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EXAMINATION OF THE INFLUENCE OF THE CONSTRUCTIVE AND TECHNOLOGICAL PARAMETERS OF A TRIBOSYSTEM UPON THE ADHESION COMPONENT OF FRICTION

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1. INTRODUCTION

Improvement of the exploitation accuracy of the operational elements of production equipment depends to a great extent on their static, dynamic and thermal behavior. One of the major factors affecting the behavior of the operational elements is friction in the moving contacts. A major role for the formation of the force of friction the contact processes and the connected with them alternations of the surface contact volumes plays.

Under special conditions of exploitation (high surface pressures, vacuum, etc.), a substantial role in the precise performance of machine tools and equipment is played by the adhesion component of the friction force.

Study of the contact processes and the connected with them phenomena is a substantial precondition for improvement of the static and dynamic behavior of machine tools and equipment.

2. PURPOSE OF THE WORK

Determing the comprehensive influence of the major construction-technological parameters of the system on the adhesion component of the force of friction, for a friction couple "brass – brass" is the purpose of the current investigations.

In order achieve this purpose to the following tasks are completed:

1. Methodology for experimental research of the adhesion component of the force of friction.
2. Experiment planning and experimental results.
3. Analysis of the obtained results, conclusions and recommendations.

3. METHODOLOGY FOR EXPERIMENTAL RESEARCH

A methodology for investigations was created, explained in [1] in order to ful fill the experimental research of the adhesion component of the force of friction. For the experiment was designed and produced an experimental stand, exhibited in fig.1. The experimental stand enables the major factors affecting the adhesion component of the force of friction to be altered independently of each other.

From the single-factor experimental research, it was determined that upon the adhesion component of the force of friction is influenced mainly by the following factors:

N – external active load force, normal to the contact surfaces;

R_A – unevenness of the contact surfaces;

V - velocity of relative motion of the body and the counterbody of the tribosystem;

S - contact surface area;

t - time period of motionless contact.

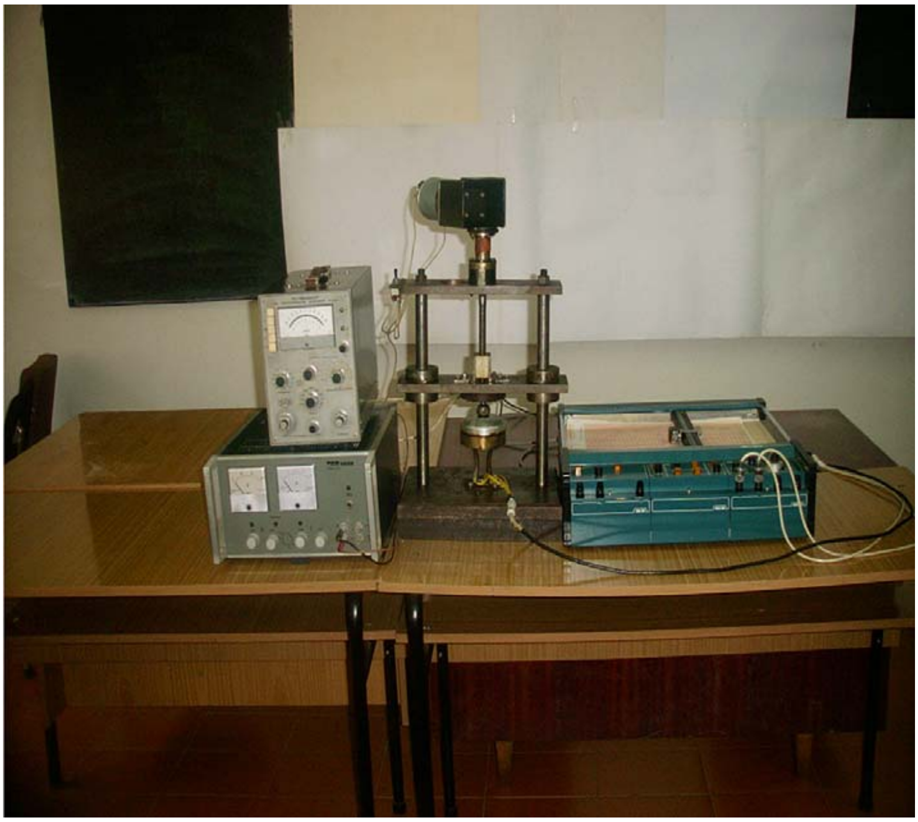

Fig.1: *Experimental stand for research of the adhesion component of the force of friction.*

In order equivalence of the experimental research to be achieved it was conducted under the following conditions:

1. Friction couple “brass – brass”.
2. Cleaning and skimming of the contact surfaces of the examined samples.
3. Experiments are conducted at an environmental temperature of - 20º ±1ºC.
4. For each experiment is repeated 20 times to be verified.
5. Removal of the contrasting aberrant cases, i.e. great mistakes is conducted by the Rank analysis by the Showine criteria.

Samples are flat cylindrical bodies with contact surfaces of type “plane – plane”,
which dimensions are conformed to the over all dimensions of the experimental stand. The nominal surface area of contact of the samples is $S=77.\ 10^{-3},\ m^2$.

4. EXPERIMENT PLANNING AND EXPERIMENTAL RESULTS.

Current research is conducted in order to be studied the dependency of the adhesion component of the force of friction on the comprehensive influence of the major factors of a tribosystem, i.e. to be studied the equation:

$$F_A = (N, R_a, V), \quad (1)$$

where N - external active load force, normal to the contact surfaces, *daN*;
R_a - unevenness of the contact surfaces,*m*;
V – velocity of relative motion () of the body and the counterbody of the tribosystem, *m/s*.

In order this equation to be found, a full factor experiment of the 2^3 type was planned [3]. In table1 levels and values of factors alternation are given, in table2 is given the matrix of the experiment planning and experimental results.

Table 1

Factors	Level			Alternation range	Dimension
	+1	0	-1		
N Ξ X_1	150	87,5	25	62,5	daN.
Ra Ξ X_2	10	5,05	0,16	4,9	μm
V Ξ X_3	0,002	0,0013	0,0006	0,0007	m/s.

Table 2

Experiment number	Experiment planning							
	X_0	X_1	X_2	X_3	X_{12}	X_{13}	X_{23}	X_{123}
1	+	+	+	+	+	+	+	+
2	+	-	+	+	-	-	+	-
3	+	+	-	+	-	+	-	-
4	+	-	-	+	+	-	-	+
5	+	+	+	-	+	-	-	-
6	+	-	+	-	-	+	-	+
7	+	+	-	-	-	-	+	+
8	+	-	-	-	+	+	+	-
B_i	B_0= 73.10^{-3}	B_1= $2,8.10^{-3}$	B_2= $30,9.10^{-3}$	B_3= $-52,3.10^{-3}$	B_{12}= $-1,9.10^{-3}$	B_{13}= $-2,1.10^{-3}$	B_{23}= $19,6.10^{-3}$	B_{123}= $1,4.10^{-3}$

Statistical processing of the experimental results

After verification by the G – criteria of Kohren, the uniformity of a number of the dispersion of the experiment was determined. The calculated values of the regression coefficients B_i are given in table2.

The verification of the statistical significance of the regression coefficients by the t – criteria of Student proved only the $b_{13}.=1,56$ coefficient insignificant, therefore the regression equation for friction couple "brass – brass" is as follows:

$$Y = (73,38 + 3,44.X_1 - 29,69.X_2 - 51,25.X_3 - 1,88.X_1X_2 + 20,94.X_2X_3 + 1,88.X_1X_2X_3).10^{-3} \quad (2)$$

The regression equation adequateness is proved by the F- criteria of Fisher. Since

$$F_{изч} = 2,995 < F_T = 4,3$$

Therefore the equation is adequate.

Model analysis

The relative influence of the three factors (N, R_a, V), on the process result (F_A), is determined by the ratio of the regression equation coefficients B_i, to the alternation range of each factor X_i:

a) relative influence of the first factor $X_1 = N$:

$$Y_1 = \frac{B_1}{\Delta X_1} = \frac{3,44.10^{-3}}{62,5} = 0,055.10^{-3}$$

The sign (+) of the B_1 coefficient proves straight dependence between the adhesion force F_A and the first factor N – normal load force to the contact surfaces;

б) relative influence of the second factor $X_2 = R_a$:

$$Y_2 = \frac{B_2}{\Delta X_2} = \frac{-29,69.10^{-3}}{4,9} = -6,06.10^{-3}$$

The sign (-) in front of the coefficient B_2 shows an inverse dependence between the force of adhesion F_A and the second factor R_A – roughness of the contact surfaces;

в) relative influence of the third factor $X_3 = V$:

$$Y_3 = \frac{B_3}{\Delta X_3} = \frac{-51{,}25.10^{-3}}{0{,}0007} = 73214{,}29.10^{-3}$$

The sign (-) of the B_3 coefficient proves reverse dependence between the adhesion force F_A and the third factor V – velocity of motion of the body relative to the counter body of the tribosystem.
This proves that the function of the Function of responce (Function of regression) (adhesion force F_A) is influenced most significantly by the velocity of relative motion between the body and the counterbody, less significant is the influence of the surface quality and the least significant is the influence of the active external load force, normal to the contact surfaces.
After appropriate transformations the following real equation of the adhesion force derived from the simultaneous operation of the three factors for a friction couple "brass – brass" is obtained:

$$F_A = (227{,}35 + 0{,}141.\,N - 12{,}47.\,R_A - 1669{,}57.V - 0{,}017.\,N\,R_A - 0{,}74.\,N\,V + 88{,}97.\,R_A\,V + 0{,}146.\,N\,R_A\,V\,).10^{-3} \quad (3)$$

5. ANALYSIS OF THE OBTAINED RESULTS, CONCLUSIONS AND RECOMMENDATIONS.

In the three-dimensional space the Function of responce (Function of regression) is described by a spatial volumetric surface. On fig2 is shown the spatial surface describing the relation of the adhesion component (Y) from the normal pressure (X_1)) and the unevenness of the contact surfaces (X_2), at X_3=1; X_3=0 и X_3=-1. The figure proves that the minimal extremities of the function Y are obtained when X_3 tends toward upper level of (+1).

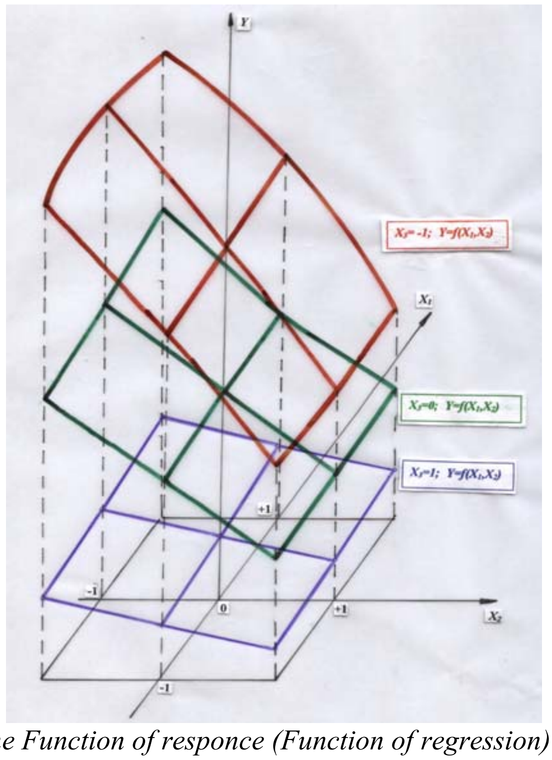

Fig2: *Spatial Surface of the Function of responce (Function of regression) Y at: Y = f(X₁,X₂); X₃=1; X₃=0; X₃=-1*

Similar surfaces are also obtained for the relations $Y=f(X_1,X_3)$ at $X_2=const$, and $Y=f(X_2,X_3)$ at $X_1=const$.

Two-dimensional cross sections of this surface with equal output, the so called isolines, are used to analyze the model. Fig.3 depicts a cross section with equal output of the response Y when

$X_1=f(X_2)$ and $X_3=+1$.

It can be seen from the figure that gradY_{min} , i.e. the minimum values of the function Y (F_a), is directed when X_1 gravitates to lower level (-1) and when X_2 gravitates to upper level (+1). Therefore, when the value of the normal force *N* decreases, and the value of the roughness of the contact surfaces R_a increases, the value of the adhesion force F_A (*Y*) decreases.

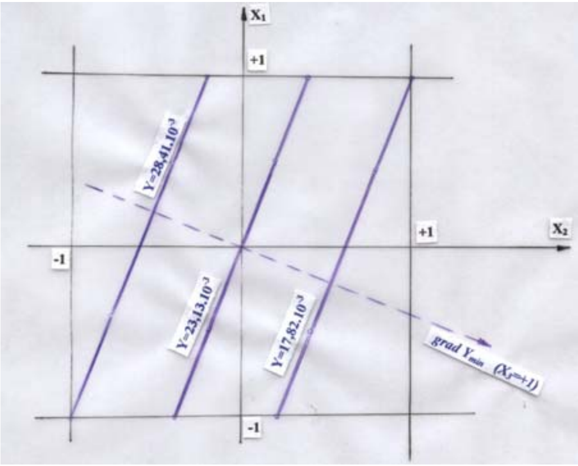

Fig. 3: *Cross section with equal output of the response Y (isolines) when Y = const; X_3= +1 u X_1 = f (X_2)*

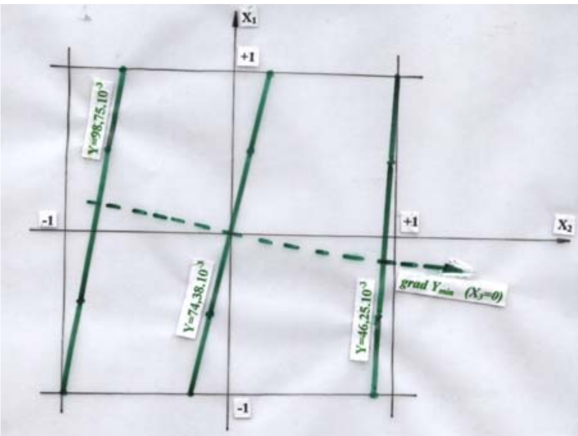

Fig.4: *Cross section with equal output of the response Y (isolines) when Y = const; X_3= 0 and X_1 = f (X_2)*

The isolines of $X_1=f(X_2)$ when $X_3=0$ an $X_3=-1$ are shown in fig.4 and fig.5 respectively. The two figures confirm the conclusion made above that *grad* Y_{min} is directed when X_1 gravitates to the lower level (-1) and X_2 gravitates to the upper level (+1).

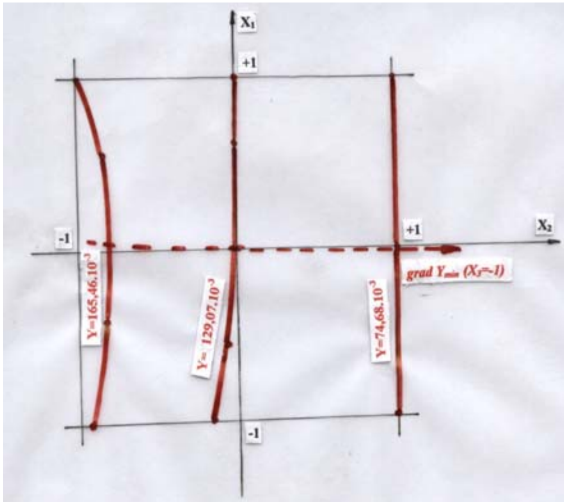

Fig.5: *Cross section with equal output of the response Y (isolines) when Y = const; X_3= -1 and X_1 = f (X_2)*

From the analysis of the three cross sections of the isolines (fig. 3, 4, 5) of the function of response and from the surface of the response (fig.2), the following conclusion can be made about the studied "brass-brass" friction couple: The minimal value of the adhesive component of the friction force, F_A, is obtained with the increase of the roughness of the contact surfaces R_A, increase of the velocity of motion *V* of the body in respect to the counter-body of the tribo-system and with the decrease of the external active loading force *N* which is normal to the contact surfaces. Therefore, the optimization of the parameters of a tribo-system, with the minimal adhesion component of the friction force being the optimization criterion, should be directed to decreasing the normal load, increasing the roughness of friction surfaces and increasing the velocity of motion.

6. REFERENCES:

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