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COMPARATIVE ANALYSIS OF /DDSS/ DYNAMIC AND CONVENTIONAL METHOD OF STATIC STIFFNESS DETERMINATION

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ABSTRACT
The article presents results of static stiffness research conducted with several heavy machine tools, where the static stiffness was determined experimentally by the use of dynamic method. The dynamic method is a recent, unique technique developed at the Department of Machine Technology uniquely suited for static stiffness determination. The major advantage of the method is significant simplification and acceleration of the stiffness measurement process, thus influencing its effectiveness so crucial for operation within industrial conditions. The present stage of method's development focuses on its verification i.e. static stiffness of selected heavy machine tools operating in normal industrial conditions is being measured and compared with static stiffness readings obtained through the application of the conventional method. The results obtained allowed identification and interpretation of the discrepancies revealed by the readings. The analysis is based on research results obtained from several machine tools conducted in the time-span of 2000 - 2009.
Keywords: machine tools, static stiffness, dynamic method

1. INTRODUCTION

The following paper presents a comparison of results obtained in the course of experimental research performed on machine tools, by the use of two methods of static stiffness determination: DDSS and conventional one. The comparison has been based on an extensive scientific in-put material that was being collected along the process of mastering the DDSS method. It can be stated undoubtedly that it forms the biggest database comprising figures and information on stiffness properties of heavy machine tools in Poland. Bearing in mind the abundance of data available, and the fact that the figures were not fully systematized (mainly due to the fact that research methods were being developed or amended during those several years of performing the task, moreover the research time-span allocated to particular machine tools varied significantly as well as technical conditions of the research) only selected results were chosen to be included in the comparison. Obviously, the choice made was fairly subjective. The comparison of results provided by the two methods, focuses particularly on dependencies between stiffness indicator values:

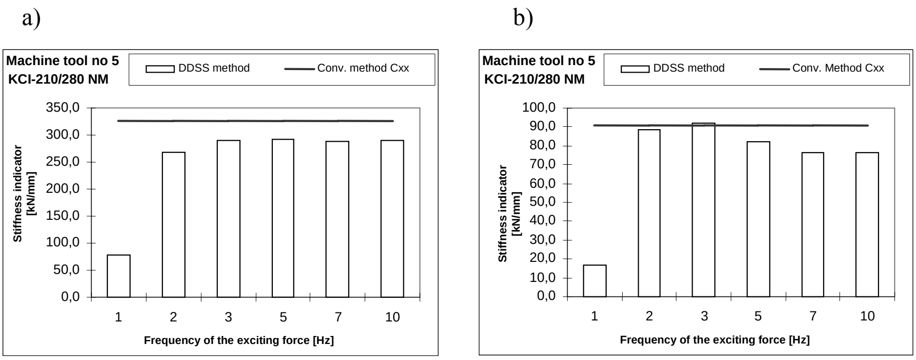
- the results obtained in the course of conventional method and DDSS are characterized by the highest convergence for exciting force frequency at the level of 3 to 7 Hz,
- the conformity of results provided by the research conducted along the two methods decreases together with the increase of contact stiffness fraction in relation to structural stiffness,
- the value of stiffness indicators determined in the direction of the servo-drive are strongly influenced by the properties of the servo-drive itself.

2. DDSS METHOD DESCRIPTION

DDSS method of a machine tool static stiffness determination relays on equality of the dislocation generated by the static stiffness with the dislocation amplitude caused by force varying harmonically with the amplitude equal to the value of the static force. This phenomenon is typical when the frequency of the exciting force is significantly lower than the initial frequency of proper vibrations of the forced element. The method involves measuring of vibrations brought about by a harmonic force with the frequency much lower than the frequency of proper vibrations of the examined element. Measuring of vibrations was conducted by the use of seismic vibration sensors. The static stiffness was calculated as a ratio of the exciting force amplitude and the amplitude of dislocation (resulting from the amplitude of vibration acceleration as measured by the seismic sensors) [1,3,4]. Application of seismic sensors, which were mounted with stable magnets onto the machine tool body, was a considerable advantage of the method. DDSS method makes it unnecessary to set up scaffolds in order to provide support for the dislocation sensors, a necessity in research following traditional methods [5].

3. THE IMPACT OF FREQUENCY OF THE EXCITING FORCE

The development of dynamic determination of the static stiffness relays on the following assumption: the research is to be conducted for the frequency of the exciting force located in the range between 1 and 10 Hz. Sample values of stiffness indicators for machine tools examined in the early years are presented in the Picture 1. The diagrams show that regardless the magnitude of the slide's travel, the indicator values determined for the lowest and the highest frequencies of the exciting force differ significantly from the results obtained in the course of the conventional method. The relations are presented using the example of turning and boring lathe units, however they can be referred to other types of machine tools as well. The frequency range below 3 Hz (the research included also frequencies of 1 and 2 Hz) provides us with unexpected results mainly due to the decreasing ratio between the level of useful signal and the level of measurement noises. In case of input function frequency over 7 Hz (the research was conducted for 10 Hz) differences in the obtained results, especially for heavy machine tools, may be evoked by the fact that the input function frequency was getting closer to the frequency of proper vibrations of the machine tool's carrying system [4].



Picture 1. Sample results on static stiffness examination of turning and boring lathe units KCI-210/280 NM, for the slide's travel: minimum (a); maximum (b)

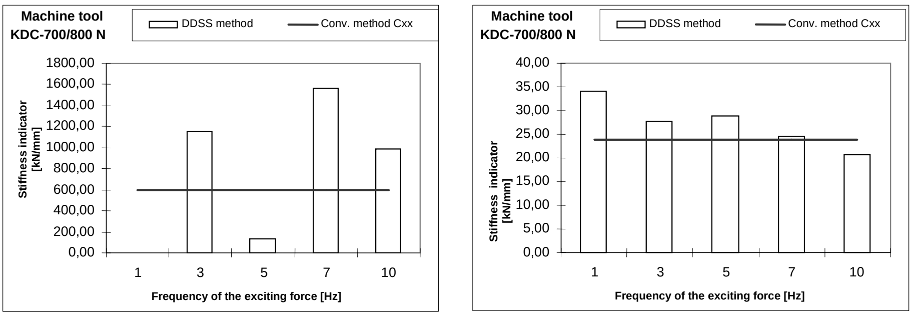
4. THE INPACT OF CONTACT STIFFNESS

The results obtained, allow formulating the present thesis: the discrepancy between results obtained in the course of both methods increases together with the increase of contact stiffness in relation to structural stiffness. The best visualization of the phenomenon is provided by the research conducted on turning and boring lathe units for the two, most extreme positions of the slide's travel. With the increase of the slide's travel, the contact stiffness decreases, and it is the structural stiffness that becomes predominant. Picture 2. depicts clearly that together with the increase of the slide's travel (structural stiffness increases as well) one can observe the increase of discrepancies between values of static stiffness indicators being determined by both methods. Despite an obvious relationship occurring between the difference in stiffness indicator and the contact stiffness, it was impossible to identify clear correlation between the discrepancy of stiffness indicators and the hysteresis area of the stiffness characteristics or discrepancy between stiffness indicators and the absolute value of the hysteresis.

5. THE INFLUENCE OF SERVO-DRIVE PROPERTIES

Two types of loading of the working unit can occur while static stiffness research. Type one: the exciting force tightens the working unit to the guide way, type two: the exciting force operates towards the travel direction of the working unit (parallel to the guide ways). In the first case, the discrepancies between stiffness indicators obtained due to conventional method and DDSS were insignificant. The second case involves shifting of the loading by the servo-drive thus not only mechanical elements but also the electrical unit of the drive is influencing the stiffness (Picture 3.).

a) b)



Picture 2. Sample results of static stiffness examination of the turning and boring lathe KDC-700/800 N, with the slide's travel: minimum (a); maximum (b).

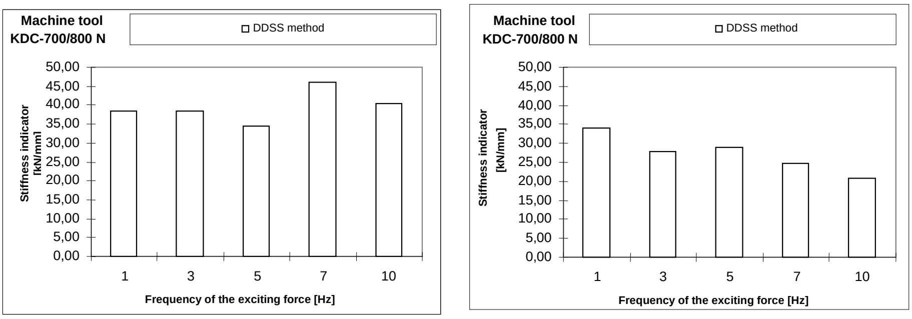
One of the crucial aspects of the research was the disclosure of the quantitative influence of the speed multiplication indicator k_V on static stiffness. The influence is fairly insignificant in case of the conventional method. The discrepancies in the determined stiffness indicators do not exceed several per cent, regardless what is being propelled either the ball screw or the ball nut. In case of stiffness indicators determined along the dynamic way, the discrepancies were much more significant reaching few hundred per cent for the lowest frequencies of the exciting force. The tendency relaying on the decrease of the stiffness indicator value in relation to the increase of the exciting force frequency can be clearly observed. The aforementioned phenomenon is brought about by the servo-drive which cannot keep up with the fast changing force [6].

The comparison of axis stiffness for CNC tool determined through both methods: conventional and DDSS one leads to the following generalizations:

- both types of stiffness differ in quality and quantity, i.e. stiffness determined along the DDSS method is not a constant quantity, since it changes together with the frequency, amplitude, the constant force component, K_v coefficient or the drive type (ball screw drive or ball nut drive), whereas the static stiffness determined through the use of conventional method is approximately constant (dependant heavily on the drive type applied),
- stiffness determined along DDSS method, in case of the ball screw drive, is generally lower than the one determined through the conventional method. Depending on the frequency, amplitude, constant exciting force component, or K_v coefficient, both stiffness types may vary 2-4 times even,

in case of the ball nut being propelled, axis stiffness for the CNC tool determined by the use of DDSS method is either similar to the stiffness level determined through the conventional method or few per cent higher. This situation takes place regardless the frequency applied, amplitude, constant exciting force component, or K_v coefficient.

a) b)



Picture 3. Results of the static stiffness research of the turning and boring lathe KDC-700/800 N (for the maximum spindle travel) towards: a-axis X, b-axis Y (the loading transferred by the servo-drive)

6. CONCLUSIONS

Relaying on the results provided, it is possible to formulate the following thesis: static stiffness indicator determined through DDSS method constitutes an intermediate value between static stiffness indicator and dynamic stiffness indicator; however it is closer to static stiffness. Thus it is senseless to compare directly the DDSS stiffness indicator with the static one. Forces operating during machine tool's performance (machine cutting forces, inertial forces) are dynamically changeable. Consequently, stiffness indicator determined along DDSS method appears to be more successful measuring tool for describing stiffness properties (than the value of the stiffness indicator determined through the conventional method).

7. REFERENCES

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