Tribological Journal BULTRIB, **Vol. IV, 2014**
Papers from the International Conference **BULTRIB '13**
October 24-26, 2013, Sofia
Society of Bulgarian Tribologists
Technical University of Sofia

INFLUENCE OF “VALENA” METAL-PLATING ADDITIVE ON THE FRICTION PROPERTIES OF BALL BEARINGS

Mara KANDEVA, Aleksandar VENCL, Emilia ASSENOVA

Abstract: *The repair-regeneration oil additives are new generation additives with important place in the application of lubricants. Added to oils or greases they assure partial regeneration of worn surfaces and, at the same time, decrease the moment of friction and the coefficient of friction in the contact pairs of machines. Most common are the organic oil-soluble additives. The paper exposes results of the study of the oil-soluble metal-plating composite additive “Valena”. The influence of this additive on the friction parameters of ball bearing lubricated by motor oil M-63/14 (SAE 15W-40, API SF/CC) and transmission oil TM-5-18 (SAE 80W-90, API GL-5) has been investigated.*

Key Words: *Friction properties, additives, ball bearings*

1. INTRODUCTION

The continuous improvement and advance technology of machines necessitate higher quality of lubricants and lubrication technologies, which influences equipment life and environment [1,2]. Being a working medium in the contact systems, lubricants reduce friction and wear replacing the external dry friction between surfaces by internal friction between lubricant molecules.

The repair-regeneration oil additives are new generation additives and have an important place in the application of lubricants. Added to oils or greases they assure partial regeneration of worn surfaces under special dynamic friction conditions. At the same time they decrease the moment of friction and the coefficient of friction in the contact pairs of machines. Different names were given to these additives, depending on their composition and condition. Most common are the organic oil-soluble additives. The hard non-soluble non-organic materials are habitually called *antifriction additives*, and the composites based on polymers – *modifiers*.

The metal-plating composite additives are also named *remetallizers*. Their development is based on:

- the theory of system self-organization as per I. Prigogine, W. Ebeling, D.N. Garkunov, G. Polzer, etc. [3,4];
- the scientific discovery and the application of the selective transfer of materials between contacting surfaces and the no-wear effect originating with the work of D.N. Garkunov, I.V. Kragelskii, G. Polzer, V. Babel, etc. [5,6]

This paper exposes results of the study of one of the newest additives, the oil-soluble metal-plating composite additive called “Valena”, manufactured by the company “Rudservice” from Kazakhstan. The influence of this additive on the friction parameters of ball bearing lubricated by motor oil M-63/14 (SAE 15W-40, API SF/CC) and transmission oil TM-5-18 (SAE 80W-90, API GL-5) has been investigated.

2. MATERIALS

2.1. Metal-plating composite additive “Valena”

“Valena” additive is a metal containing oil-soluble composite lubricant additive registered as patent in 2005 in Russia by V. Babel, D. Garkunov, S. Mamikin and P. Kornik [5]. It is designed for improvement of the tribological properties of lubricants, namely the decrease of friction, normal wear and seizure. The additive is a dense dark-green liquid with good solubility in oils and greases, in which it forms a solution, with the metal in the form of ions. The solubility of this additive is due to its particular composition; it contains metal salts of non-organic and organic acids. The non-organic acid salts are salts of Cu, Co, Pb, Sn, Ni (chlorides, bromides, and iodides). The organic acid salts belong to metals of variable valence with carbon atoms C_{15}….C_{18}.

Improvement of the tribological properties by use of “Valena” additive is achieved through the selective transfer of material between the frictional surfaces and the effect of no-wear during friction process. The essence is in the forming of 1 to 4 μm thick protective layer on the real contact area of the friction surfaces called by D.N. Garkunov “servotite” metal-plating layer. This layer compensates the wear and screens the infiltration of hydrogen in the surfaces, reducing thus the hydrogen wear. The recommendations of the manufacturer for the percent contents of “Valena” additive in the lubricant depend on the state of the tribological pair, as given in Table 1.

Table 1: *Recommended percent contents of “Valena” additive*

Condition of the tribological pair	% of Valena additive	
	Grease	Oil
new	1 %	1 %
in-service	5 %	3 %
worn-out	9 %	9 %

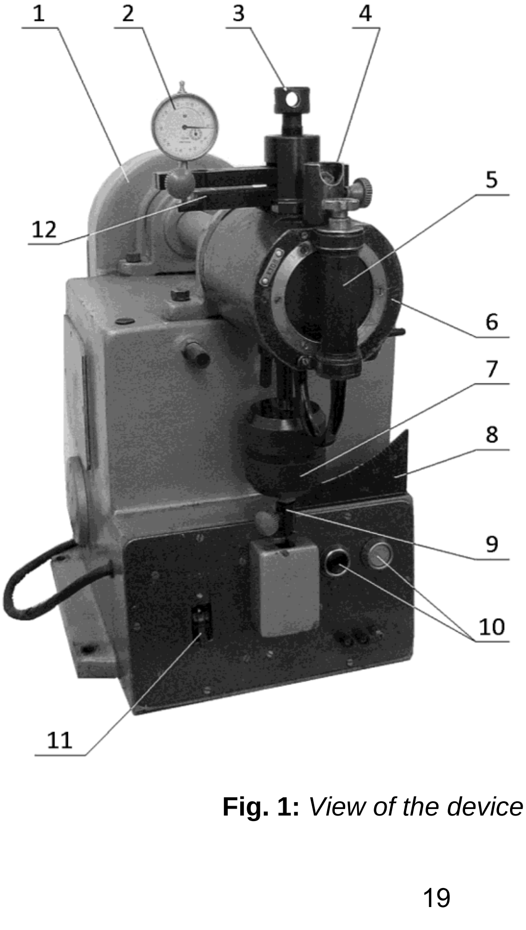
2.2. Motor oil M-63/14 and transmission oil TM-5-18

The motor oil M-63/14 is a multigrade mineral oil designated as SAE 15W-40, API SF/CC. It is designed mainly for petrol engines, but it can be used in Diesel engines as well.

The transmission oil TM-5-18 is a universal multigrade mineral oil designated as SAE 80W-90, API GL-5. It is designed for mechanical gear boxes and, transmission gears of petrol and Diesel engines.

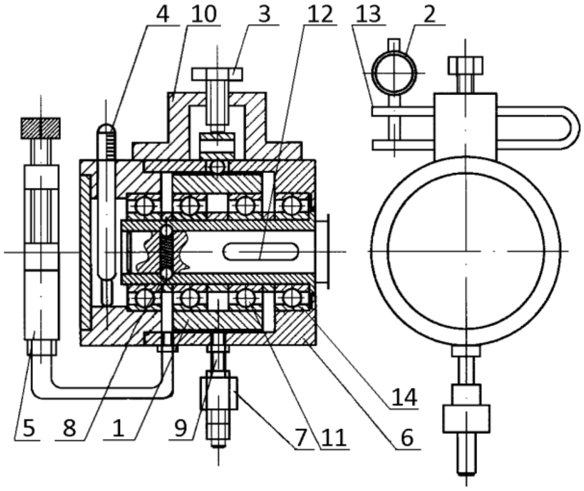
3. EXPERIMENTAL PROCEDURE

The tribological parameters: moment of friction and coefficient of friction have been studied under lubricated conditions, with motor and transmission oil at various normal loads. Device “DM 28M” used for measurement of moment of friction in ball bearings is shown in Figs. 1 and 2. The device consists of casted housing with mounted driving shaft. A bearing (measuring) box is connected to the end of the shaft, where the four ball bearings (two in the middle and two at the end), which are tested, are located. Single-row steel ball bearings (Designation 308, GOST 8338-57) were used, with bore diameter of 40 mm, outside diameter of 90 mm and width of 23 mm.



1 – belt-drive in housing
2 – indicator
3 – loading screw for the bearing
4 – location for the thermometer
5 – injector for regulation of oil level
6 – bearing box
7 – load of the pendulum
8 – dial for moment of friction reading
9 – pendulum
10 – on and off buttons of the motor
11 – switch on for the circuit
12 – dynamometric beam

Fig. 1: *View of the device “DM 28M”*



1 – external housing;
2 – indicator;
3 – loading screw for the bearing;
4 – thermometer;
5 – injector;
6 – cased housing;
7 – load of the pendulum;
8 – ball;
9 – pendulum;
10 – clamp;
11 – middle bearings;
12 – driving shaft;
13 – dynamometric beam;
14 – end bearings

Fig. 2: *Bearing box (detail from the Fig. 1)*

The outer rings of the two middle bearings are located in common chamber, and the outer rings of the two end bearings are fixed tightly in the housing of the bearing box, so that they form tight contact. The inner rings of the bearings are connected tightly on the driving shaft. In this manner the motion of the driving shaft is transmitted to the inner rings of the bearings and to the outer rings of the bearings by means of the rolling balls. The outer rings of the bearings transmit the motion to the housing of the bearing pair, and the bearing box tends to rotate in the direction of shaft rotation. As a result, the appearing moment of friction sweeps along the bearing box. A pendulum is connected to the bearing box. The deflecting angle of the pendulum against the vertical position corresponds to the value of the moment of friction.

The bearing are externally loaded by means of the loading screw. The load is read on the loading indicator dial, graduated in accordance with the reference characteristic of the dynamometric beam. Oil is put into the bearing box through the casted housing and its level is regulated by means of piston displacement. All experiments are done at one, same for all tests, oil level, measured near the center of the bearing balls in order to ensure equal lubrication conditions in the bearing box. During the lubricant change, the bearing box is cleaned with benzene and dried by hot air. Bearing temperature is measured by the thermometer immersed in the oil. Appropriate limiters inhibit bearing head rotation during engine start. The number of revolutions (1880 min^{-1}) was constant, set through the regulation of the belt-drive, and controlled by the remote revolution counter.

Moment of friction and temperature is measured in the regime without load (unloaded conditions) and under four different loads (1130, 1635, 2725 and 5650 N). Test durations were the same for each load, i.e. 10 minutes, with data readings on every 2 minutes. The reduced (arbitrarily brought to one of the four bearings in the box) coefficient of friction in a bearing is determined by the formula:

$$\mu_r = \frac{2M}{P \cdot d},$$

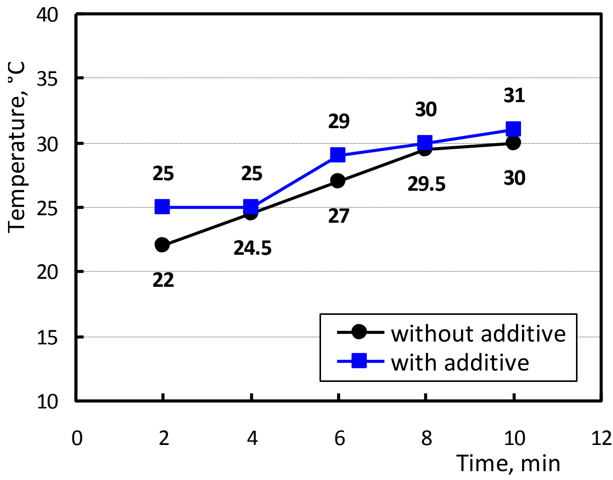
where: M is moment of friction, P is normal load and d = 0.04 m is inner (bore) diameter of the bearing.

4. EXPERIMENTAL RESULTS AND DISSCUSION

4.1. Study of friction in bearings, lubricated by motor oil M-63/14 without and with additive

Experimental results show the variation of the moment of friction with the temperature of oil in the bearing, in regime without normal load, for motor oil M-63/14 without and with additive. The values are measured every 2 min with overall duration of 10 min. Figure 3 shows the variation of temperature and Fig. 4 shows the variation of moment of friction during the period of 10 min. For both variants (without and with additive) moment of friction reached steady-state values after 8 to 10 minutes (Fig. 4). This is the reason why time interval of 10 minutes was chosen as test duration in loaded bearings studies. The temperature of oil with additive is slightly lower than that of oil without additive (Fig. 3).

Four different loads are applied in tests with loaded bearings, with test duration of 10 minutes for each load. Oil temperature and moment of friction are measured for each load and are presented in Figs. 5 and 6. Calculated values of the corresponding coefficient of friction, for each load, are shown in Fig. 7.



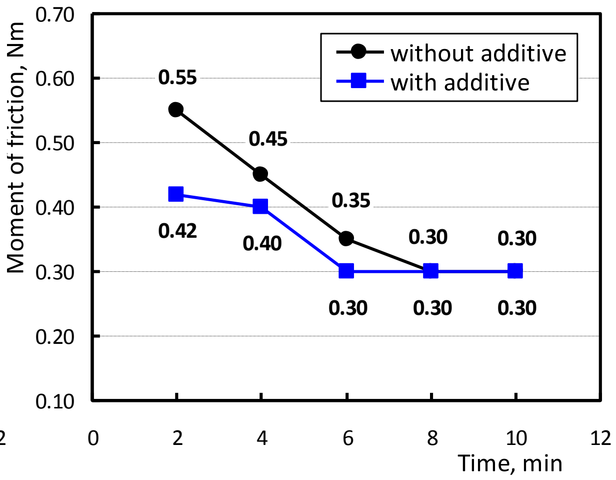
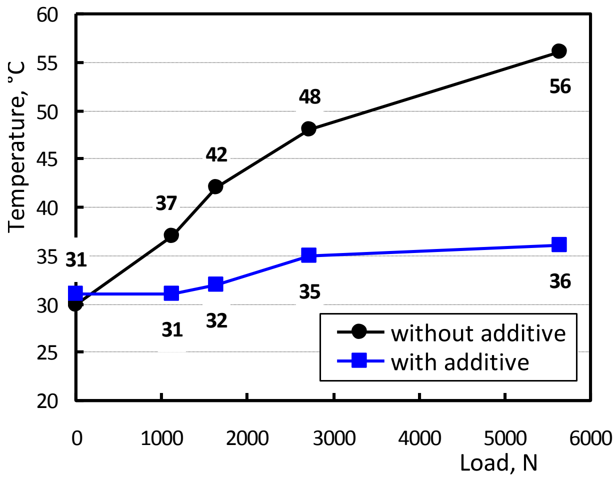


Fig. 3: *Variation of temperature of M-63/14 oil in bearing during friction without loading*

Fig. 4: *Variation of moment of friction during friction without loading*



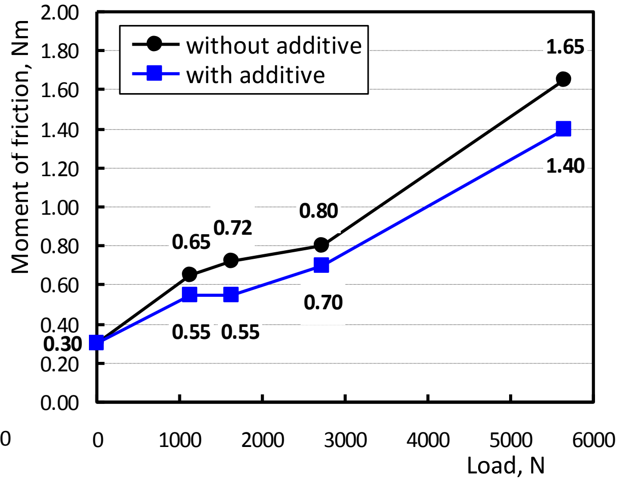


Fig. 5: *Variation of temperature of M-63/14 oil in bearing during friction with different loads*

Fig. 6: *Variation of moment of friction in bearing during friction with different loads*

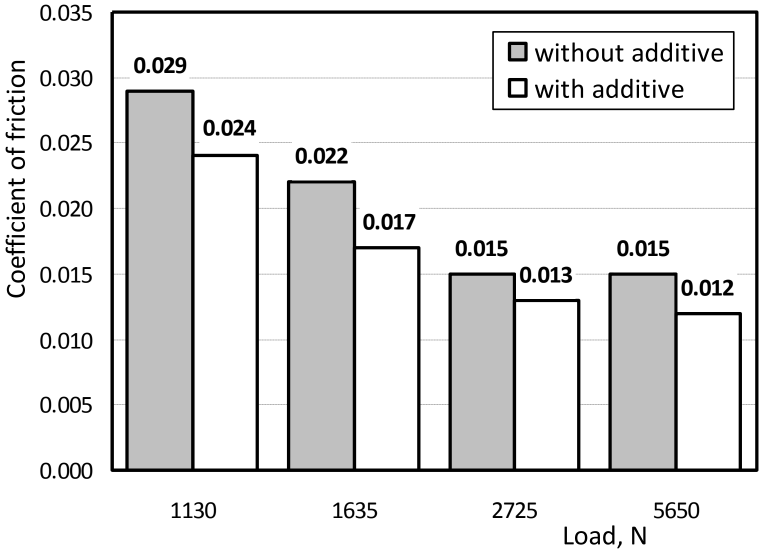


Fig. 7: *Dependence of the coefficient of friction on load for motor oil M-63/14 without and with additive*

From Figs. 6 and 7 it is obvious that the values of the moment of friction and coefficient of friction are for each load lower in the case of motor oil that contain “Valena” additive. Fig. 6 shows that the moment of friction increases with the increment of the normal load, and the relationship is non-linear. The differences between moments increase with the augmentation of load. The reduction of the coefficient of friction by using “Valena” additive differs (from 13 to 23 %) with the applied load, and the average reduction is 18.3 %.

The results for oil temperature measurement (Fig. 5) show that in the case of motor oil with additive the temperature increases only 5 °C from unloaded to fully loaded conditions, while in the case of motor oil without additive temperature increases 25 °C for the same load increase. This suggests that the decrease of moment friction and coefficient of friction in the case of motor oil with “Valena” additive is not due to oil viscosity reduction at higher temperature, but due to the physic-chemical surface effects in the contact region during friction. Although it was not measured the wear of the balls and rings might be also diminished by the presence of additive, since its positive effect on friction properties.

After dismantling, the presence of thin reddish film on shaft surface was observed. The composition, structure and thickness of this film were not exanimate in this investigation, but it seems logical to suggest that this film has been formed during friction, due to physic-chemical and mechanical processes of selective transfer of copper on the steel shaft surface. The metal-plating additive “Valena” contains copper ions which are possibly transferred on the shaft under the specific conditions of the experiment. The formed film compensates the roughness on the surface, and due to the small tangential resistance it makes the plastic deformations during friction in the surface layers easier.

4.2. Study of friction in bearings, lubricated by transmission oil TM-5-18 without and with additive

Experimental results show the variation of the moment of friction with the temperature of oil in the bearing, in regime without normal load, for transmission oil TM-5-18 without and with additive. The values are measured every 2 min with overall duration of 10 min. Figure 8 shows the variation of temperature and Fig. 9 shows the variation of moment of friction during the period of 10 min. In case of transmission oil lubrication (without and with additive), moment of friction reached steady-state values after 4 to 6 minutes (Fig. 9). This time interval is shorter than it is in the case of motor oil lubrication (see Fig. 4), but the same time interval of 10 minutes was chosen as test duration in loaded bearings studies with transmission oil.

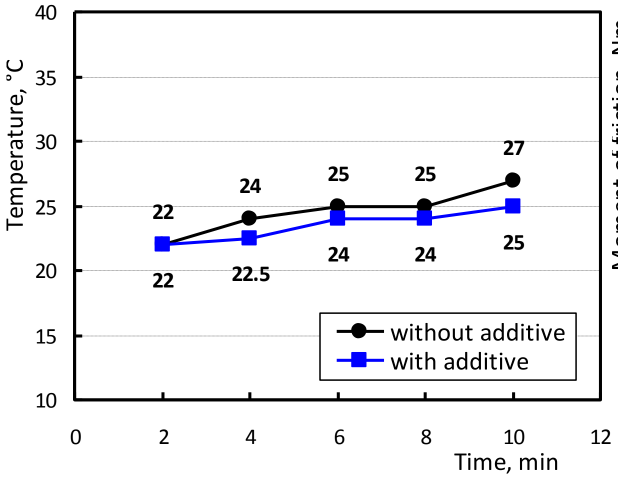


Fig. 8: *Variation of temperature of TM-5-18 oil in bearing during friction without loading*

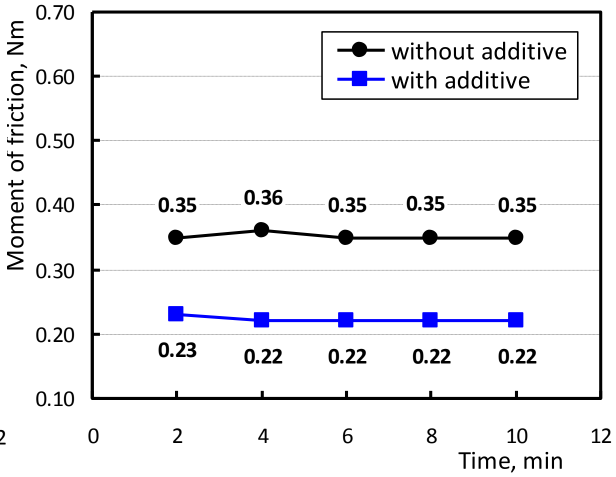


Fig. 9: *Variation of moment of friction during friction without loading*

Figure 8 shows that the temperature of oil with additive is slightly lower than that of oil without additive (as it was in the case of motor oil lubrication, see. Fig. 3). The moment of friction (Fig. 9) is almost constant in time for both transmission oil variant (without and with additive), being significantly lower for oil with additive. This difference in the moment of friction for oil without and with additive is much bigger in the case of transmission oil compared with the motor oil (see Fig. 6).

As in the case of motor oil test, four different loads are applied in transmission oil tests with loaded bearings. The duration of the test for each load is also 10 minutes. Oil temperature and moment of friction are measured for each load and are presented in Figs. 10 and 11. Calculated values of the corresponding coefficient of friction, for each load, are shown in Fig. 12.

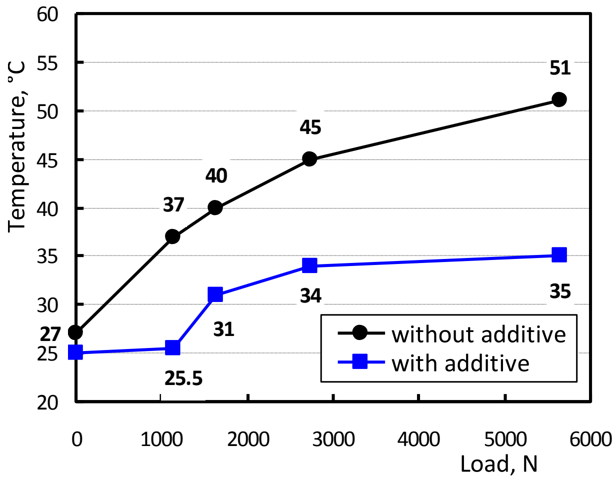


Fig. 10: *Variation of temperature of oil TM-5-18 in bearing during friction with different loads*

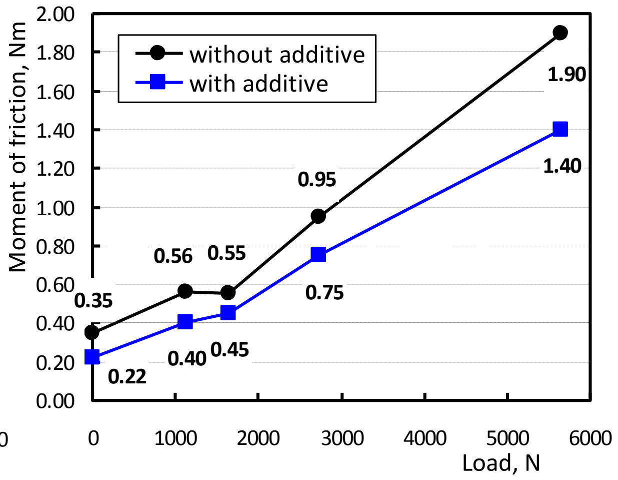


Fig. 11: *Variation of moment of friction in bearing during friction with different loads*

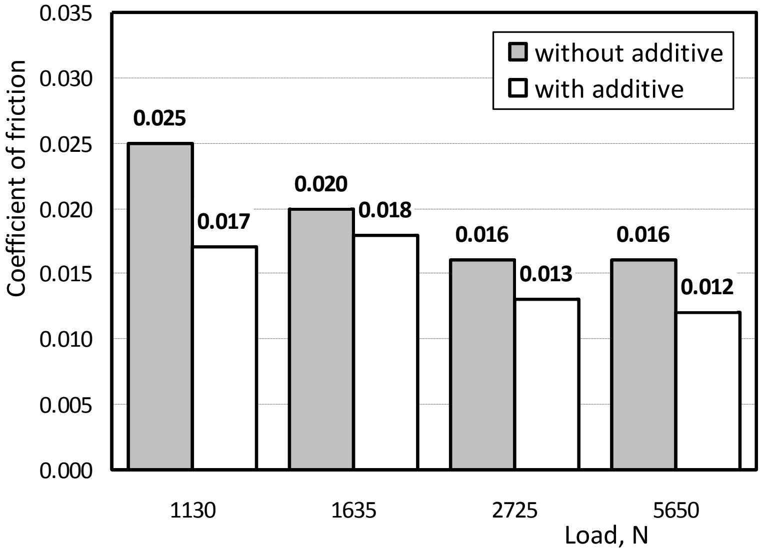


Fig. 12: *Dependence of the coefficient of friction on load for transmission oil TM-5-18 without and with additive*

From Figs. 11 and 12 it is obvious that the values of the moment of friction and coefficient of friction are for each load lower in the case of transmission oil that contain “Valena” additive. Fig. 11 shows that the moment of friction increases with the increment of the normal load, and the relationship is non-linear. The differences between moments increase with the augmentation of load. The reduction of the coefficient of friction by using “Valena” additive differs (from 10 to 32 %) with the applied load, and the average reduction is 21.4 %.

The results for oil temperature measurement (Fig. 10) show that in the case of transmission oil with additive the temperature increases only 10 °C from unloaded to fully loaded conditions, while in the case of transmission oil without additive temperature increases 24 °C for the same load increase. This suggests that the decrease of moment friction and coefficient of friction in the case of transmission oil with “Valena” additive, similar to the case of motor oil with “Valena” additive, is not due to oil viscosity reduction at higher temperature, but due to the physic-chemical surface effects in the contact region during friction. Although it was not measured the wear of the balls and rings might be also decreased by the presence of additive, because of the positive effect of the additive on friction properties.

After dismantling, the presence of thin reddish film on shaft surfaces was observed. The composition, structure and thickness of this film were not exanimate in this investigation, but it seems logical to suggest that this film has been formed during friction, due to physic-chemical and mechanical processes of selective transfer of copper on the steel shaft surface. The metal-plating additive “Valena” contains copper ions which are possibly transferred on the shaft under the specific conditions of the experiment. The formed film compensates the roughness on the surface, and due to the small tangential resistance it makes the plastic deformations during friction in the surface layers easier.

5. CONCLUSION

The influence of “Valena” metal-plating additive on friction properties of ball bearings is studied in two cases, i.e. with motor oil and with transmission oil lubrication.

In both cases the values of the moment of friction and coefficient of friction are for each load lower in the case of oil that contain “Valena” additive.

The reduction of the coefficient of friction in the case of motor oil was app. 18 %, and in the case of transmission oil app. 21 %.

The results for oil temperature measurement confirmed that the decrease of moment friction and coefficient of friction in the case of oil with “Valena” additive is not due to oil viscosity reduction at higher temperature, but due to the physic-chemical surface effects in the contact region during friction.

The obtained results stimulate a future systematic study of the influence of “Valena” additive on friction, wear and other tribological process in tribosystems operating under various conditions and various characteristics, i.e. additive concentration, composition and structure of the contacting surfaces; the parameters of friction regime: loads, sliding speeds, presence of particles, vibrations, temperatures, lubricant availability (lubricity) in different friction regimes, etc.

ACKNOWLEDGMENTS

This study embraces the completion of tasks under the following projects: (a) Program for scientific-technological collaboration of the Tribology center in TU-Sofia and the company “Rudservice” from Gezkazgan, Kazakhstan; (b) Stage 2 of the first tribological network under CEEPUS project CIII-BG-0703-02-1314 “Modern Trends in Education and Research on Mechanical Systems – Bridging Reliability, Quality and Tribology”; (c) International cooperation agreement between the Faculty of Industrial Technology at TU-Sofia and the Faculty of Mechanical Engineering at the University of Belgrade.

REFERENCES

1. MORTIER, R.M., FOX, M.F., ORSZULIK, S.T. (Eds.), Chemistry and Technology of Lubricants, 3rd ed., Springer, Dordrecht, 2010.
2. BHUSHAN, B. (Ed.), Modern Tribology Handbook, CRC Press, Boca Raton, 2001.
3. NICOLIS, G., PRIGOGINE, I., Self-organization in Nonequilibrium Systems, John Willey & Sons, New York, 1977.
4. ASSENOVA, E., KANDEVA, M., Self-organization in tribology: The role of synergism and selective transfer, in Proceedings of the 7th International Conference on Tribology – BALKANTRIB ’11, October 3 – 5, 2011, Thessaloniki, Greece, pp.305 – 310.
5. GARKUNOV, D.N., No-wear Effect Under Friction: Hydrogen Wear of Metals, MAA Publishing House, Moscow, 2007.
6. POLZER, G., Der Erfahrungsaustausch: Reibbeschichten und selective Uebertragung, Publ. Bezirks-Neuerer-Zentrum, Gera, 1988.

CORRESPONDENCE

Mara Kandeva
Technical University-Sofia, Faculty of Industrial Engineering, Tribology Center,
8, Blvd Kl. Ohridski,1156 Sofia, Bulgaria,
e-mail: kandeva@tu-sofia.bg

Aleksandar Vencl
University of Belgrade, Faculty of Mechanical Engineering, Tribology Laboratory,
Kraljice Marije 16, 11120 Belgrade 35, Serbia,
e-mail: avencl@mas.bg.ac.rs

Emilia Assenova
Society of Bulgarian Tribologists, 74B, G. Sofiiski St., 1606 Sofia, Bulgaria,
e-mail: emiass@abv.bg