# A RESEARCH ABOUT COEFFICIENT AND MOMENT OF FRICTION DURING INTERACTION OF DEPOSITED LAYERS OBTAINED THROUGH INCREASED WIRE ELECTRODE VIBRATING FREQUENCY

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***Abstract**: The article presenting a results about dynamics of moment and coefficient of friction change is established by experimental research of applied layers upon steel parts through vibrating gas metal arc overlaying process with increased wire electrode vibrating frequency. It was established that increasing of the vibrating frequency at rate of 150 Hz leading to significantly shorter time for interaction of both surfaces to obtain a process of established wear.*

**Keywords**: running-in, coefficient of friction, iron and steel parts; agricultural machinery; overlaying

## Introduction

The interaction of frictional surfaces appears to be one of the most important stages of the process of reconditioning causing a significant influence to the durability of the automotive and agricultural equipment. Basically, it is a non-stable process of alteration of tribological characteristics, geometrical parameters, physical and chemical properties of the applied layers during friction (Garkunov, 2001). One of the main tribological characteristics is the moment of friction because of its intensive alteration during friction and it is an important criteria at point of process's evaluation.

The aim of the research is an establishing of alteration of the tribological characteristics – moment and coefficient of friction obtained during process of friction of applied layers within vibrating gas arc overlaying process.

## Exposition

A frictional pair "roller-sector" with an appropriate geometrical and physical parameters is accepted as a physical model of the real frictional pair "shaft-bearing". The parameters of the frictional pair are determined by statistical analysis about reconditioning of worn parts from automotive and agricultural equipment (Tonchev and Stanev, 1979).

The material of frictional pair is accepted as main variable of the process of interaction during sliding friction as there were three different frictional rollers – a roller made of steel grade 45 without applied layer; a roller made of steel grade 45 with applied layer of 30HGSA through wire electrode's vibrating frequency at rate of 47,6 Hz and rolled made of steel grade 45 with applied layer of 30HGSA through wire electrode's vibrating frequency at rate of 150 Hz. The material of specimens is chosen in relation to the most used materials for details of agricultural and automotive equipment – steel grade 45 and lead bronze BO30.

The treated rollers of Steel 45 has a deposited layers with 30HGSA wire electrode with diameters of 1,6 mm within vibrating frequency of 150Hz quenched by conducted current at high frequency. The overlaying process is done through ENTON 60 overlaying apparatus and modified overlaying apparatus. The working regime parameters were accepted as follow – wire electrode's vibrating frequency at rate of 150 Hz; amplitude at rate of 1,7 mm; voltage of 20V; welding current of 180A, welding speed of 2,51 m/min; wire electrode feeding rate of 2,0 m/min; welding pace rate of 3,25 mm; wire electrode outlet rate of 15 mm; shielding gas rate of 10 l/min [TODOROV and NIKOLOV, 2012].

The standard and overlayed rollers were mechanically and thermally treated. They were quenched and retorted to hardness of 55±2 HRC (HV5 = 6100±400 MPa) and grinded to final rate. The rollers are with diameter of 50+0,02 mm; misalignment and unperpendicularity not more than 0,01 mm; width of 12+0,05 mm; thickness of the applied layer of 0,5 mm measured on the radius; roughness Ra = 0,28...0,32 μm for overlayed with DUR 500 roller and Ra = 0,55...0,58 μm for overlayed with 30 HGSA roller. The weight of the rollers is varying between 160 and 170g.

The sectors are made of steel with applied anti-frictional layer of leaden bronze BO-30 hardened at rate of HV5 = 490±50 MPa and thickness of 0,1…0,5 mm measured along the radius. The length of the frictional area of the sector is 20 mm with a width of 10+0,05 mm. The surface area of contact is 2 $cm^2$ and the weight of the sectors is varying between 15 and 20 g. The outer surface of the sectors is grinded to diameter of 70+0,1 mm as well as the inner surface - to diameter of 50+0,06 mm. The roughness of the sectors is measured at rate of Ra = 2,0...2,8 μm. The radial distance between the roller and sector is at rate of 0,04...0,05 mm.

The moment of friction is accepted as main criteria for evaluation of the processes of interaction and wear as three of its components are established during experiments – a moment of friction at the end of loading; a moment of friction during interaction of the frictional surfaces and moment of friction at the end of the experiments. A coefficient of friction as secondary criteria for evaluation is accepted.

The examination is taken on a standing machine SMC-2 equipped with an appropriate systems and devices to ensure working conditions similar to the operational. A cooling oil camera with a capacity of 150 ml is used to control the oil temperature at rate of 40°C that is typical for "cold" interaction of new or reconditioned engines as well as system for oil mixing and magnetic cleaning of wear products. The examination is taken on "roller-sector" scheme within following working regime: roller turnovers cycle rate of 540 $min^{-1}$; relative sliding velocity at rate of 85 m/min; loading of the frictional pair at rate of 1 MPa/min; pressing force of sectors to the rollers at rate of 100 daN; pressure at rate of 5 MPa and tribological characteristic PV at rate of 425 MPa..m/min.

The alteration of the moment of friction is controlled and recorded continuously by inductive sensor placed between spindle and reducer. The signal is being transformed by controlling plate that measuring the difference in the voltage value at both coils of the sensor. The registration and recording of the signal is done by multifunctional device NI-USB 6210 connected to personal computer. The results of the experiments are being recorder in *xls document as its further calculation is done through Microsoft Office Excel.. The moment of friction is being recorded continuously and presented graphically and digitally on the screen.

The results of the experimental research are presented graphically at figures 1 to 4 which showing the alteration of the moment and coefficient of friction during process of interaction and wear of the frictional surfaces. The interaction of frictional surfaces is characterized by moment of friction at the end of loading as its value determines the ability of the surface against excessive wear and blocking. The alteration of this parameter is shown at fig.1.

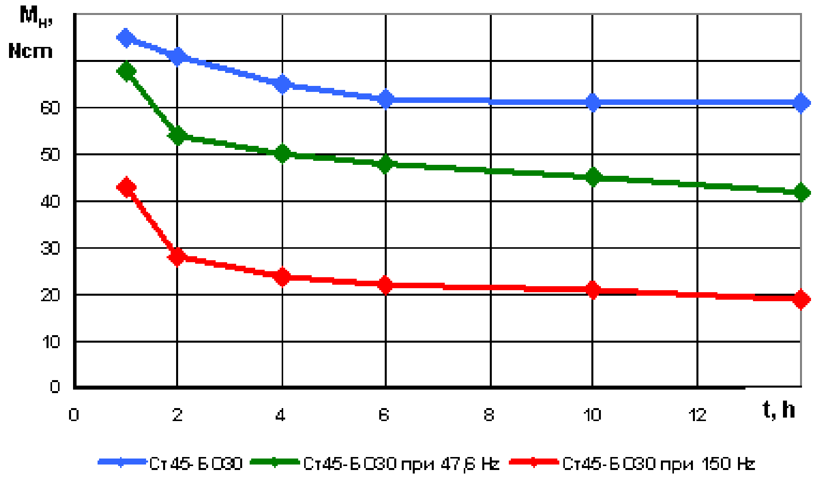


***Figure 1*** *Dynamics of alteration of the moment of friction at the end of loading during interaction of standard and overlaid frictional pairs within sliding friction conditions.*

As it is shown at fig.1, the initial alteration of the moment of friction has a steep character during the first two hours of the examination for both overlaid pairs explained by lower roughness of their surfaces compared to the standard one. Also, the moment of friction reduces its value almost double that is criteria about fluent process of interaction and established wear of the frictional surfaces. The overlaid pairs are characterized by lower values of the moment of friction which is a sign about better interaction with the material of the sector. The lowest value of the moment for the pair overlaid at rate of 150 Hz showing that increasing of wire electrode's vibrating frequency decreases the moment of friction nearly 2,5 times. Therefore, the coefficient of friction decreasing as well as possibility of excessive wear on the frictional surfaces. The moment of active interaction is basically a difference between values of both – moment of friction at the end of loading $M_н$ and moment of friction at the end of examination $M_к$. Its alteration is shown at fig.2.

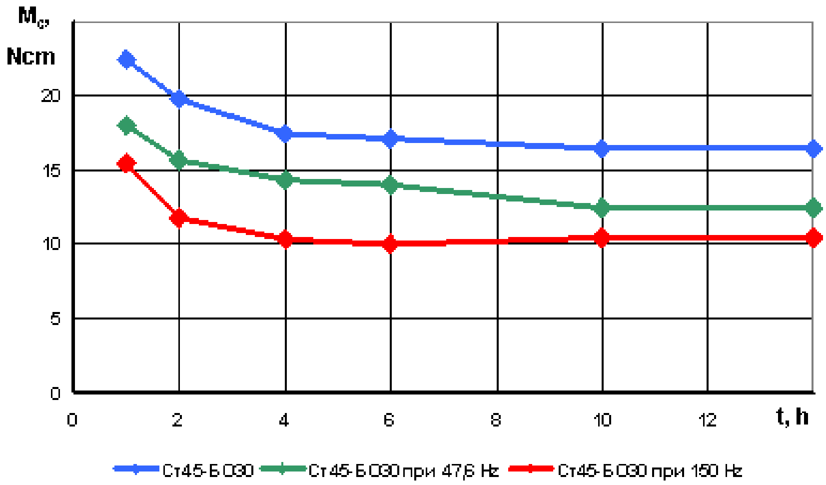


***Figure 2*** *Dynamics of alteration of moment of active interaction during interaction of standard and overlaid frictional pairs within sliding friction conditions.*

As it is shown at fig.2 all of the pairs has similar character of alteration as it is most intensive within the first few hours. The standard pair has higher alteration of the moment of friction during interaction in comparison to both overlaid pairs as its interaction takes around 10 hrs. Obviously, the process of interaction of the pair overlaid with wire electrode vibrating frequency at rate of 150 Hz is done within first 4 hrs followed by process of established wear judging by insignificant alteration of the moment of active interaction from 4-th till 14-th hours – at rates of 10,2 to 10,5 Nm.

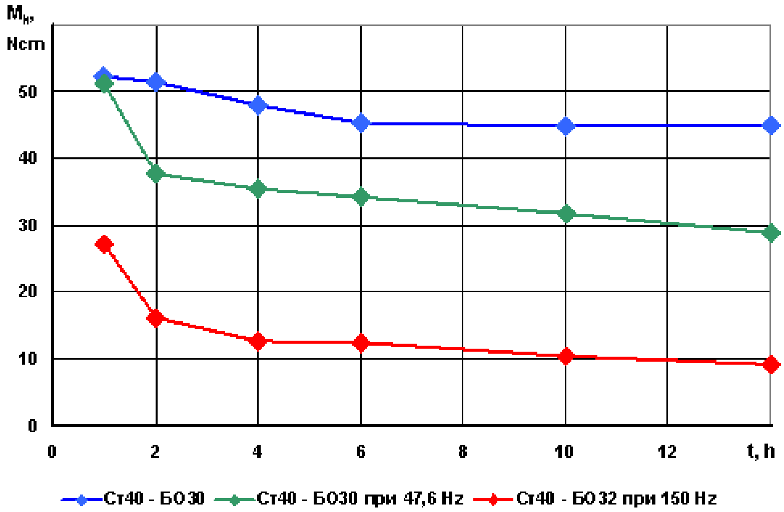


***Figure 3*** *Dynamics of alteration of moment of friction at the end of examination during interaction of standard and overlaid frictional pairs within sliding friction conditions.*

The alteration of the moment of friction at the end of the examination $M_k$ is show at fig.3 as there is trend to its decreasing for all 3 pairs. As it is shown, the moment of friction for the pair overlaid at rate of 150 Hz decreasing steeply within the first 4 hrs followed by insignificant alteration to the end of examination at rates of 12,3 to 9,8 Nm. The lower values of the moment of friction at the end of examination compared to the ones for the moment of friction at the end of loading could be considered as criteria about the process of interaction because of its fluent transition into process of established wear.

The coefficient of friction $f$ during interaction was accepted as secondary criteria for process evaluation. Its value is determined through the following formula:

$$f = \frac{M_c}{N.r},$$

$M_c$ – moment of friction during interaction, Ncm; N – applied loading, N; r – radius of the roller, cm

*The values of the coefficients of friction during interaction are presented at table 1.*

| parameters | frictional pairs | duration of the experiments, hrs | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 4 | 6 | 10 | 14 |
| $M_c$, N.cm | St.45-BO30 standard | 22.8 | 20 | 17.7 | 17.3 | 16.8 | 16 |
| | St.45-BO30 at 47,6 Hz | 18.1 | 15.5 | 14.3 | 14 | 12.5 | 12.5 |
| | St.45-BO30 at 150 Hz | 15.4 | 11.8 | 10.2 | 9.9 | 10.1 | 10.1 |
| $f_c$ | St.45-BO30 standard | 0.009 | 0.008 | 0.007 | 0.006 | 0.006 | 0.006 |
| | St.45-BO30 at 47,6 Hz | 0.007 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 |
| | St.45-BO30 at 150 Hz | 0.006 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 |

**Conclusion**

1. The applied layers obtained through vibrating gas arc overlaying process with wire electrode vibrating frequency at rate of 150 Hz passing into process of established wear according insignificant alteration of the moment of active interaction from 4-th till 14-th hours at rates of 10,2 to 10,5 Nm.

2. The pair overlaid at the mentioned rate of 150 Hz is characterized by almost 2 times lower value of the moment of friction at the end of loading in comparison to both – standard and overlaid at rate of 47,6 Hz pairs.

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