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RESEARCH

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A Proposition of the Constructive Solution for Improvement of Tribological Characteristics of Eccentrically Loaded Slide Ways

With this work an attempt has been done to improve the tribomechanical systems fro guiding the eccentrically loaded elements, or, more precisely, for eccentrically loaded slide ways on machine tools.

By the proper choice of slide ways in machine tools, the friction can be decreased, and the accuracy of machining can be increased, so due to those reasons the special attention should be devoted to selection of the slide ways geometry and analysis of their stress state.

By theoretical analyses were conceived the new construction of eccentrically loaded slide ways. This construction ensures decrease of influence of the slider width upon the value of the friction force, namely the traction force, for any slider length.

Decrease of the slider's length to the minimum length means the possibility for significant increase of the working distance, or at constant working distance, it means decrease of the machine's weight and price, what directly has impact on material and energy consumption.

Keywords: *slide ways, eccentric load, friction*.

1. INTRODUCTION

Machine tools, by their presence in industry, represent the significant group of the complex machine systems. Each machine is required to have high productivity and reliability.

The most frequent reason for not achieving the required accuracy and quality of the machined surface is either direct or indirect consequence of wear of the contact surfaces of elements in the tribomechanical systems for guiding. Due to wear, clearances appear between those elements and the deviation occurs of real from the nominal trajectories of motion. This directly affects the machining accuracy.

Due the previously mentioned reasons in all machine tools the tribomechanical systems for guiding, have a special importance.

2. ANALYSIS OF THE STRESS STATE ON SLIDE WAYS

The proper selection of the slide ways of machine tools has an exceptional importance for the machining accuracy and quality of the machined surface. All faults, that are the consequence of clearances between the contact surfaces or deformations in the contact zone, directly affect the machining error. Related to that, the correct analysis of slide ways is of the exceptional importance.

In order to ensure mobility of slide ways the existence of clearance is necessary in sliding joints. Under the action of eccentric (moment) load the cross section of slide ways rotates for a certain angle □, Figure 1. The total angle of the cross section's free rotation can be expressed by the relation:

1.

Figure 1. Rotation of slide ways due to action of the moment load

By analysis of this expression one can come to indicators, which point to influence of the ratio between the slide ways size (*B/L*) and clearance size to magnitude of the angle of free rotation □. Results of such analysis, which is not presented here, indicate that the angle □ increases with increase of the (*B/L*) ratio within the constant clearance. It was also indicated that, within the constant ratio (*B/L*), at increase of clearance, the angle of free rotation also increases. When the angle □ reaches the critical value $□_{cr}$, the automatic braking of slide ways occurs.

Due to action of the moment load, the elastic displacement of points *P* to *P′* appears (Figure 2) in material in the vicinity of the contact of slider with the guiding elements. In Figure 2 is shown the position of the sliding pair ways - slider under action of the moment load *M*.

Figure 2. Rotation of the slider due to action of the moment load

Stresses on the contact surfaces represent the complex functions of the material characteristics and coordinates *x* and *y*. Starting from the assumption that the elementary displacements in the contact zones occur on the circular paths, one can come, via the elasticity theory, to distribution of stresses on the contact surfaces.

Since the stresses in the direction of the *z*-axis are negligibly small, the plane stress state will be considered of an element of the unit thickness. The magnitude of the elementary particles' displacements along the *x* and *y* axes are:

2

where:

3.

The magnitude of strains $□_x$ and $□_y$ are being determined as derivatives of displacements with respect to corresponding coordinates according to expressions:

4.

The total normal strain amounts to:

5,

while the shear strain (sliding) is determined according to expression:

6.

Based on the extended Hooke's law one can establish the relationship between the stresses and strains by relations:

7

where

8.

By given expressions the linear stresses are determined as functions of coordinates. After substituting the expressions by which the strains are defined, the above expressions obtain the following form:

9.

The force on the surface $dy \cdot 1$, balances the part of the moment load M, or the whole moment load, what depends on the magnitude of the load itself, Figure 3, so the moment equation can be established as:

10.

Figure 3. Normal and shear stresses on slide ways

By solving the system of the last three equations, the final expressions are obtained for calculation of stresses and contact surface $dy \cdot 1$ as functions of coordinates and the moment load:

11.

Theoretically speaking, the shear stresses are equal zero for the zero value of the coordinate *x*, namely for the zero value of the sliding ways width *B*.

This means that the constructive solution of the guiding system should be sought where the slide ways width *B* tends to zero in order to minimize the shear stresses, namely to ensure the smaller value of the friction force.

3. ADOPTION OF THE BASIC MODEL FOR ECCENTRICALLY LOADED SLIDER

For further investigations of the influence of the slide ways width *B* on the length *L*, the model of eccentrically loaded slider is adopted (for which was shown that the distance between slides does not affect appearance of the critical slider length L_k), shown in Figure 4.

Figure 4. The chosen model of eccentrically loaded slider

4. PROPOSITION OF THE CONSTRUCTIVE SOLUTION FOR IMPROVEMENT OF THE TRIBOLOGICAL CHARACTERISTICS OF ECCENTRICALLY LOADED SLIDE WAYS

Through recapitulation of the above discussion, one enters into conceiving the new construction of guiding of eccentrically loaded slide ways, whose correctness, and accordingly properness, is checked experimentally on, for that purpose specially constructed, device.

Figure 5. The basic model of eccentrically loaded slide ways

Namely, let us consider the basic model of eccentrically loaded slider of the straight-line slide ways, with coordinate system *x*, *y*, *z* placed at point *O*, where acts the traction force *F*, by which the slider moves, as shown in Figure 4. In order to better present the problem of reconstruction of thus set model, it should be observed in 3-D presentation as shown in Figure 5.

The slider is moving with velocity *v* along the slide ways due to action of the external traction force *F*, to which opposes the torque of force F_3 through its reactions F_N and $F_{N□}$.

By decreasing the slide ways length *L*, with other constant values, at one moment the automatic braking will occur. The traction force *F* depends on mutual interrelations of geometrical variables *L*and *B*, as well as the friction coefficient □.

In order to keep the traction force *F* below the threshold value of the driving engine, an attempt has been made to reconstruct the sliding surfaces of the slider, where it is expected to decrease the influence of the slider's width *B* upon the magnitude of the traction force *F* for any slider's length *L*, Figure 6.

Figure 6. The first version of reconstruction scheme of the slide ways slider shape

On the presented scheme with K_1 are denoted the contact surfaces of the slider with the slide ways, whose mutual distance is B_{k1}. By reconstruction of the slider along the slide ways, whose contact surfaces were K_2, K_3 and K_4, the mutual distance of the contact surfaces is decreasing, so they are:

12.

Reconstruction of the sliding surfaces can be performed also in another way, as shown in Figure 7.

Same as with the first version, in this case also decreases the value of B_{ki} starting from Bk1 to B_{k4}, when it is reached that $B_{k4} = 0$.

Estimates have shown that the second version of the slider reconstruction is more convenient for production, so the experimental part is realized with distribution of the sliding surfaces according to this version, where, for the case $B_{k4} = 0$, is expected that the slider's length *L* can arbitrarily be decreased without increase of the traction force *F*.

Figure 7. The second version of reconstruction scheme of the slide ways slider shape in the sense of decreasing the influence of slider's width B upon the value of the traction force F.

The appearance of the straight-line slide ways with sliders K_1, K_2, K_3 and K_4 is shown in Figure 8.

Figure 8. Characteristic examples of reconstructed eccentrically loaded slide ways

Figure 9. Appearance of realized sliders

Experimental investigations (due to restricted volume they are not presented in this paper) which are performed on specially designed and realized apparatus (Figure 10), have shown the significant decrease of the friction force in all the new versions of geometry of eccentrically loaded slide ways, and especially in slide ways denoted by K_4.

Figure 10. Apparatus for investigations of the slide ways

5. CONCLUSION

The general conclusion could be that for all the four cases of the varied geometries K_1, K_2, K_3 and K_4, the friction force F_t has the lowest value for the shape of K_4, where the width between the slide ways is decreased to zero.

The performed experiment has shown the significant improvements of the shape of slide ways K_4 with respect to K_1 for the more severe working regimes, for the cases of higher eccentric loads. Thus, for work with eccentric force of $F_e = 30\ daN$ the decrease of the friction force was achieved within limits from *28.2* to *32.0* %.

For different cases of the varied values of the sliding velocity from 2.5 to 12.5 *m/min* and eccentric load from *10* to *30 daN*, the percentage of the friction force decrease F_e, with respect to the most inconvenient shape of the slide ways K_1, and in favor of the shape of slide ways K_4, is within limits ± *l*□, from *25* to *32 %*.

By construction of eccentrically loaded slider K_4 and corresponding slide ways, is enabled the shortening of slider and extension of the useful working distance in machine, with decrease of the phenomenon of automatic braking of slider along slide ways.

6. REFERENCES