12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

A STATIC STIFFNESS ANALYSIS OF A HEAVY VERTICAL LATHE

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ABSTRACT
This article looks at experimental research findings related to static stiffness of a prototype, heavy vertical lathe KDC 700/800N. Double column heavy, turning and boring lathe (KDC 700/800N) was constructed according to a planer mill system. The gate overall dimensions are 11200 x 11000 mm. The lathe is also equipped with a sliding carriage beam, with two sliding lathe carriages installed on it. The lathe carriages slide with maximum line feed of 3000 mm. Stiffness research included tests using two methods of static stiffness determination: conventional and dynamic. The article is concluded with an analysis of the obtained results, which was summarized with conclusions related to properties of the tested machine tool.
Keywords: static properties, machine tool, DDSS method

1. INTRODUCTION
The research focused on a double column, heavy, turning and boring lathe (KDC 700/800N) constructed using a planer mill system. Overall dimensions of the gate are 11200 x 11000 mm. The lathe is also equipped with a sliding carriage beam, with two sliding lathe carriages installed on it. The lathe carriages slide with maximum line feed of 3000 mm. The machine tool undergoing the research is presented in picture no. 1.

Stiffness research included tests using two methods of static stiffness determination: conventional and dynamic. The detailed information on the subject of the methods used are included in [1,2,3,4].

During the research conducted by the use of conventional method, the machine tool was loaded through application of a hydraulic servo-motor constituting a part of force generator. Thus making it possible to simulate selected components of the machine cutting force affecting both the machined element and the machine tool during its operation.

The data on dislocation of selected machine tool units and the machined object was recorded by inductive sensors.

Dynamic method research DDSS, involved loading the machine tool in a dynamic way (with the force sinusoidally changeable) in the direction of a selected component of the machine cutting force. The tested machine tool was loaded with a hydraulic force generator used in conventional method research. It allowed setting the permanent value of the component, amplitude, and the frequency (in the range of $1 \div 10$ [Hz]) of the extortion force. The value of dislocations (amplitude of dislocation) of selected machine tool units was recorded by vibration sensors (accelerometers) of increased sensitivity. The amplitudes of vibration acceleration referring to chosen points were recorded during the research and later they enabled the determination of dislocation amplitudes.

The construction of the station used in the research is presented in [2,3,6], and the detailed plan is included in [X, Y].

a) b)

Figure 1. General view of the turning and boring lathe KDC 700/800N

2. RESULTS OF THE STATIC STIFFNESS RESEARCH CONDUCTED BY THE USE OF THE CONVENTIONAL METHOD

The static stiffness research conducted by the use of a traditional method resulted in stiffness diagrams (in a force-dislocation system) describing properties of selected units and the machine tool as the whole. On their basis, two indicator values of static stiffness were determined (as a slope of a straight line regression).

According to the analysis of the results obtained during load application onto the left slide, it is possible to concluded that the biggest dislocation appeared in the tool post, regardless the value of the line feed of the slide (0, 830, 3000 mm –three analyzed cases). With the minimum line feed of the left slide, maximum dislocation of the tool post (~42 μm) appears at the Y axle and it is more than twofold bigger than its dislocation in the X axle direction. Similar relation appears in the case of dislocation of the left slide's end. Dislocation in the Y axle direction is smaller by approximately 7 μm in relation to the dislocation observed in the tool post, and it is 1,5 times bigger than the dislocation of the slide's end in the X axle direction. Dislocation of the left carriage in both directions does not exceed 4 μm (fig.5).

Having increased the line feed of the slide up to 830 mm the observed dislocation increased approximately threefold, assuming the highest values (in the case of the left slide) at the tool post in the Y axle (~174 μm). It was twice as big as dislocation occurring in the X axle. During the tests focusing on the right slide, similar relations were observed. Dislocations of the slide's end vary significantly from dislocations of the tool post (in axle X ~29 μm, in axle Y ~82 μm). The lowest values of dislocations were observed at the carriage (in axle X nearly 4,5 μm).

The last stage of the research focused on testing the dislocations occurring at the tool post, slide's end and the carriage at the maximum line feed of the slide (3000 mm). Thus the crossrail of the machine tool was raised by 2170 mm. Additionally the loading force applied onto the machine tool was decreased by half (to 10 kN). Dislocations of the tool post and the slide's end increased more than twofold. Values increased by 1,5 were observed in the direction of the axle Y, (at the tool post approximately 530 μm) in relation to dislocations occurring at the tool post in the X axle direction. The dislocations of the slide's end were approximately 15% lesser than those of the tool post.

Similarly to the left slide, the dislocation appearing at the right tool post in the Y axle direction were observed to be greater by 1,5 than dislocation occurring in the X axle direction (axle X ~407 μm; axle Y ~622 μm).

The tests conducted while imposing the load on the right slide, confirmed similar properties of both slides. The only noticeable difference is a slight increase of dislocation at the right slide as compared to the left one (in axle X approximately 7%, and in axle Y approximately 15%), which results in deterioration in its properties.

On the basis of dislocation values recorded at selected measurement points, it was possible to determine appropriate stiffness indicator values describing properties of the machine tool KDC 700/800N. With the minimum line feed of the left slide the stiffness indicator values were relatively high (over 250 kN/mm). It was characterized by better stiffness properties in the X axle direction than in the Y axle direction. The left carriage possessed the best stiffness properties (8000 kN/mm).
Having increased the line feed of the slide up to 830 mm the stiffness indicator values describing machine tool properties dropped significantly (in the axle X they assumed the level of 280 kN/mm). Yet, the slide still displayed better properties in the direction of X axle than in the Y axle direction (~230 kN/mm). The highest stiffness (exceeding 4000 kN/mm) was displayed by the carriage.
The right slide underwent the same research. The values of the determined stiffness indicators were similar to the values obtained for the left slide. Additionally, tests in the Z axle direction were carried out. The value of stiffness indicators determined in this direction exceeded nearly threefold the value of stiffness indicators determined in other directions.
A considerable decrease in value of stiffness indicators was observed with the maximum line feed of the slide. They reached the value from 20 to 25 kN/mm in the Y axle, and from 30 to 35 kN/mm in the X axle. The right slide displayed similar properties (in axle: X 29,58 kN/mm; Y 20,08 kN/mm).
Concluding, on the basis of the conducted research it is possible to argue that both slides are characterized by similar properties (the maximum discrepancies amount up to 2%).

4. STATIC STIFFNESS RESEARCH RESULTS OBTAINED BY THE DDSS METHOD

The analysis of stiffness indicators obtained in the course of stiffness research conducted by the use of dynamic method reveals the occurrence of the same relations that were observed while applying the conventional method. Stiffness indicators describing the properties of the tool post, slide and the left carriage assume higher values in the X axle direction than in the Y axle direction. The discrepancy with the maximum line feed amounts up to 30%. Furthermore, together with the increase of slide's line feed, the value of stiffness indicators decreases even 10 times.
During the research conducted on the second slide (the right one) of the turning and boring lathe KCD 700/800N it was observed that with the line feed of the right slide equal to 830 mm the value of stiffness indicators assumes values from 180 to 250 kN/mm. A drop in stiffness indicators can be observed in this case (for 7Hz a drop in value ~16%; for 10Hz a drop in value ~50%) as compared to similar properties of the left slide. Stiffness indicators determined on the basis of the right slide's end dislocation assume values from 160 o 250 kN/mm. In this case again the right slide displays worse properties (a drop in relation to the left slide ~50%). The best properties are displayed by the right carriage, yet it is possible to notice significant stiffness decrease as compared to the left carriage. Stiffness indicators determined after the increase of the line feed of the slide up to 3000 mm assume following values: in the direction of axle X from 30 to 38 kN/mm; in axle Y from 17 to 24 kN/mm. In both cases a 30% drop of properties can be observed, in relation to the left slide. The right slide is characterized by better properties in the X axle direction.

5. CONCLUSIONS

1. The carrying system of the examined machine tool displays good stiffness properties. Dislocation of the slide's end (tool post) for small line feed does not exceed several micrometers (43 μm).
2. Higher stiffness of the carriage-slide-tool post unit in axle X (the axle of servo-motor operations) as compared to axle Y (an axle perpendicular to carriage ways) is observed for all analyzed line feed types of the slide. It means that the servo-motor parameters have been selected properly, on one hand, and it suggests the participation of dislocation of the crossrail in dislocation in Y axle or certain construction difference e.g. in the way of setting the clearance at the slideway in the axle X and Y on the other.
3. Figure 2 presents dislocation determined during the research and their percentage participation in dislocation of the tool post end for the left carriage in X axle. Regardless the slide's line feed there is a relatively significant dislocation share between the tool post and the slide in the overall dislocation. The change of the construction joint would cause visible improvement of the stiffness properties of the whole machine tool.

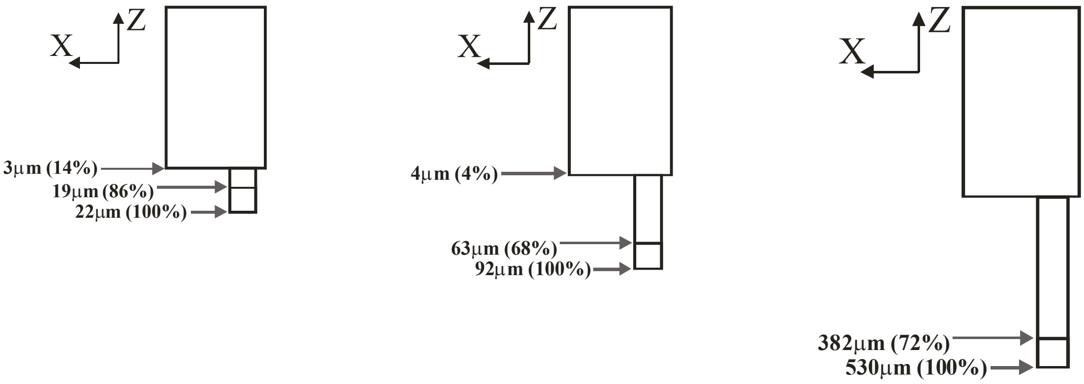

Figure 2. Percentage share of the observed partial dislocation in the dislocation of the slide's end for the left carriage in axle X with: a) minimum line feed of the slide, b) line feed of 830 mm and c) line feed of 3000 mm

4. Stiffness resultant of the carrying system of the examined turning and boring lathe depends above all on the volume of the line feed of the slide and together with the volume increase it decreases significantly. The only alternative way to improve the stiffness properties of this key element is the increase of the textural stiffness (cross-section) of the slide (contact stiffness at the slide's rails is satisfactory, the dislocation between the carriage and the slide with the minimum line feed does not exceed 19 μm).

5. REFERENCES

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