15th "International Scientific Conference"
RE & IT - 2016, SMOLYAN - BULGARIA

FACTORS AFFECTING THE ACCURACY OF POSITIONING OF RECTILINEAR MOTION SYSTEMS

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Abstract: *In the current paper in-depth theoretical investigations of factors affecting the accuracy of positioning of rectilinear motion systems into production machines are made. The results analysis of researches are particular importance for CNC machine tools.*

Key words: *static and dynamic behavior of the production equipment, tribology*

1. Introduction

The development of the machine building industry and the increase of the efficiency and the quality of the production, requires manufacturing of machine tools with high productivity, accuracy and reliability, with high static and dynamic indices.

To achieve these qualitative and quantitative indices of these technical characteristics a deployment of more in-depth research is required, including expand research to improve the smoothness of movement of the machine tool working bodies and increase the positioning accuracy and repeatability during (after) positioning.

The existence of self-induced oscillations (self-induced oscillations) in machine tools is usually linked to aggravation of the working process and decrease in the technical and economic indices. Therefore, self-induced oscillations in rotary moving and in rectilinear moving parts and systems are harmful phenomena affecting the machine production, , especially CNC machine tools, high-speed metal cutting machines and machine tools with parallel kinematics.

The current understanding of self-induced oscillations, which occur in different in their physical nature systems, is associated with three main components: a power source; a valve, regulating the energy input into the oscillation system and oscillation system itself. Typical for the self-induced oscillations is constant surge of energy on the input of the system and periodic movement of the output, i.e. self-induced oscillation cycles represent periodically uneven movement of the mechanical system when there are kinematic conditions for even movement.

Stick slip systems are irreversible systems. They are closed systems, i.e. there is feedback and therefore the interaction between their components is complicated: on one hand the valve controls the movement of the oscillation system, on the other hand the systems movement controls the operation of the valve.

All researchers of self-induced oscillations in machine production agree that the main cause of the oscillation is the friction in the moving contacts 1, 2, 3, 4, 5, 6, 11, 18, 19, 20, etc..

From the researches of various authors 7, 9, 10, 12, 13, 14, 15, 16, 17, etc. it is visible that the stability in motion direction, friction force, kinematic velocity and mass of the rectilinearly moving parts determines almost unambiguously the dynamic behavior of the machine tools. From the energy criterion 17, 21, 22, etc. it can be seen that the degree of influence of stability and friction force on the dynamic stability of the machine tool is highest. Issues, related to machine tools stability have initiated numerous studies 1, 25, 26, 2, 3, 8, 10, 12, 13, 14, 16, 23, 24, etc.. At the current stage of development of machine tools dynamic, the influence of stability on some important dynamic indicators such as system stability, smoothness of the movement, stock sustainability, etc. is already clear.

2. Factors influencing the position accuracy in rectilinearly moving systems

Position accuracy is one of the most important indicators of a machine tool. Position accuracy means the accuracy of approximation of the support to a preliminary point A relative to a fixed coordinate system OXY at a random direction of approximation (Fig. 1).

Quantitatively the position accuracy is given by the equation:

$$\Delta = l_{\delta} - l_{з} \quad (1)$$

where: l_{δ} is the actual positioning distance;
$l_{з}$ - set off positioning distance.

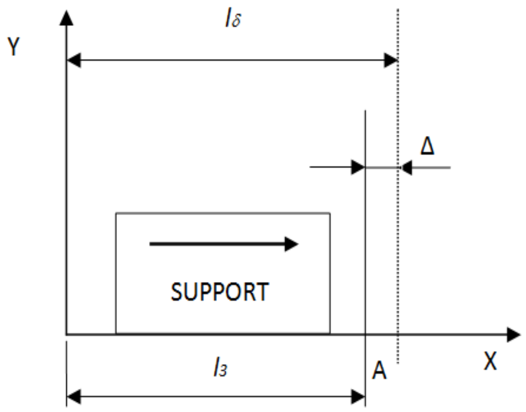

Fig. 1. *Position accuracy*

Probabilistic maximum position error $\Delta\sum$ is determined by the sum of its partial errors, most probably considered as one-way and is given by the equation:

$$\Delta\sum = \sum_{i=1}^{n} / \Delta_i^{\delta} / \quad (2)$$

where Δ_i^{δ} represents factors errors, which are influenced by the positioning accuracy.

2.1. Influence of the temperature on the position accuracy - Δ_1

The range of positioning is constantly changing as machine tools reach thermal balance. This error occurs due to temperature deformations. Thermal balance of a machine tool is reached after 3-4 hours of continuous work, which actually represents 40-50% of the time for a working shift. After interruption of the machine operation for 5 hours, first positionings are in the same range as at the beginning of the work process. Therefore if n CNC machines frequent adjustment is needed (this might be due to the durability of the cutting tool) then the long process of temperature setting decreases the working accuracy of the machine. One of the measures to limit the harmful effects of thermal deformation is to reduce the value (time equilibrium and rate) of thermal strain. This is done by introducing temporegulation, where the increase in the system temperature to be minimal compared to the initial temperature.

2.2 Errors from constructing machinery - Δ_2

Errors from constructing machinery can be seen as deviations from the standards of accuracy. These include errors, occurring with formulation of the dimensional chains; errors, occurring during the machining of the parts; errors, occurring with assembling and with regulation of the feed mechanisms.

The most significant error in machine manufacturing is the error of clearance in ball-screw pair $\Delta_2^{в-г}$. A measure to reduce or eliminate this error is to create a preload in the ball-screw pair. This is especially applicable for CNC machine tools.

Another significant error in machine manufacturing is the error of axial clearance in the bearings - $\Delta_2^{л}$. This error similarly occurs as the one of the clearance of the ball-screw pair.

Another error in machine manufacturing is the error of the pitch of the screw and the nut - Δ_2^{s}.

Next error in machine manufacturing is the error of non-parallelism or the error of crossing the axis of the spindle and the axis of the slide guides - $\Delta_2^{в-н}$. When the feeding system is loaded, the nut will perform an unidentified movement against the screw leading to a sharp increase in the variance of the slide position.

The total error in machine manufacturing is going to be:

$$\Delta_2 = \sum_{i=1}^{n} \Delta_2^{i} = \Delta_2^{в-г} + \Delta_2^{л} + \Delta_2^{s} + \Delta_2^{в-н} \quad (3)$$

2.3 Errors from road command equipment of the machine - Δ_3

1. The error in variance of the course of the microswitch has a significant influence on the position accuracy -Δ_3^{x}. The dissipation of the microswitch run is due to nonlinearity, type of dry friction and a variable friction force. It also influenced by the stability of the spring elements in the axis of the microswitch.

2. One of the major errors of command automation is the error due to the variance of the time to transmit the signal from the microswitch to

turning off the clutch and to the full brake application - $\Delta_3^{в}$. The maximum scattering of the time is proportional to the transfer rate.

3. A substantial error of inaccuracy in the control automatics is the error of eccentricity in the roll of the microswitch - Δ_3^{e}. It is assumed that the gap between the hole and the axis of the roll does not make an error in positioning.

The balance of the error from the command road equipment, providing maximum positioning error is given by the equation:

$$\Delta_3 = \Delta_3^{x} + \Delta_3^{в} + \Delta_3^{e} \quad (4)$$

2.4 Errors from dynamic behaviour of the machine - Δ_4

For the dynamic behaviour of the machine, the essentials are: constant loading force of the feeding system; the values of the inertial forces and accelerations; the fading ability of the system; conditions for the occurrence of relaxation oscillations of the slide movement. The current experimental studies 25, 21 show that with the increasing of the loading force, the positioning accuracy of the slide sharply deteriorates.

1. The most significant error from the dynamic behaviour of the CNC machines is the error of available friction forces in the guide and in the ball screw couple - Δ_4^{m}. In slide movement the error in relocation is determined by ratio of the difference between friction force at rest and in motion and bent stability of the feeding system. When there is a large friction force and less stability of the feeding system at a low speed, the movement of the support can be at a leap i.e. there is stick slip effect. This self-induced oscillations of the support movement can be caused by insufficient axial and torsion stability of the lead screw. The use of roller guides greatly improves dynamic behaviour of the slide.

2. Another significant error from the dynamic behaviour of the machines is the error in rate positioning - Δ_4^{c}. This error occurs as a result of inertial forces and accelerations in the system.

Total error of the dynamic behaviour of machine is determined by the equation:

$$\Delta_4 = \Delta_4^{m} + \Delta_4^{c} \quad (5)$$

Contact deformations in the system that affect the final positioning accuracy are not reported separately. They are present in an implicit form in the friction force and axial stability of the system.

3. Conclusions

● The main factors, affecting the position accuracy of the straight moving mechanical systems are determined.

● A total maximum error of position accuracy is determined:

$$\Delta\sum = \sum_{i=1}^{n} / \Delta_i^{\delta} / = \Delta_1 + \Delta_2 + \Delta_3 + \Delta_4$$

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Acknowledgments: The authors are grateful to the leadership of Plovdiv University "P. Hilendarsky" for funding the research project № НИ15-КС-016/24.04.2015. A part of the theoretical researches are subject of this paper.

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