

DYNAMICS OF CHANGE IN THE ROUGHNESS DUE TO FRICTION OF THE SLIDING SURFACES OF VIBROARC WELD OVERLAID COATINGS AGAINST STEEL AND CAST-IRON PARTS

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Abstract

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The dynamics of change in roughness due to friction of the sliding surfaces of vibroarc weld overlaid coatings against steel or cast-iron parts, has been established in the process of running-in and estimated wear. The vibroarc weld overlaid surfaces in gas mixtures on components made of cast-iron have higher equilibrium surface roughness which sets better conditions for the formation and retention of the oil layer.

Keywords: running-in, friction moment, coefficients of friction, steel and cast-iron parts, agricultural machinery

INTRODUCTION

During friction between sliding surfaces there is an undergoing process of running-in, which is accompanied by a change in the microgeometry of the friction surfaces. As a result the unevenness of the surfaces changes their shape, size and direction. Contrary to the original roughness, the unevenness following the running-in is directed in the direction of the sliding of the friction surfaces (Garkunov, 2002; Poltsner and Maysner, 1984).

For a long time the running-in was primarily connected with a change in the geometry of the surfaces within the range of wear, not exceeding the height of the initial roughness of these surfaces. It was believed that the process of increasing the bearing capacity practically coincides with the process of increasing the supporting surface at approximation of the friction surfaces, whereas the wear at running-in is described only in the gradual abrasion of the micro-roughness from top to bottom.

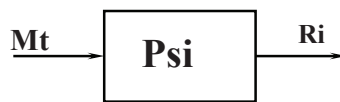
Aim of the Study

The aim of this study is to establish the change in roughness due to friction of the sliding surfaces of coatings restored by vibroarc weld overlay in gas mixtures against steel and cast-iron parts from tractors and agricultural machinery.

Subject and object of the study is the roughness of the restored components from tractors and agricultural machinery during friction at sliding in the process of running-in.

Exposition

The microgeometry of the surfaces following the running-in is characterised by rule with random nature of the profile height. As a result of the running-in the roughness of the working surfaces reaches a certain equilibrium value characteristic for the given conditions of friction and wear. The physico-mechanical properties of the surface layers also change as a result of the plastic deformation. The roughness due to



1: Model for studying the process of running-in and wear of weld overlaid coatings during friction at sliding: M_t is the material of the friction pair, R_i – vector of the parameters of the roughness of the friction surfaces of the pair

friction of the sliding surfaces changes not only due to the deformations but also due to the wear of the tips of micro-roughness.

The material of the friction surface of the restored by vibroarc weld overlay steel and cast-iron parts from tractors and agricultural machinery served as an input factor of the test model for studying the process of running-in and wear during friction at sliding (Fig. 1) (Kangalov, 2012; Tonchev and Stanev, 1979). Three materials of the friction surface of the roller were tested, steel 45, hardened and vibroarc weld overlaid with DUR500, as well as cast-iron ENGJL200 vibroarc weld overlaid with Sv 08G2S.

The pair ‘roller-sector’ was taken as a physical model of the friction compound ‘shaft-bearing’ with the respective parameters of physical and geometrical similarity. The parameters of the test specimen have been chosen with structural features selected on the basis of statistical survey of the parts from tractors and agricultural machinery (Tonchev and Stanev, 1979).

The restored samples are made of St45 weld overlaid with wire electrode DUR500 in gas mixture of argon and carbon dioxide in the following composition: 60% Ar and 40% CO_2 and grey cast-iron ENGJL200 weld overlaid with wire electrode Sv 08G2S in gas mixture of 50% Ar and 50% CO_2 , (Nikolov, Tonchev and Todorov, 2003) 1.6 mm in diameter, with high hardness of the weld overlaid surface without cracks after being hardened with HFC. The weld overlay has been carried out on a system with an inertia axial vibroarc apparatus “ENTON-60” with a nozzle for shielding gases in the following mode: working voltage 20 V, amperage 180 A, speed of weld overlay 1.26 m/min, wire feed speed 2.3 m/min, pace of weld overlay 3 mm, outlet of wire electrode 15 mm, shielding gas expenditure 15 l/min, frequency of vibrations 46.7 Hz.

The patterns and the weld overlaid samples have been processed thermally and mechanically. They have been hardened under heating by HFC to reach hardness of 55^{+2} HRC ($\text{HV}_5 = 6100^{+400}$ Hv) and then polished to their ultimate size by using special methods, followed by making rollers out of them for testing. The rollers have a diameter of the friction surface of $50^{+0.02}$ mm, misalignment and nonperpendicularity of no more than 0.01 mm, width $12^{+0.05}$ mm, thickness of the weld overlaid coating of 0.5 mm along radius with roughness $R_a = 0.28\text{--}0.32\text{ }\mu\text{m}$ for the steel parts weld overlaid with DUR500, and $R_a = 0.58\text{--}0.64\text{ }\mu\text{m}$ for the cast-

iron ones weld overlaid with Sv 08G2S with a mass of 160–170 g.

The sectors of the friction pairs are bimetallic with a steel base, which is covered with anti-friction layer of BO-30 with hardness of $\text{HV}_5 = 490^{+50}$ MPa and thickness of 0.1–0.5 mm along the radius. The length of the friction surface of the sector is 20 mm, width $10^{+0.05}$, and the area of the support surface is 2 cm^2 and a pass of 15–20 g. Before cutting the bearing rings with a central angle of 46° , from which the sectors are made, the outer surface is polished to reach a diameter of $70^{+0.1}$ mm, and the inner surface of the bearing rings is ground to a diameter of $50^{+0.06}$ mm with roughness $R_a = 2.0\text{--}2.8\text{ }\mu\text{m}$. The clearance of the pair has to be 0.04–0.05 mm in order to achieve an even running-in with the necessary oil wedge.

The pair steel 45 and leaded bronze BO-30 was adopted as a pattern for the running-in, since they are the most common materials for the manufacturing of sliding bearings in tractors and agricultural machinery. For comparison the running-in in the pair of restored coatings on St45 and grey cast-iron ENGJL200 with BO-30 was used. The running-in and the wearing of the pattern pair and the restored pair was done in oil SEA 30.

For evaluation of the process of running-in and wearing of the friction of the sliding surfaces, the vector of the parameters of roughness was adopted (average roughness of the roller and the section, roughness of the input and output of the sector, as well as the change in roughness along the length of the sector).

The study has been carried out on a friction and tear testing machine SMC-2, improved with various systems and devices for the supply of conditions of friction and wear that are close to the operating ones. For the precise measuring of the tribotechnical characteristics a special water-cooled chamber has been designed, of small volume for friction and tear in the conditions of liquid lubrication with 150 ml volume, together with systems for cooling of the chamber, maintenance of constant temperature of 40°C , typical for cold launches of the new and restored engines of tractors and agricultural machinery, a system for constant stirring of the lubrication fluid and magnetic cleaning of the products of wear. The testing is done according to the ‘roller-sector’ scheme at rotation speed of 540 min^{-1} , providing relative speed of sliding of 85 m/min. The load of the friction pair was done steplessly at a speed of 1 MPa/min, clamping force of the sectors against the rollers of 100 daN, which provides a pressure of 5 MPa and tribotechnical characteristics $\text{PV} = 425\text{ MPa.m/min}$. These values have been chosen in compliance with the requirements regarding the permissible values for sliding bearing.

In the process of running-in and wear of the masters the following parameters were measured and recorded: the duration of every testing, the temperature of the oil, rotation speed

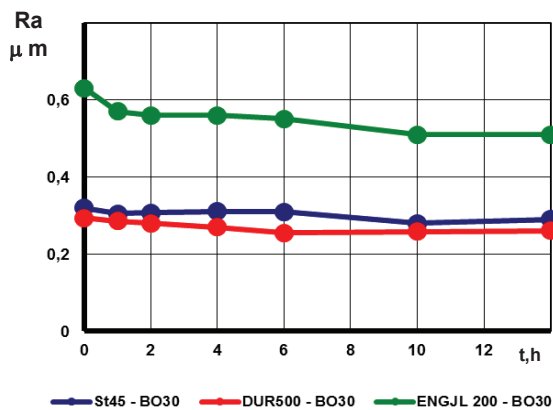
as well as the total revolutions of the roller. Before and after each testing the roughness of the friction surfaces of the roller and the sector was measured. The roughness was determined according to the average deviation from the mean line of the profile of the micro-roughness (R_a , μm) with profilometer of the "Caliber" model 283 type in four sections for the roller and five for the sector.

The test results are represented by graphical relationships (Figs. 2–6), which show the dynamics of change in the roughness of the friction surfaces of the roller and the sector.

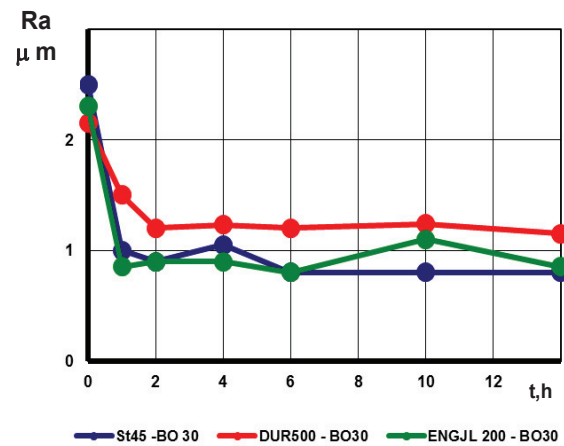
It is known that in the process of running-in and wear the contact interactions of the friction surfaces are of great importance (Garkunov, 2002; Poltsner and Maysner, 1984). The running-in is related to a greatest extent to the geometry of the friction surfaces within the limits of wear, not exceeding the height of the initial roughness of the surfaces.

The change in roughness of the pattern and restored steel rollers (Fig. 2) is equidistant and the value of the equilibrium roughness depends on the initial roughness of the friction surfaces. The initial and the equilibrium roughness of the restored cast-iron roller is higher than that of the steel one.

In the process of running-in and wear it has been established that the roughness of the steel rollers, the master and restored ones, decreases insignificantly from $R_a = 0.30\text{--}0.32\mu\text{m}$ to $R_a = 0.29\text{--}0.26\mu\text{m}$ compared to the roughness of the friction surface of the restored cast-iron roller from $R_a = 0.63\mu\text{m}$ to $R_a = 0.51\mu\text{m}$. The roughness of the restored cast-iron roller decreases significantly in the process of running-in during the first two hours from $R_a = 0.63\mu\text{m}$ to $R_a = 0.56\mu\text{m}$. The work surface of the steel rollers is run-in faster and the equilibrium roughness is established faster after the first hour of the test, whereas the cast-iron roller is run-in till the sixth hour. The lower equilibrium roughness of the weld overlaid and the master surfaces of the rollers $R_a = 0.26\mu\text{m}$ compared to the equilibrium roughness of the weld overlaid



2: Change in roughness of the roller with a different material of the friction surface
Source: own



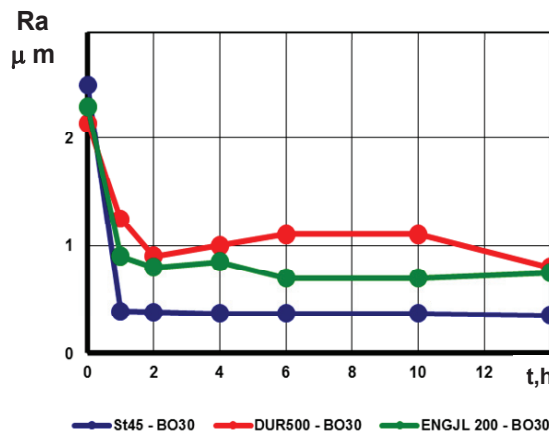
3: Change in roughness of the friction surface of the sector with different material of the surface of the roller
Source: own

cast-iron roller $R_a = 0.51\mu\text{m}$ leads to less wear in the process of running-in and established wear (Fig. 2).

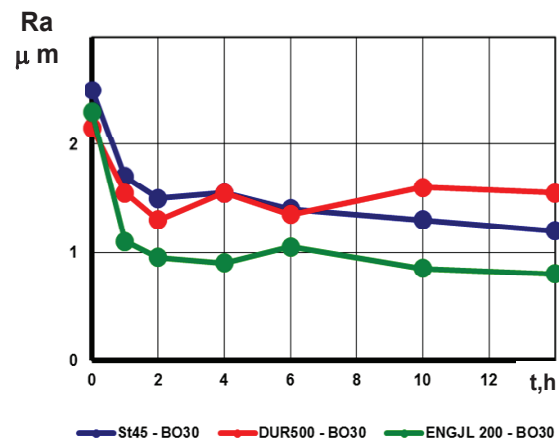
In the process of running-in and established wear the roughness of the sectors changes significantly with the roughness of the rollers (Fig. 2 and Fig. 3), due to the ten times lower microhardness of their surfaces. The roughness of the anti-friction layer of the sector (Fig. 3) for the three pairs decreases nearly twice for a short time in the process of running-in, from $R_a = 2.15\text{--}2.50\mu\text{m}$ to $R_a = 0.80\text{--}1.15\mu\text{m}$.

The running-in of the sectors for the three pairs happens within the first two hours. The establishing of the equilibrium roughness for the three pairs is done within this period of time, till the end of the testing the roughness stays nearly constant, and this is clearly evident in the weld overlaid roller. The equilibrium roughness of the sector of the pair with weld overlaid coating on the steel parts is the highest $R_a = 1.15\mu\text{m}$, whereas that of the sectors of the pattern and the cast-iron pairs is almost the same $R_a = 0.80\text{--}0.85\mu\text{m}$. Despite the higher initial roughness of the anti-friction layer of the master pair, its equilibrium roughness $R_a = 0.80\mu\text{m}$ is lower compared to the equilibrium roughness of the restored pairs $R_a = 0.85\text{--}1.15\mu\text{m}$. The higher equilibrium roughness of the pairs with a weld overlaid cast-iron roller creates better conditions for formation and retention of the oil layer, less wear in the process of running-in and established wear and greater wear resistance at the same microhardness of the work surfaces.

The difference between the equilibrium roughness of the sector and the roller is two and a half times bigger in the pair with the restored steel roller ($0.89\mu\text{m}$) than in the pair with the restored cast-iron roller ($0.34\mu\text{m}$). The difference with the master roller is ($0.51\mu\text{m}$). The smaller difference in the equilibrium roughness of the restored cast-iron pair means that the process of running-in and



4: Change in the roughness of the friction surface on the input of the sector with different material of the surface of the roller
Source: own



5: Change in the roughness of the friction surface at the outlet of the sector with different material of the surface of the roller
Source: own

wear is more intense with it than with the master and weld overlaid steel roller.

The equilibrium roughness of the friction surface at the input of the sector (Fig. 4) is established faster and at a lower level with the master pair ($R_a = 0.35 \mu\text{m}$), and the value is 7 times lower than the initial roughness ($R_a = 2.50 \mu\text{m}$), and the equilibrium roughness is established after the second hour, as it is with the friction surface of the roller in this pair. With the restored pairs this decrease is nearly 2.5 times smaller, while the equilibrium roughness of the surfaces at the input of the sector is twice bigger than that of the master pair (Fig. 4).

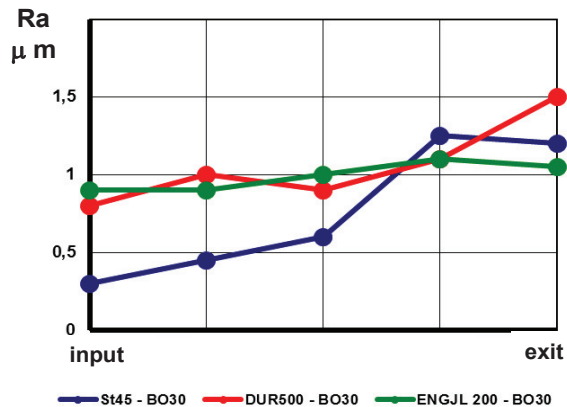
The equilibrium roughness of the friction surfaces at the output of the sector $R_a = 1.20 \mu\text{m}$, for the master pair is 3.5 times bigger than the equilibrium roughness at the input of the sector. This difference between the input and output of the sector of the restored steel roller is two-fold, whereas the equilibrium roughness at the input and output of the sector in the pair with the restored cast-iron roller are almost equal $R_a = 0.80 \mu\text{m}$ (Fig. 5).

The difference in the equilibrium roughness at the output of the sectors for the restored pairs (Fig. 4) is bigger than that at the input of the sectors for the restored pairs (Fig. 5).

The increase of the equilibrium roughness along the length of the sector (Fig. 6) is the greatest with the master pair ($R_a = 0.30\text{--}1.20 \mu\text{m}$). The change of the roughness along the length of the sector is bigger with the restored pair with the steel roller ($R_a = 0.80\text{--}1.50 \mu\text{m}$), whereas with the cast-

iron one, the roughness along the whole area of the sector „input-output” is almost the same ($R_a = 0.90\text{--}1.05 \mu\text{m}$) Fig. 6. This shows that the running-in along the whole length of the sector with the restored cast-iron roller is complete for the period of the experiment.

The running-in of the surface at the input of the sector happens much faster than that at the outlet, which is explained with the different hydrodynamics of the friction and wear of the input and output surfaces and this tendency is better expressed for the sector in the master pair (Fig. 6).



6: Change in the roughness along the length of the friction surface (input-output) of the sector with different material of the surface of the roller
Source: own

CONCLUSION

1. The friction surface of the shaft of the steel weld overlaid roller and that of the pattern roller have lower equilibrium roughness than that of the weld overlaid cast-iron roller, which is an indicator of their quicker running-in.
2. The difference between the equilibrium roughness of the sector and the roller in the pair with the restored steel roller is two and a half times bigger compared to the restored pair with the cast-iron roller. The higher equilibrium roughness of the pair with the weld overlaid cast-iron roller creates better conditions for formation and retention of the oil layer.

3. The equilibrium roughness of the friction surface at the input and output of the sector is established the fastest and at a lower level in the master pair. ($R_a = 0.35 \mu\text{m}$).
4. The equilibrium roughness at the output of the sector is the lowest ($R_a = 0.80 \mu\text{m}$) in the pair with the restored cast-iron roller, and the running-in along the whole length of the sector happens faster.

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