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Method of Structural Design of Heavy Machine Tools

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Abstract

This paper presents a method of arrangement the frames of heavy lathes with dispersed forces along the coordinate axes of the loads that act on the machine while it is running. Mathematical models of large bearing systems, taking into account typical and boundary loads are developed. The field trials of the action of frames are conducted. We analyzed the movement of the frame on the coordinate axes due to its loading. A solid modeling and research of support of heavy lathe using a package Solid Works Simulation are conducted. The perspective ways to further improve the accuracy of machine tools are proposed.

Keywords: accuracy; rigidity; support; frame of support; a technological system; modeling.

1. Introduction

Modern trends in mechanical engineering, the transition to the use of automated machine tools have requirements to increase accuracy of the size and quality of the machined surfaces of machine parts and devices. This is due to the appearance of new more precision machines and instruments. It is no accident since the 40s of the 20th century every 20 years the accuracy of the technique increases on the order. In the design and operation of technological processing systems there is a continuously increasing demand to enhance their accuracy characteristics.

Currently, as a result of theoretical and experimental research of a large number of scientists accumulated considerable material on technological quality assurance processing that allows to create mathematical models of management of process machining [1].

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However, the efficiency of these models does not always give a satisfactory result, since they insufficiently take into account the impact of the complex multi-axis elastic system of machine for static and dynamic stiffness of technological system, therefore, the quality of treatment. In addition, the absence of dependencies describing the effect of elastic multi-axis machine tool system to stiffness of technological system and the accuracy does not allow uniquely identify the range of parameters that provide the status of the machine accuracy in operation. Analysis of design schemes based on the foregoing concept shows that the stiffness of the multi-axis elastic machine tool system is variable and depends on the ratio P_z and P_y components of the cutting force, relative displacement of the elements of the system of stiffness on the so-called main axes of the rigidity of the system, the position of the main axes of rigidity in the time and other factors [2]. In other words, considering the technological system based on synergetic theory of self-organizing systems, we can say that the rigidity of the machine, as element of technological system, determining the accuracy state machine obeys to the principle of self-organization in space of the working area of the processing detail in real-time. In this regard, research and description of the influence of the multiaxis elastic machine system on the stiffness of the technological system and quality of treatment to be used in mathematical models of the management of machining process, and for determining the machine normalized parameters of stiffness which are subject to ensure in process of design is an actual scientific challenge. The purpose of work is improving the quality of the work pieces on the basis of the prediction accuracy of the machine in real time, taking into account the part of its hardness distribution in the space of the working area.

2. Method

We are currently developing a method process management treatment on CNC machines on a priori information based on the prediction accuracy of processing with the external perturbations in the technological system [3-5]. Machining error is arising from displacement of the elements of machine under the action of external forces, to a greater extent by the rigidity of the system along the vector of applied force. Let us examine more character errors in the processing of machine tools. We distinguish the two groups of errors: errors of size and shape of the surface error. Size error must be understood as the arithmetic mean deviation of the positions of the surface points in the direction of the position under review, given the size of the drawing. For example, the diameter deviation can be represented as

$$\Delta d = \frac{2\int_0^l \int_0^\varphi (r - r_0)\,dl\,d\varphi}{l\varphi} \tag{1}$$

where l – longitudinal coordinate of the cylinder; φ – angular coordinate; r – radial coordinate of the surface; r0 – radius of a given drawing.

The error of form and position generally represents the difference between the coordinate points with minimum and maximum deviation with sign

$$\Delta r = r_{\max} - r_{\min} \tag{2}$$

From this it is easy to understand that the error of size in its properties are identical to the setting the size of the technological system, caused by its change, and thus can be compensated by its change, while the error shape of the surface may totally not depend on the dimensional configuration of the technological system [6-8]. For this reason, the surface shape error is much more serious problem than the error of the size, especially for heavy machines. This statement is also confirmed by the analysis of the operating experience of heavy machinery equipment in a production environment. In this analysis it has been identified and classified the factors that have a significant impact on each specific type of error and found that the most significant factor in assessing the balance of precision is the precision of shape in longitudinal section. Frame of heavy machines consist of several sections connected to each other in the "whole" support structure. The settlement and experimental investigations of elastic deformations cast and compound bed frames were compared. The problems affect the accuracy of the tightened joint compound frames [9-11]. For convenience, the analytical research stiffness of the joint of bending moment and the shearing force is represented as equivalent stiffness and damping:

$$C_{eq} = C_b = \frac{1}{S_M} = C_{r.j} + C_{r.b.}, \; k_{eq} = k_{r.j} + k_{r.b} \qquad (3)$$

$C_{r.j}$, $k_{r.j}$- reduced coefficients of stiffness and damping pin connection interface;

$C_{r.b.}$, $k_{r.b}$- reduced coefficients of stiffness and damping of bolted connections arranged in the joint portion.

It was designed welded bed frame of heavy lathe. Support system of the machine consists of two stand. One two flanges bed frame for basing and fixing the work piece. The second two flanges bed frame is used to move the caliper. Each of a frame consists of two sections interconnected by bolts. The length of each section is 7.8 m. On the basis of the calculation of limit values of distributed loads which act on the base frame support, modeling of deformation strength by method of finite elements with package of tools Cosmos Works were made [12-14]. A method for linking the trails of heavy lathes with a system of forces distributed over the axes of loads that act on the machine during its operation. Heavy modeling lathe bed with capacity of 100 tons is produced to determine the stiffness of the support system under the action of stresses arising in the processing of parts. To summarize the model had to simplify the calculation of the parameters solid model and simulate the base frame in parts. The loading frame of support held in two places: at the junction of the two sections and at a distance of 1200 mm from the edge of the section. Fig. 1 shows an embodiment of the loading frame at the junction of the two sections [15-17].

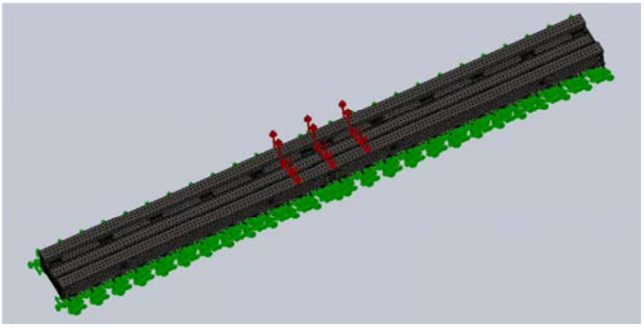

Fig 1. The finite element mesh.

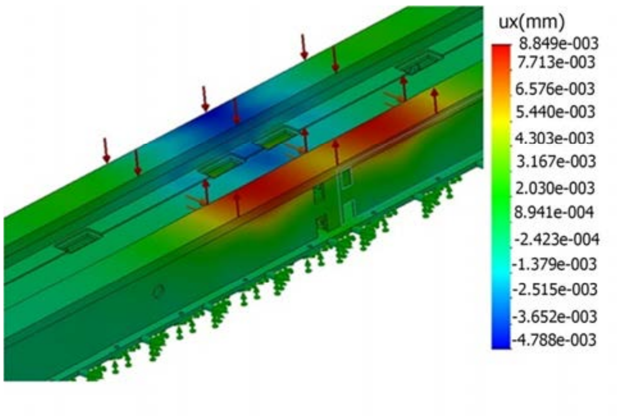

Fig. 2. Analysis of the movement of the frame on the coordinate axes (along X and Z) as a result of the loading frame at the junction of the two sections

The analysis of the displacement of the axes was made on Fig. 2. Fig. 3 shows a diagram of the loading bed of a support at a distance of 1200 mm from the edge of the section.

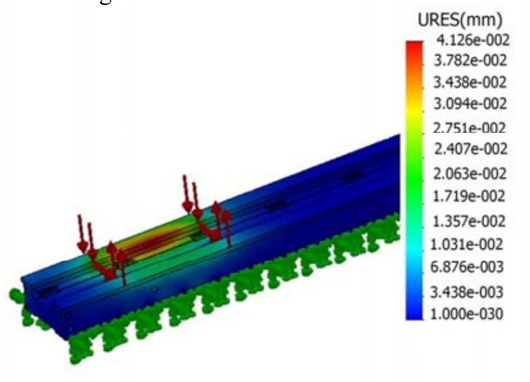

Fig. 3. The finite element mesh.

The analysis of the displacement of the axes was made.

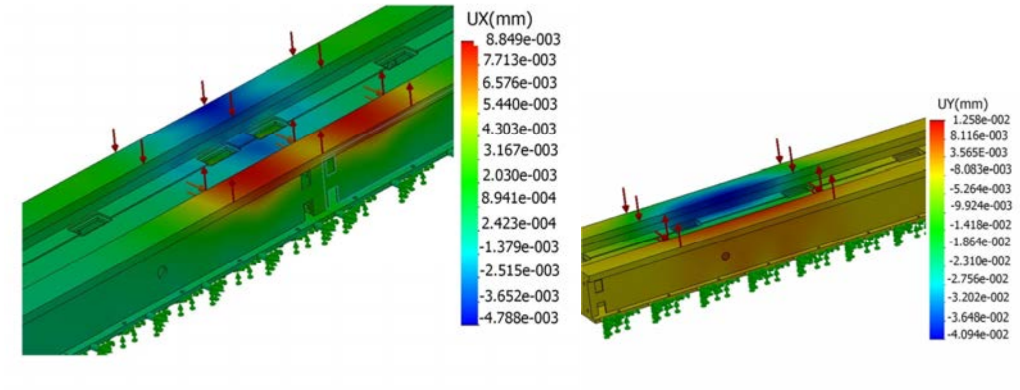

Fig. 4. Analysis the movement of the frame on the coordinate axes (along X and Z) as a result of the loading frame at a distance of 1200 mm from the edge of the section

As we can see from the above figures maximum resultant displacement from action of the applied forces are within acceptable values for this class of machine. The researches and the trials of a support as a part of the technological system of the machine in the environment of Solid Works Simulation have been carried. The support has been loaded with the calculated maximum cutting force, which corresponds to the roughing P_z = 200kN, P_y = 90kN, P_x = 70kN. There was also a force of gravity. As a supporting surface receiving the loads were the surfaces to come into contact with the frame.

Fig. 5. The scheme of loading of a support

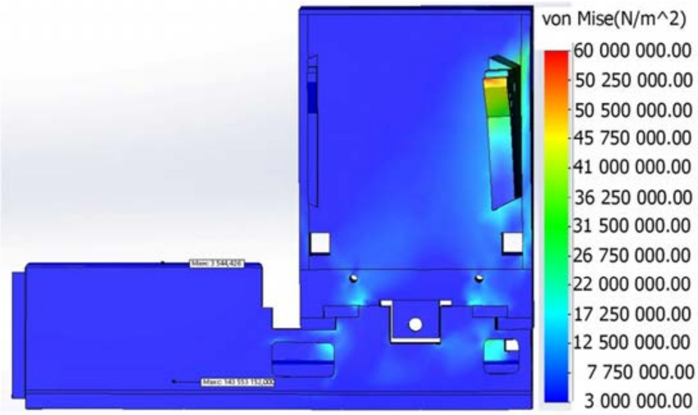

Fig. 6. The internal voltage of metal structure

Analyzing the diagrams we can conclude that the entire components support group have passed the test, because the maximum stress state are in the green zone of the scale corresponding to the nominal load cell.

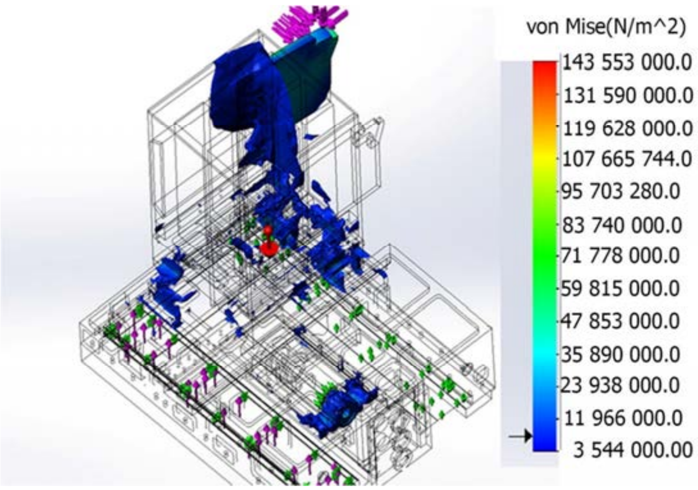

Fig. 7. The most loaded sections of a support

3. Experimental results

The results of theoretical simulation were compared with the results of field tests on the trails rigidity real sizes in the laboratory PAT KZTS (Fig. 8). We have reached a satisfactory agreement of theoretical and experimental results, which allows the use of the methodology developed for research and design real machines of a new generation. Based on these investigations select one or more parameters of the technological system, what automatic controlling would be most effectively increase accuracy of treatment. The proposed system of adaptive management is one of the solutions to the problem of obtaining information about the current parameters of the treatment process. Spite of the large number of developments in this field, the system under consideration favorably in that allows you to measure and take into account the deformation of the work piece, including large, which is especially important in the processing of non-rigid work pieces on heavy machines.

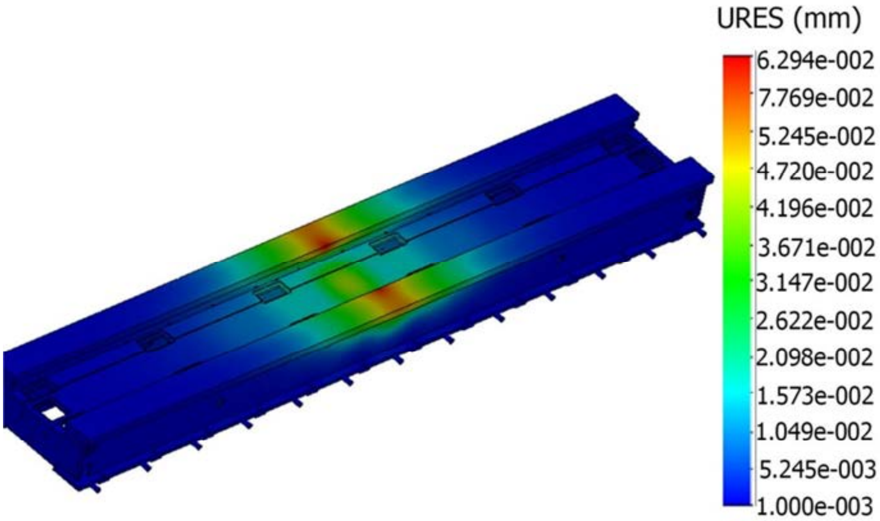

Fig. 8. The most loaded sections of a bedplate.

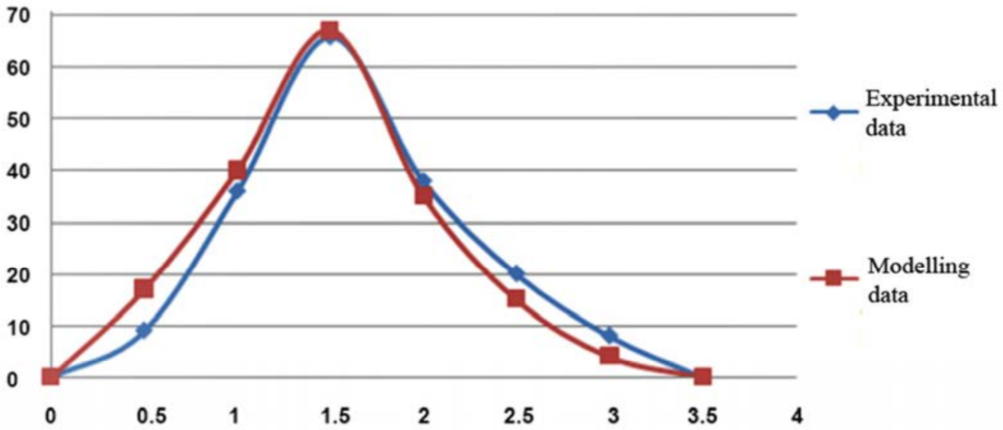

Fig. 9. Comparison of trails rigidity tests.

Analysis of the heavy machine indicates the number of tasks that need to be addressed in their design and operation. They are increase the hardness of bearing systems of machine tools, minimizing the elastic deformation of the trails through the optimal placement of support staff, with the help of which frame are installed on the foundation, as well as robust and reliable control of the accuracy in the working space of the machine, forecasting of reduce the accuracy, development of special methods to ensure the accuracy of the equipment, etc. Further discussion can be found in research by [18-22].

One of the most perspective ways further improve the accuracy of machine tools is to equip their with adaptive systems, in particular, the adaptation of bearing systems of machine tools to the changing conditions of operation, sharply increases their accuracy.

4. Conclusion

A method of investigating the accuracy of composite bed with the help of mathematical modeling was developed. The technology for design supporting structure of heavy machines through the use of the results of the preliminary calculation based on the contact deformation (internal forces, displacements) as the boundary conditions for the design of the individual load-bearing structures, allowing us to obtain the design geometry of the cross section having the lowest possible weight while meeting specified standards of performance and precision machining was developed.

Developed a three-dimensional model of a support of heavy machine, test results at high loads lead to the conclusion about it operability. The design of the frame heavy lathe of high accuracy load capacity of 100 tons with the possibility of machining up to 12.5 m and 2.5 m in diameter with maximum cutting powers of 200 kN are developed. Recommendations on designing of bearing systems of CNC heavy machine tools high accuracy are given. Deformations of the frame of supports under extreme workloads are presented in a range from 29 microns to 83 microns. The results are introduced at PAO KZTS range with the release of heavy CNC lathes of new generation.

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