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STATICAL STIFFNESS RESEARCH OF THE MILLING MACHINE USED FOR CRANKING

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ABSTRACT
The objective of the described undertaking was to determine stiffness' properties (static stiffness) of the FS 550 CNC milling machine. The machine tool, which represents a unique construction, has the face milling cutter with a diameter of 5,5 meters, which is used for milling cranks of ship shafts. Due to specific construction of the analyzed machine, the research team focused mainly on stiffness determination of the milling cutter. The analysis included also the milling table. The stiffness determination involved two methods: conventional and the one relying on the input of dynamically variable force (DDSS).
Keywords: static properties, milling machine, DDSS method

1. INTRODUCTION
The article presents the analysis of stiffness research of the FS 550 CNC milling machine produced by F.O. 'RAFAMET' S.A. The milling machine has been presented in the Fig. 1. The experimental research during which static stiffness of the machine tool was determined involved two methods:
- conventional method,
- dynamic method DDSS (the so called Dynamic Determination of the Static Stiffness).

The conventional method is widely used in industrial practices. It has, however, one basic drawback: the research is conducted in static environment that is without any motion, which means that particular machine tool's units do not move against each other. Such research conditions differ significantly from real conditions reflecting real machine tool's work while all the units perform relative movements (programmed, or appearing due to friction). In the situation of reciprocal motion of machine's units, its static stiffness changes, as the conditions of friction of contacting surfaces in particular units change. Changeable conditions of friction on contacting surfaces refer to various coefficients, which are considerably higher in the case of static friction as compared to kinetic friction. On this basis we can assume that the same force influencing the machine tool corresponds to different static and dynamic displacements. It can be expected, that displacements in static environment will be lesser, so consequently static stiffness will be greater than in real working conditions.

2. RESEARCH SCHEME
During the static stiffness research of the FS 550 CNC milling machine the focal point was the stiffness determination of the milling cutter. Additionally, in one case the stiffness of the table was determined. The research scheme based on the conventional method was as follows:

VARIATION 1 – static stiffness determination of the milling cutter at three selected points marked in the scheme (figure 2) with the following symbols CI1, CI2, CI3, which correspond to the location of induction sensors. Induction sensors were based on the stand independent from the machine tool. The research was conducted in the lower and upper extreme location of the milling cutter loaded in the axel Z with the force of maximum value equaling 10 kN. The input point on the scheme is marked with Fz symbol.

Figure 1. FS 550 CNC milling machine

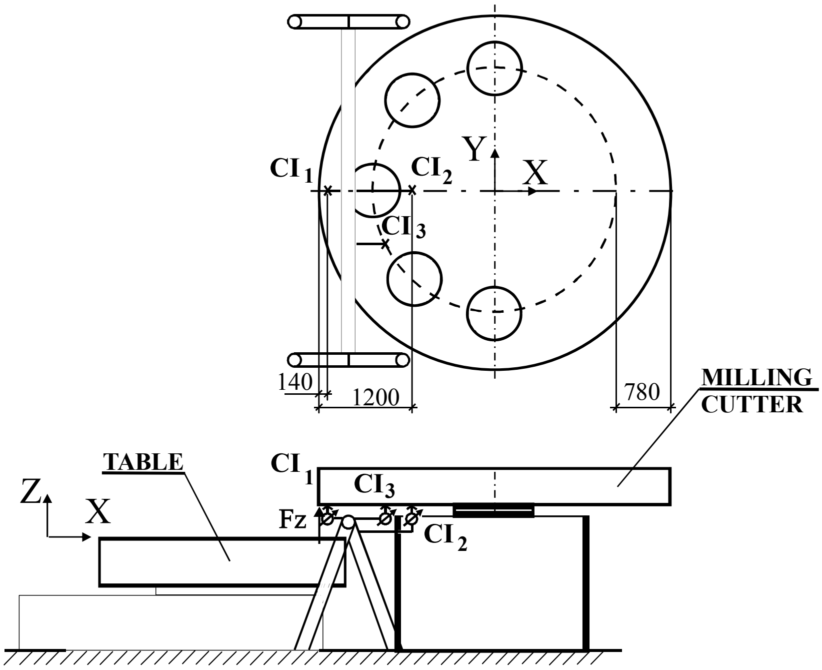

Figure 2. The scheme presenting the location of measuring points during the static stiffness research of the milling cutter at its extreme lower position with the load at the Z axle

VARIATION 2 – static stiffness determination of the milling cutter and the table at the selected points marked in the scheme (figure 3) with the following symbols CI11, CI12, CI13, which correspond to the location of induction sensors. Induction sensors are based on stands independent of the milling machine. The research was conducted in the upper position of the milling cutter loaded in the X axle with the maximum force of 10 kN. The point of force application is marked with Fx symbol.

3. THE RESULTS

The conventional static stiffness research resulted in a chart representing force –dislocation system. Consequently, the stiffness indicator was determined on this basis. The research results are presented in the sample chart included in the figure 4.

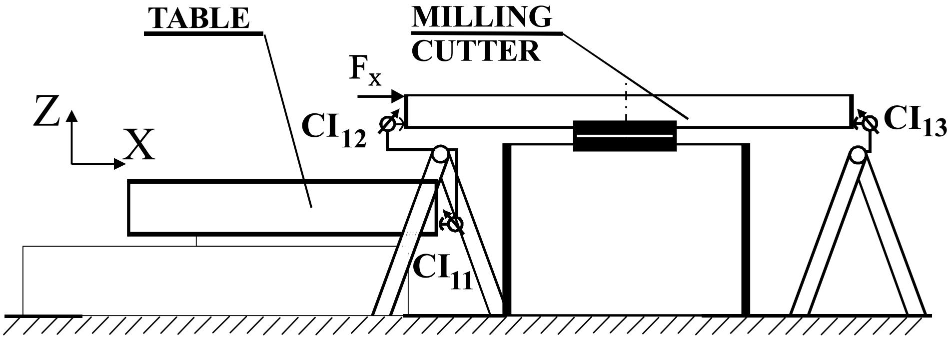

Figure 3. Scheme of measuring points location during the static stiffness research in the upper position of the milling cutter with the load in the X axle

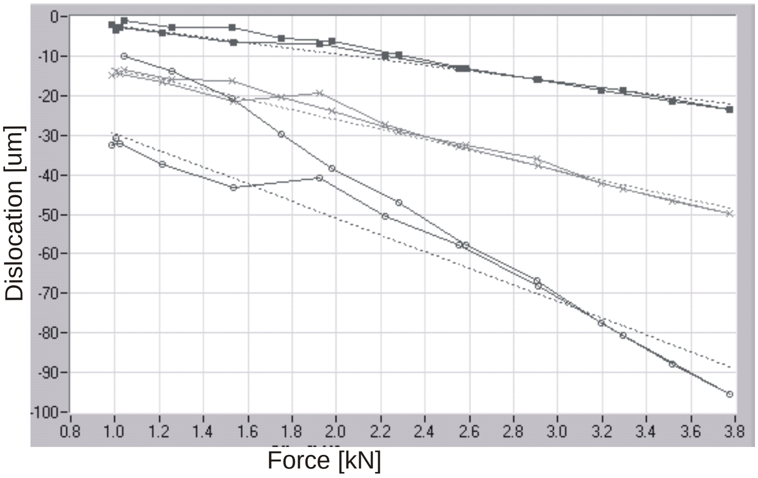

Figure 4. The diagram representing force-dislocation system referring to milling cutter's stiffness determined with the load applied to the Z axle at its extreme lower position for the sensors: looking from the top CI6, CI5, CI4

A considerable increase in the values of stiffness indicators while approaching the milling cutter's axle was observed (see figure 5.). The increase of the stiffness indicators' values determined as the ratio of the maximum force and the maximum displacement amounted up to almost 90%. In the case of stiffness indicators determined by the use of linear regression equation, it amounted up to approximately 80%.

The research schedule for the static stiffness of the milling machine by the use of dynamic method was similar to the conventional method research plan. The focal point was the determination of the milling cutter's stiffness. During the stiffness determination by the use of dynamic method, the result obtained consisted of stiffness indicators, determined in each case with the four different (3, 5, 7 and 10 Hz) frequencies of the exciting force.

4. CONCLUSIONS

The conducted research led to the following conclusions as referred to the static stiffness of the FS 550 CNC milling machine:

1. The stiffness of the OUPN system relays on the figural stiffness of the milling cutter, which is in the extreme case (X-direction axle) two times smaller than the table's stiffness.
2. While analyzing the stiffness charts (a sample chart is presented in the picture 4) it has been observed that the contact stiffness is considerably smaller as compared to the figural stiffness of the milling cutter (hysteresis field is too small in the charts presented above).

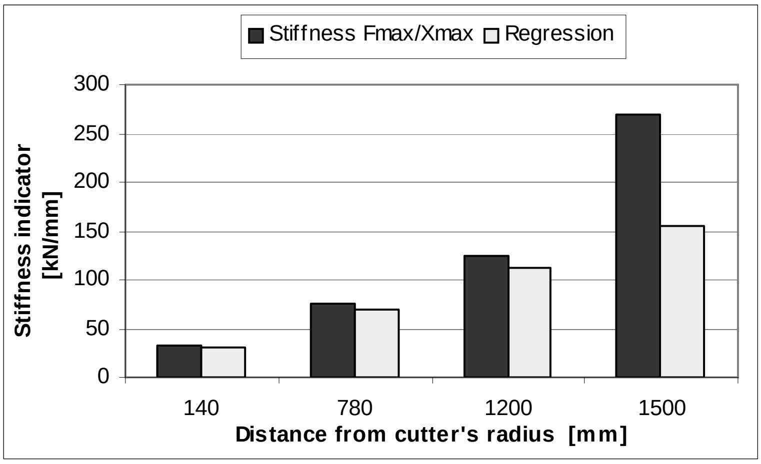

Figure 5. The comparison of stiffness indicators' values as dependant on the distance between the measuring points located along the milling cutter's radius

3. The accuracy of the machining process is determined by the tool's stiffness towards X direction, which oscillates between 337 – 414 kN/mm. The milling cutter's stiffness is considerably smaller at the milling cutter's circuit towards the Z axle (minimum 25 kN/mm). However it does not influence significantly the accuracy of the machining process.
4. The relatively low stiffness of the tool towards the Z axle may be the cause of the excessive vibrations of the milling cutter during the machining process.
5. The line feed of the tool has no visible impact on the stiffness resultant of the milling machine.
6. A significant conformity of the results obtained through conventional and dynamic method has been reported (Fig.6).

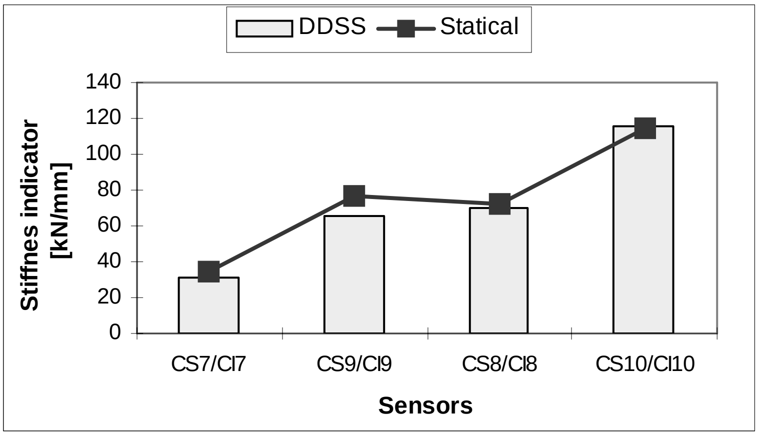

Figure 6. The comparison of the stiffness indicators' values determined by the use of: conventional and dynamic methods. Upper positioning of the milling cutter.

5. REFERENCES

[1] Target Project KBN no 6 T 07 2004 C/06520: The Special Milling Machine Implementation for the Crankshaft's Cranks of the FS 550 CNC Type. Department of Machine Technology at the Silesian University of Technology, FO RAFAMET, Gliwice, Kuźnia Raciborska 2004.

[2] Kosmol J., Śliwka J.: The Repeatability of the Static Features of Heavy Machine Tools. Scientific Papers of the Scientific Institute Machine Technology and Automation of the Wrocław University of technology No 84, series: Conferences No 41, t. I, Session And Plenary lectures, Wrocław 2003, pp. 533-540.

[3] Research Project KBN no 5 T07D 002 23: Static Stiffness Determination of the CNC Machine Tools by the Use of the Dynamic Method. Department of Machine Technology at the Silesian University of Technology, Gliwice 2002-2005.