ball-to-ball"

The friction pair selected was tested on the updated machine of friction МАСТ - 1, Fig. 2.

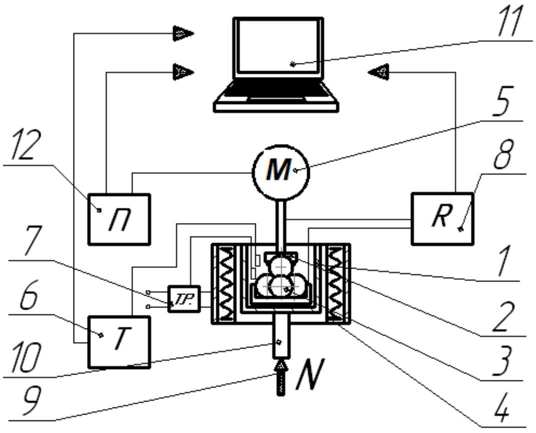

Fig. 2. The schematic installation for determining the carrying capacity of an lubricating film of surface-active-agent molecules: I - glass; 2 - rotating ball; 3 - bottom block of balls; 4 - heating element; 5 - engine of the top-ball drive; 6 - thermo-resistor; 7 - heat controller; 8 - ohmmeter; 9 - set of weights; 10 - mobile platform; 11 - computer; 12 - tachometer.

The moving platform 10 presses the bottom balls 3 to a rotating ball 2 with a set of weights 9 with the given effort N. The ball 2 rotates at rotational frequency set by the electric motor 5.

During tests the temperature of the working liquid was maintained by means of the heating device 4 with heat controller 7. To measure oil temperature in glass 1, thermo-resistor 6 connected to computer 11 was employed. The resistance in "ball-to-ball" contact is controlled with ohmmeter 8. Indications of tachometer 12, ohmmeter 8 and tensoresistor 6 were displayed on computer 11.

The moment when the friction pair transit into mode of boundary lubrication corresponds to the moment when metal contact of surfaces occur on individual microasperities. At this point the value of electrical resistance reaches its minimum, which was fixed by ohmmeter 8.

To hold accelerated friction-surface wear tests, it was necessary to determine the range of loads within which the effect of the lubricating film becomes evident in metallic contact. The range of loads varied from the moment of squashing the lubricating layer of the surface-active-agent until the film layer creates essential effect on surface wear.

In order to establish the variation range of the load and the rate of ball rotation, preliminary tests were conducted. Loads and the rate of ball rotation varied at working liquid temperature t = 323K until the point of transition from boundary lubrication to liquid lubrication and point at which the film does not play an essential role were identified. The tests established that the first point was determined by values N = 0.5 N, $n = 0.4\ s^{-1}$ ($v = 1{,}84 \cdot 10^{-3}$ m/s); the second point - N = 1.5 N, $n = 0.4\ s^{-1}$.

The purity class of the working liquid, speed of sliding surfaces, and the temperature of the working liquid were maintained constant throughout the tests.

The experimental investigations into dependence of friction surface wear vs. load in contact in mode of boundary friction while the working liquid is in operation were conducted under the following conditions: the temperature of the working liquid, t = 323K; the rate of ball rotation, $v = 1.84 \cdot 10^{-3}$ m/s; the load in contact was within N = 0.5...1.5 N with 0.5 N step; the operating time of the working liquid was within T = 0...1000 machine-hours with a step of 500 machine-hours; the purity of the working liquid during the tests was not below 10 according to National Standard 17216-2001; the time of friction pair staying under load was assumed as 800 s.

**Experimental results.** The results of experimental investigations are shown in the diagrams Fig. 3,4.

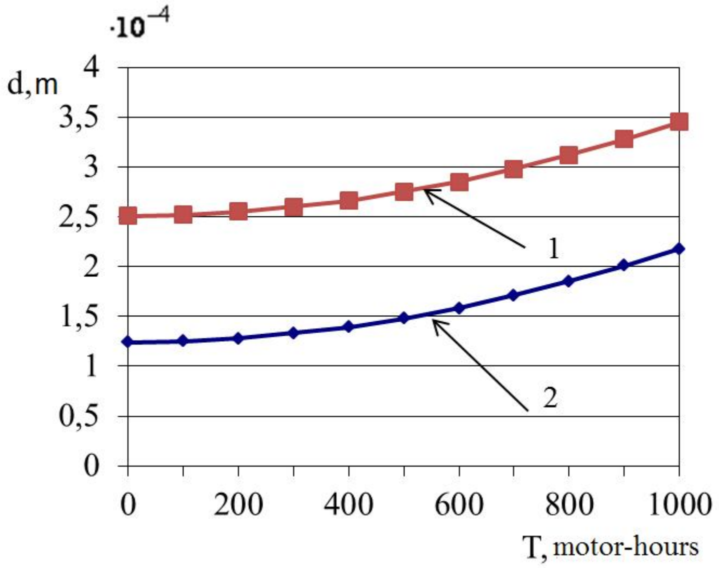

Fig. 3. The function graph of the wear stain diameter size vs. the operating time of the working liquid (v = 1,84·$10^{-3}$ m/s, t = 323 K): 1 - load in contact is 1.5 N; 2 - load in contact is 0.5 N

The analysis of wear functions (Fig. 3) vs. the operating time of the working liquid at boundary load values within the load range under investigation (0.5 N, 1 N) shows the following. The wear fiinction can conditionally be divided into two ranges, one being 0...600 motor-hours and the other being 600...1000 motor-hours; when the operating time of the lubricant is 0...600 machine-hours, the wear function is of nonlinear growing character, and if the operating time is 600...1000 motor-hours the function is approaching to the linear one. The lubricant wear rate with the operating time 0...600 machine-hours at load of 0.5N is higher in comparison with the wear rate at load of 1.5 N (at smaller absolute value of wear); when the operating time exceeds 600 machine-hours the wear rate at various loads in contact is leveling.

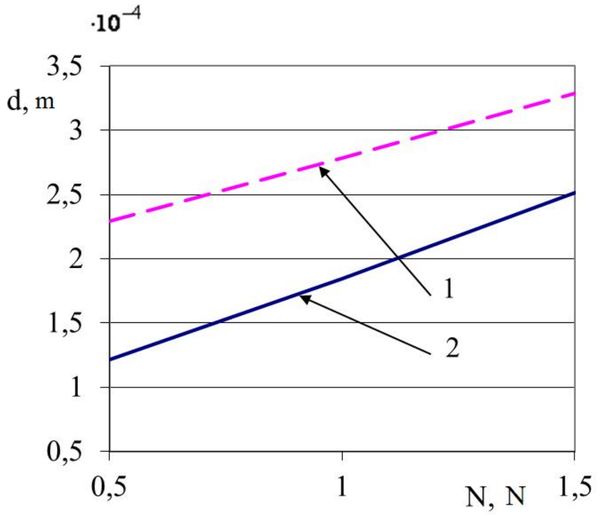

Fig. 4. The function graph of the wear stain diameter size vs. the load in contact (v = 1,84·$10^{-3}$ m/s, t = 323 K): 1 - the operating time of the working liquid is 1000 motor-hours ; 2 - the operating time of the working liquid is 0 motor-hours .

The analysis of the wear functions (Fig. 4) vs. load in contact at boundary values of the operating time of the working liquid (0 and 1000 motor-hours ) shows that the wear function vs. load in contact at a various operating time of the working liquid in mode of boundary friction is close to linear. The higher is the load the larger is the wear stain diameter size; the effect of load on the wear stain diameter size decreases as the operating time of the working liquid increases.

**Conclusions**. As the operating time of the working liquid grows the increasing wear of friction surfaces is observed. If compared to the working liquid which is being delivered, the wear of friction surfaces in the range under investigation amounts to 120-225% depending on load in contact of friction surfaces. This essential gain is explained by the fact that in the process of operation the additive depletion occurs forming a lubricant layer on friction surfaces.

When the load in contact is getting higher, the wear of friction surfaces is increasing, and the effect that the load produces on the wear lows down as the load increases. This fact suggests a decrease in the carrying ability of the film and a destructing lubricant layer on microasperities.

Thus, the working liquid with a high carrying capacity of a lubricant film layer should be applied to prevent the increased wear of friction surfaces in hydraulic drives of harvesting machines .

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## Аннотация

### ИССЛЕДОВАНИЕ ПРОТИВОИЗНОСНЫХ СВОЙСТВ СМАЗОЧНОЙ ПЛЕНКИ РАБОЧЕЙ ЖИДКОСТИ ГИДРОПРИВОДА ЛЕСОЗАГОТОВИТЕЛЬНЫХ МАШИН

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*Исследовано влияние несущей способности масляной пленки в контакте трибосопряжений в режиме граничной смазки на противоизносные свойства смазочной пленки рабочей жидкости в процессе эксплуатации гидропривода* *лесозаготовительных машин. Установлено, что при повышении нагрузки в контакте и наработки рабочей жидкости наблюдается увеличение износа трибосопряжений. Это объясняется тем, что в процессе эксплуатации гидропривода происходит срабатывание присадок и разрушение смазочной пленки на микронеровностей.*

**Анотація**

## ДОСЛІДЖЕННЯ ПРОТИЗНОСНИХ ВЛАСТИВОСТЕЙ МАСТИЛЬНОЇ ПЛІВКИ РОБОЧОЇ РІДИНИ ГІДРАВЛІЧНОГО ПРИВОДУ ЛІСОЗАГОТІВЕЛЬНИХ МАШИН

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*Досліджено вплив несучої здатності мастильної плівки в контакті трибосполучень в умовах граничного мащення на протизносні властивості мастильної плівки робочої рідини в процесі експлуатації гідроприводу лісозаготівельних машин. Встановлено, що при підвищенні навантаження в контакті і наробітку робочої рідини спостерігається збільшення зносу трибосполучень. Це пояснюється тим, що в процесі експлуатації гідроприводу відбувається спрацьовування присадок і руйнування мастильної плівки на мікронерівностях.*