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TESTING OF WEAR IN CONTACT WITH STRENX 700 AND AUTOFRETTED STEEL

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Abstract: *This paper presents an experimental test of the contact wear between STRENX 700 material and autofretched steel, which is obtained in practice by the autofretching (material reinforcement) of artillery pipes. Three types of lubricants were varied during the test: HD 46 oil, Hysol T15 emulsion, and For 3 grease. Also, the experiment was performed by varying three values of normal load: 10, 20 and 30 N, as well as two values of disk rotation speed: 0.5 and 1 m/s. The test was performed on a tribometer "TR – 95", which operates on the basis of block-on-disk configuration. "ASTM G 77" standard was used for testing. The metallurgical optical microscope "MEIJI MT8500" was used to image the wear marks. The purpose of the test is to determine the most suitable means of lubricating the contact of the materials used. By a comparative analysis of the results obtained, it was concluded that the emulsion is the most suitable means of lubricating the contact of the materials used, since it allowed very low material consumption under all conditions.*

Key words: w*ear, lubrication, STRENX 700, autofretched steel.*

Ispitivanje habanja u kontaktu materijala STRENX 700 i autofretovanog čelika. *U ovom radu prikazano je eksperimentalno ispitivanje habanja u kontaktu materijala STRENX 700 i autofretovanog čelika, koji se u praksi dobija procesom autofretovanja (ojačanje materijala) artiljerisjkih cevi. Tokom ispitivanja varirane su tri vrste sredstva za podmazivanje: ulje HD 46, emulzija Hysol T15 i tovatna mast "For 3". Takođe, eksperiment je izvršen variranjem tri vrednosti normalnog opterećenja: 10, 20 i 30 N, kao i dve vrednosti brzine rotacije diska: 0.5 i 1 m/s. Ispitivanje je izvršeno na tribometru "TR – 95", koji funkcioniše na osnovu blok–on–disk konfiguracije. Za ispitivanje je korišćen standard "ASTM G 77". Za slikanje tragova habanja korišćen je metalurški optički mikroskop "MEIJI MT8500". Cilj ispitivanja je da se odredi najpogodnije sredstvo za podmazivanje kontakta korišćenih materijala. Uporednom analizom dobijenih rezultata, došlo se do zaključka da je emulzija najpogodnije sredstvo za podmazivanje kontakta korišćenih materijala, jer je pri svim uslovima omogućila veoma malo trošenje materijala.*

Ključne reči: *habanje, podmazivanje, STRENX 700, autofretovani čelik.*

1. INTRODUCTION

Wearing of materials is a process that occurs on surfaces, between interactive bodies, and is usually hidden because of the diverse components, located near them. Scientists have given a great deal of attention to exploring the various modes and mechanisms of wear. Types of wear, such as abrasion, adhesion and fatigue, which were originally used in the classification of wear mechanisms, have become insufficient today as new materials and surface coatings emerge, the wear of which is more specific. In order to understand the processes of material wear, predict the wear rate and certainly reduce it, it is necessary to overcome the various challenges that engineers face. Understanding wear and tear often involves a thorough knowledge of the mechanics, physics, chemistry, and materials science, while predicting wear in many cases is very difficult [1].

The quantification of wear is done on the basis of volume, mass of wear products, or change in linear dimension. Also, the amount of wear can be estimated based on the wear rate, which is defined as the amount of material removed in a unit of time [2]. It is very helpful for scientists to understand the mechanisms of wear and tear in order to study the tribological characteristics of the material. Tribological characteristics can be understood by surface roughness, hardness and transfer between surfaces [3].

Although the laws of friction are fairly well established, there are no satisfactory laws of wear. In general, it can be said that wear increases depending on the sliding time and that on hard surfaces the wear is less than on softer ones, but there are many exceptions where wear depends on load, surface type, touch, speed, etc. There are many factors involved in wear and even a small change in conditions can completely change the significance of certain factors or change their way of interaction.

One of the most common characteristics of metal wear, for both dry and lubricated surfaces, is that due to a certain lower load, less (mild) wear occurs, while with increasing the load it also significantly increases wear, which can be 1000 or even 10 000 times greater (large wear). In the case of heavy wear, which is most commonly caused by dry metal contacts, the wear process takes place by cutting intermetallic joints. If the joints are very strong, wear occurs at the surface of the material, which is manifested by the formation of wear products. This occurs most commonly in metals of similar structure [4].

The main purpose of lubricants is to reduce friction between surfaces, to prevent wear and rust, to cool by removing heat that occurs in contact between surfaces. In practice, it is also used to lubricate car engines as a protection against friction and wear damage. Mechanical friction losses in automotive engines vary between 17% and 19% of the total energy generated by the engine [5].

The parameters for tribological testing, as well as the methods for testing with macro loads of standard metallic materials, are quite well defined. In recent years, some problems have emerged in tribological testing, related to porous structures of materials. One of the main problems is to ensure continuous contact between surfaces, which are in relative motion. The problem arises because porosity occurs on one surface and therefore continuous contact in the pore zones is interrupted [2].

This paper presents an experimental examination of the wear characteristics of a STRENX 700 material and autofretched steel, which is used to make artillery tubes. Three types of lubricants were varied: HD 46 oil, Hysol T15 emulsion and For 3 grease. Also, the experiment was performed by varying three values of normal load: 10, 20 and 30 N, as well as two values of disk rotation speed: 0.5 and 1 m/s. The aim of the experiment is to determine the most suitable conditions for the use of a particular lubricant.

2. MATERIALS, LUBRICANTS AND EQUIPMENT

2.1 Materials and preparation of test steam

The tested contact pair meets the requirements of the "ASTM G 77" standard, which was used for tribological testing. This standard involves sliding wear, which involves complex wear mechanisms that take place on the contact surface, such as adhesive wear, abrasive wear, etc. The tribological testing method, which uses this standard, enables the estimation of material wear in different simulated conditions and enables reliable ranking of material pairs for specific tribological applications. This standard operates on a block-on-disk configuration [6].

It consists of a rotary disc, 35 mm in diameter and 6.35 mm wide and a block 6.35 mm wide, 15.75 mm long and 10.16 mm high. The disc is made of autofretched artillery tube material, with a hardness of about 400 HB, and the tile is made of STRENX 700 material, with a hardness of 220 HB. The test pair is shown in Figure 1.

Fig. 1. Disk and block

Since autofretched steel is used in the military industry, its chemical composition will not be shown. The chemical composition of STRENX 700 is shown in Table 1.

C [%]	max	0.12
Si [%]	max	0.21
Mn [%]	max	2.1
P [%]	max	0.02
S [%]	max	0.01
Al [%]	min	0.015
Nb [%]	max	0.09
V [%]	max	0.2
Ti [%]	max	0.15

Table 1. Chemical composition of STRENX 700 materials [7]

2.2 Lubricants

The HD 46 hydraulic oil is designed to transmit power and movement in all hydraulic systems, operating under conditions of moderate loads and relatively constant temperatures. It has excellent anti-corrosion, anti-wear and antioxidant properties. It is used in medium power, pressure and load hydraulic systems (presses, cranes, machine tools). In addition, it is suitable for lubrication of gear and rotary piston pumps to medium pressure and temperature conditions. The characteristics of the oils are shown in Table 2 [8].

Characteristic	Unit	Value
Viscosity gradation	-	ISO VG 46
Viscosity at 40°C	mm^2/s	41.4 – 50.6
Viscosity at 100°C	mm^2/s	6.6
Minimum viscosity index	-	120
Minimum ignition point	°C	200
Maximum flow point	°C	-15
Corrosion on Cu	level	1a
Oxidation stability	hour	>1200
Maximum deemulsivity at 54°C	minute	30
Maximum oil extraction capability, 50°C	minute	10

Table 2. HD 46 oil characteristics [8]

The Hysol T15 emulsion is a high-performance water-miscible semi-synthetic chlorine-free machining agent. Using a unique additive package enables excellent machining parameters and surface quality, long-term biostability and reduced overall machining costs. This emulsion is suitable for single tanks as well as large central systems. It is recommended especially for machining steel castings and low to medium alloy steels. Possesses the following positive characteristics: resistance to bacterial and fungal infections which reduces the cost of replacement and cleaning and raises operational readiness, foaming resistance, good corrosion protection of the piece and machine, excellent lubrication properties ensure tool protection and higher surface quality, good surface wetting property ensures cleanliness of the machine and reduces wear on pieces and clamps. The emulsion characteristics are shown in Table 3 [9].

Concentrate	
Appearance	Yellow liquid
Mineral oil content [mass fraction, %]	29
Emulsion	
Appearance	Translucent fluid
PH at a concentration of 5%	9.0
Factor for refractometer	1.5
Recommended working concentrations	
Grinding	4 – 6%
Milling, scraping	5 – 7%
Drilling	6 – 8%
Slicing, indulging	6 – 8%
Purging	6 – 8%

Table 3. Hysol T15 emulsion characteristics [9]

The For 3 grease is a lithium multifunctional, smooth structure. It is made on the basis of lithium soap, higher fatty acids and highly refined mineral oil. Thanks to the technological production process, excellent mechanical stability has been achieved. Advantages of For 3 grease: excellent mechanical stability, high degree of protection of the lubricated assembly against corrosion, good pumpability, good resistance to water, good lubricity in moderate loads and good low temperature properties. This lubricant is used in construction machinery, agricultural and mining machinery, motor vehicles, transport equipment, etc. It is mostly used for lubrication of rolling and sliding bearings, sliding tracks, joints, electric motors, machine assemblies in all industrial branches, at moderate loads, speeds and operating temperatures. Regarding the temperature range, it is used in the range: -30 °C to +110 °C. Recommended storage temperatures: -5 °C to +25 °C [10].

2.3 Equipment

The tribological characteristics were tested on a computer-assisted TR – 95 tribometer (Figure 2), with a block-on-disk contact geometry. This tribometer allows the variation of contact conditions in terms of the shape, dimensions and materials of the contact elements, normal contact load and sliding speed. Tests can be performed with and without lubrication [11].

Fig. 2. TR – 95 tribometer

The block is mounted in a specially made bearing bracket (Figure 3).

Fig. 3. Placing the block in the bracket

Figure 4 shows the metallurgical optical microscope “MEIJI MT8500”, which shows images of wear traces.

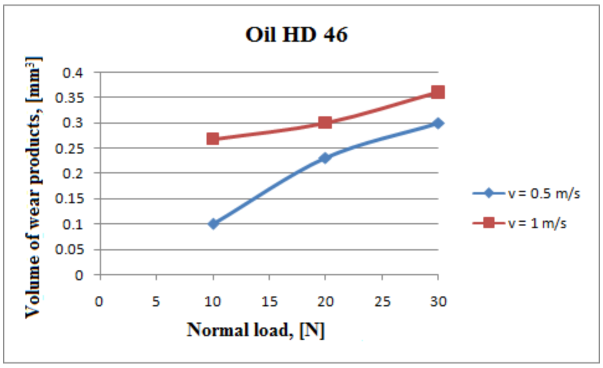
Fig. 4. Metallurgical optical microscope “MEIJI MT8500”

3. EXPERIMENT

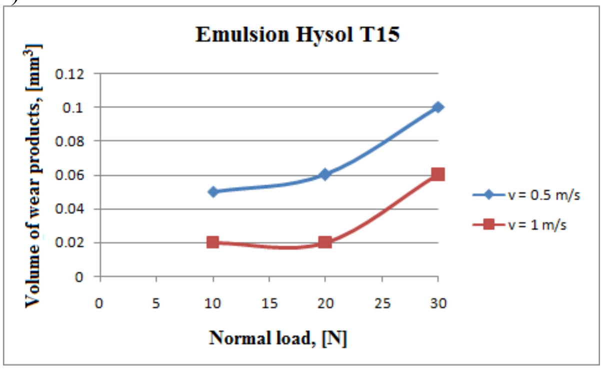
The experiment was carried out with lubrication using the following means: HD 46 oil, Hysol T15 emulsion For 3 grease. The test was performed by varying the normal load (10, 20 and 30 N) and varying the rotation speed of the disk (0.5 and 1 m/s). The duration of one experiment is 10 minutes and the length of the glide path is 600 m. In terms of the type of relative motion, all experiments represent rolling wear. The experiment was repeated three times for each type of lubrication, each normal load, and each speed of rotation of the disc in order to check whether approximate tribological characteristics would be obtained. The width of the wear trace on the contact surface of the block was used as the basic wear parameter. The volume of the wear products was used to compare the tribological characteristics of the lubricant.

4. RESULTS AND DISCUSSION

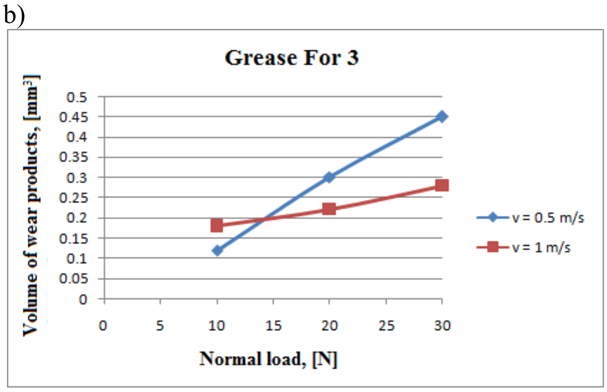
Based on the analysis of the results obtained, some conclusions were reached. Figures 5a, 5b and 5c show the diagrams of change in the volume of wear products depending on the normal load, for both disk rotation speeds: a) HD 46 oil, b) Hysol T15 emulsion and c) For 3 grease.



a)



b)



c)

Fig. 5. Diagrams of changes in the volume of wear products depending on the normal load

The diagrams show that the volume of wear products increases with the increase of normal load and that the growth trend is higher at a lower disk rotation rate for all types of lubrication. The smallest value of the volume of wear products is observed in the emulsion lubrication for both rotational speeds of the disc.

Highest value achieved with grease lubrication at maximum normal load and lower disk rotation speed.

By observing the behavior of the oil and the grease, with regard to the lowest load and both speeds, the oil contributed to increased wear at a speed of 1 m/s, so its use can be limited to lower speed conditions.

Under medium load conditions, the volume of the wear products ranges over an interval (0.22 – 0.3 mm^3). At this load, it is recommended to use the oil at lower speeds, while grease is recommended to use at higher speeds.

Observing the highest load, the volume of the wear products varies at intervals (0.28 – 0.45 mm^3). Both speeds have contributed to increased wear and tear, so they should be avoided in such conditions.

6. CONCLUSION

This paper deals with the contact wear testing of STRENX 700 material and autofretched steel, varying three types of lubricant (HD 46 oil, Hysol T15 emulsion and For 3 grease), three normal load values (10, 20 and 30 N) and two disk rotation speed values (0.5 m/s and 1 m/s).

The analysis of the obtained results revealed that Hysol T15 emulsion lubricant was the most suitable lubricant because it allowed the least wear of the material, under all conditions used, varying in the range (0.02 – 0.1 mm^3).

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