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STATIC STIFFNESS ANALYSIS OF THE CARRYING FRAMEWORK OF SPECIAL MACHINE TOOLS UBF-112 N

Kaźmierczak M.
Sliwka J.
Kosmol J.
Department of Machine Technology, Silesian University of Technology
Poland
Gliwice

ABSTRACT
The article presents results of experimental research on static stiffness of two special machine tools UBF-112 N. The value of static stiffness indicators, analyzed in the course of this research, was determined by the use of two experimental methods: traditional (conventional) and dynamic DDSS (Dynamic Determination of Static Stiffness) one. The final part of the article includes the analysis of the obtained results, which is followed by conclusions referring to properties of the carrying framework of machine tools of that type.
Keywords: static properties, machine tool, DDSS method

1. INTRODUCTION

UBF-112 N special machine tools are meant for machining wheel profiles of axle sets used in railway vehicles. Picture 1. displays the general view of the machine tools involved in the experimental research, whose results are presented in the present article. Machine tools of that type are used for machining wheel sets. The key elements of a machine tool are the two slides equipped with a cutter holder and measuring heads (one of the machine tools undergoing the tests was equipped with a movable slide). This constructional arrangement enables automatic measurements of a wheel profile raceway prior to the machining process; (the results obtained allow machining in automatic cycle).

a) b)

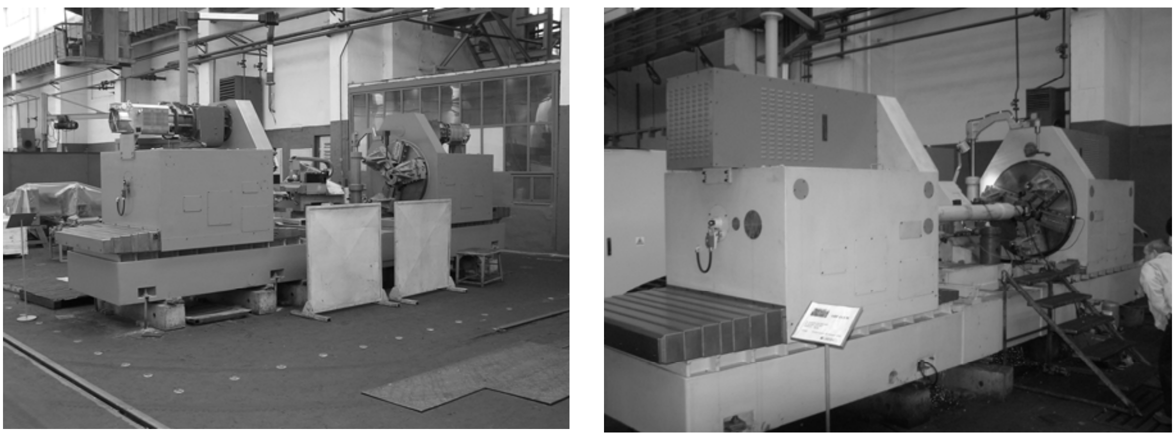


Figure 1. General view of special machine tools UBF-112 N, involved in the experimental research

2. STATIC STIFFNESS RESEARCH PLAN FOR UBF-112 N MACHINE TOOLS

The research plan for special machine tools included studies focusing on static stiffness conducted by the use of two methods: conventional and dynamic one - DDSS. During the research carried out according to the conventional method, the machine tool was loaded in three directions (axles X, Y and Z). The load was applied by the use of a hydraulic servo-motor, which constituted a part of force generator (the research stand is described in [2]). Thus it was possible to simulate selected components of the machine cutting force affecting both the machined element and the machine tool during its operation. The value of extortion force and the place of its application were diversified during the testing. The data on dislocation (relative e.g. slide against machine tool body) of selected machine tool units and the machined object was recorded by inductive sensors.

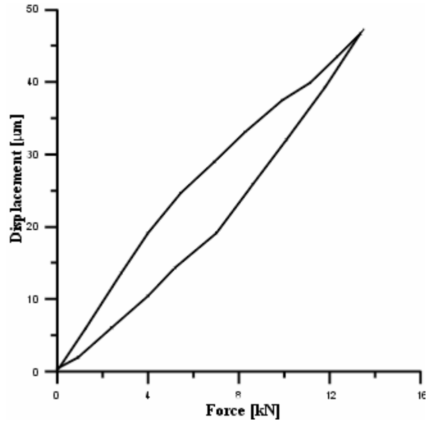
Dynamic method research DDSS, involved loading the machine tool in a dynamic way (with the force sinusoidally changeable) in the direction of a selected component of the machine cutting force. The tested machine tool was loaded with a hydraulic force generator used in conventional method research. It allowed setting the permanent value of the component, amplitude, and the frequency (in the range of 1 ÷ 10 [Hz]) of the extortion force. Thus the machine tool was subjected to extorted vibrations of low frequencies, which reflected real operating conditions. 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. They enabled the determination of dislocation amplitudes, which together with the data on the extortion force amplitude allowed the identification of values of selected stiffness indicators. *The research plan details presenting thorough information on machine tool load application and location of the measuring points are described in the paper [2].*

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

The static stiffness research conducted by the use of a traditional method resulted in a stiffness diagram (in a force-dislocation system). Picture 2. presents exemplary stiffness diagrams determined during the research. On their basis, two indicator values of static stiffness were determined in each case (as Fmax/Xmax, or as a slope of a straight line regression).

The experimental research that was conducted points to high stiffness of UBF-112 N special machine tools. Both machine tools that underwent testing display a relatively high stiffness. In the case of the latter, which was subjected to more thorough testing, none of the determined stiffness indicators assumed the value below 200 kN/mm (pic. 3). The maximum dislocation recorded did not exceed 55 μm. While applying the load onto the machine tool in the direction of an X axle, it was the slide that displayed the lowest stiffness (the value determined through the measurement of slide dislocation against machine tool body). The stiffness indicator assumed the value of approximately 300 kN/mm (pic. 3a). Similar stiffness indicators' values were reported while applying the load in the direction of Y axle (pic. 3c). Then the biggest relative dislocation appeared between the raceway of the wheel set and the machine tool body.

a)



b)

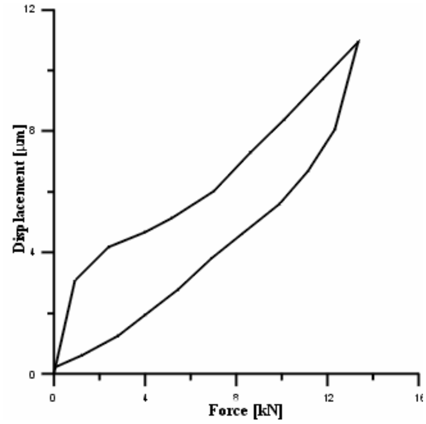


Figure 2. Sample stiffness diagrams; a- sensors CI_{1xx}; b- sensors CI_{2xz}

During the testing conducted in the Z axle direction, again it was the slide that displayed the lowest stiffness indicator (the value was determined on the basis of measurements of slide dislocation against the machine tool body; (pic. 3d). Similar properties were noticed in tests on the first special machine tool UBF-112 N. The lowest value of the determined stiffness indicator did not fall below 200 kN/mm, and the maximum dislocation equaled 56 μm. Furthermore, having compared the determined stiffness indicators' values for measuring points CI_{7yy} and CI_{13yy}, both machine tools displayed similar properties.

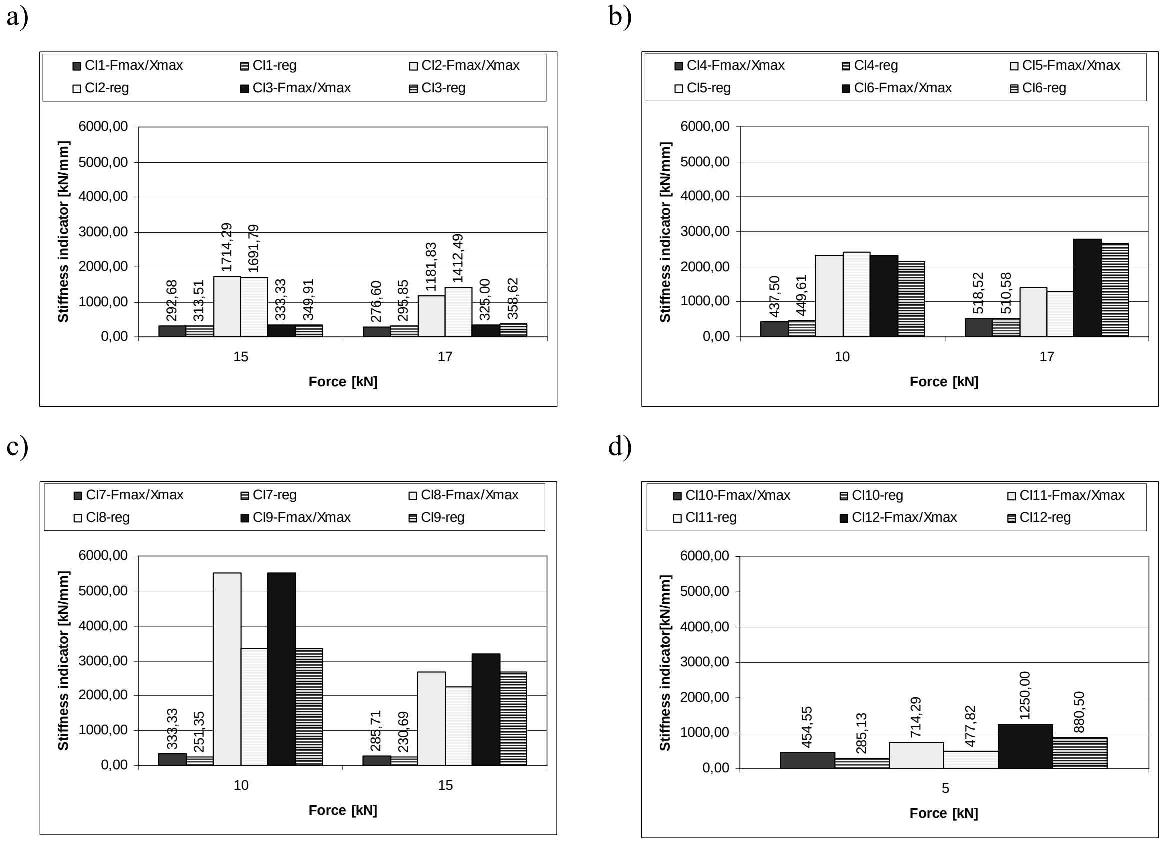


Figure 3. Comparison of stiffness indicators' values UBF-112 N machine tool

4. STATIC STIFFNESS RESEARCH RESULTS OBTAINED BY THE DDSS METHOD

Static stiffness research resulted in providing static stiffness indicators' values determined through the measured amplitudes of force and dislocations of selected machine tool units. The analysis of the results allows the following statement: the values determined for the extreme frequency of the extorting force (1 and 10 Hz) differ significantly from the others, thus they shall be ignored in the further analysis. When the load was applied onto the machine tool (UBF-112 N) in X axle, it was the shield that represented the lowest stiffness CS6 (~180 kN/mm), whereas the slide represented the highest stiffness CS1 (~300 kN/mm). While applying the load in the X axle direction, the amplitude of slide dislocation was recorded in the Z axle, consequently it served as starting point for determining the value of the slide's stiffness indicator CS2 (~510 kN/mm).

When the load was applied onto the machine tool (UBF-112 N) in the Y axle direction, the lowest value (~240 kN/mm) was assumed by the stiffness indicator determined on the basis of dislocation (~35 μm) appearing at the raceway of the wheel set CS7. In other cases the values of stiffness indicators were the following:

- ~410 kN/mm; determined on the basis of dislocation appearing in the wheel set in the center area (~20 μm),
- ~1150 kN/mm; determined on the basis of dislocation appearing on the shield/holder (~7 μm).

Research of the special machine tool UBF 112-N no. 1 was conducted with the same load application method (in the Y axle direction). According to the research plans presented above, the location of measuring points CS7 and CS13 as well as CS9 and CS15 was identical in both cases:. For the machine tool UBF-112 N no. 1 the stiffness indicator determined on the basis of the dislocation amplitude gauged at the raceway of the set (CS13) equaled ~200 kN/mm. This machine tool is characterized, at this measuring point, with stiffness lower by approximately 15% from the other machine tool of the same type that was tested, since the latter displays stiffness ~240 kN/mm at the same measuring point. The machine tool displayed slightly higher stiffness indicator ~220 kN/mm, at the second measuring point located on the driver. In the case of second repeated measuring points (CS9 and CS15) the determined values of measured indicators equaled ~400 kN/mm.
The last case analyzed was the one when the machine tool was loaded during the research and the extortion force was applied to the slide block of the right slide in the direction of the Z axle. The special machine tool UBF-112 N displayed the highest stiffness in this direction.
All the stiffness indicators determined had high values (over 450 kN/mm). Maximum dislocation amplitudes recorded that appeared at the analyzed measuring points did not exceed 5 μm.

5. CONCLUSIONS

1. Basing on the results obtained for points located near the machine tool center (point C15) and for those located on the shield of the spindle (point C16), we can state that static stiffness of the carrying framework of the machine tool UBF-112 N no. 1 is satisfactory and not lower than approximately 1300 kN/mm.
2. The precision of the machining process of the set's raceway conducted by the machine tool UBF-112 N no. 1 is strongly affected by stiffness gauged at C13 point. Its value during the tests ranged from 200 to 270 kN/mm.
3. On DDSS method application in UBF-112 N no.1 machine tool testing, the results were similar to those obtained in the course of the traditional method. The only exception were the results obtained at C15 point (for conventional method the stiffness equaled not less than 1300 kN/mm and for DDSS method approximately 400 kN/mm). It is not possible to explain this discrepancy at the present stage of research.
4. While applying the load onto the machine tool UBF-112 N no. 2 in the X axle direction, it was the slide that represented the lowest (but still satisfactory) stiffness (sensors C1 – 313 kN/mm), much higher stiffness was noted at the center-axle system of the wheel set (sensors C4 – 450 kN/mm), the stiffness of the shield of the spindle exceeded 2600 kN/mm.
5. Load application onto the machine tool UBF-112 N no. 2 in the Y axle direction causes slide raise by approximately 38 μm (sensor C3), the slide raise due to load application in Z axle is insignificant and equals approximately 4 μm.
6. In the case of load application onto the machine tool UBF-112 N no. 2 in the Z axle direction, the slide stiffness still represented satisfactory level (minimum 285 kN/mm).
7. The stiffness of the wheel set measured at the raceway (sensor C7) was approximately 230 kN/mm, similar figure was obtained for the machine tool no. 1.
8. Similarly to the machine tool no. 1 the research conducted on the machine tool no. 2 confirmed satisfactory level of stiffness displayed by the carrying framework of the UBF-112 N machine tool type. The static stiffness did not fall below approximately 200 kN/mm. for any of the measuring points.

5. REFERENCES

[1] S. Zeweld: Ocena porównawcza struktury nośnej obrabiarek ciężkich. Rozprawa doktorska, Gliwice, 1990.
[2] M.Kaźmierczak, J.Śliwka: Analiza sztywności statycznej układu nośnego tokarek specjalnych UBF-112 N. Prace naukowe Katedry Budowy Maszyn Nr X/X, Gliwice 2007
[3] J. Śliwka: Wyznaczanie sztywności statycznej obrabiarek metodą wymuszenia dynamicznego. Rozprawa doktorska, Gliwice, 1999.
[4] M. Kaźmierczak: Metodyka badań sztywności statycznej obrabiarek ciężkich w warunkach przemysłowych. Rozprawa doktorska, Gliwice, 2006.