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EVALUATION OF NC LATHE PROPERTIES

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Abstract: *The assessment of machine tools taking into account geometrical and form deviations of machined workpiece and the quality of its surfaces for machining tasks can be a very useful tool in production planning. The aim of this paper was the conduction of quantitative assessment of structure and operational characteristics of a numerically controlled lathe. Using original assessment method, assessment index values were obtained based on measured geometrical deviations of a machined workpiece, as well as waviness and roughness of its surface. Such indexes are expressed as dimensionless numbers connected to ISO tolerance classes.*
Key words: *CNC lathe, assessment of properties, assessment index*

1. INTRODUCTION

Achievable machining accuracy and quality of machined surface are some of basic criteria for the assessment of machine tool operational characteristics. Research on machine tools is conducted in order to verify their operational qualities, to assess possible methods of improving their structure, as well as to determine the influence of particular factors which define static, dynamic and thermal characteristics. It is sought to determine the relationship between machine tool characteristics and the possibility of machining a workpiece with dimensions falling into a specific tolerance class. Widely applied methods of machine tool testing have many limitations. They apply to measurement procedures, methods of machine tool loading, possibilities of relating research results to specific elements of the structure, as well as to confirm research results with reference values.

The aim of this research was the conduction of quantitative assessment of structure and operational characteristics of a numerically controlled lathe. A method for testing machine tools was applied, presented in the paper (Skoczyński & Krzyżanowski, 2002). Basis of this method consists in considering real-life working loads, realised machining tasks, as well as geometric and form accuracy and surface quality of machined workpieces.

2. ANALYSIS OF MANUFACTURING TASKS

The scope of manufacturing tasks is the most important factor in searching for functional characteristics and properties of machine tool structures, as well as the factor integrating particular phases of their constructing. The analysis of machined surfaces on a particular machine tool can be used to determine the distribution of loads in its working space. This allows defining representative load states of the structure (Krzyżanowski, 1990).

Definition of representative methods of fixing machined workpieces and for various types of machining is another step of the assessment method. It is estimated that at least 80% of workpieces machined on lathes are fixed in different types of chucks, mainly self-centering. Therefore, a three-jaw self-centering chuck can be treated as a representative. The analysis of machining tasks allows stating that among most often realised machining task are straight turning and facing. Due to the fact that total length of longitudinal motions of a tool in order to realise machining of the analysed workpiece group would probably be much larger than total length of lateral motions, the straight turning was selected as a representative operation.

During operation, machine tool realises particular work cycles. They are based on relative movements of components which result in changes of system structure and load state. Based on analyses of conducted machining tasks it is possible to divide machine's working space to elementary machining zones taking into account the probability of cutting forces occurring in these areas. Such probabilities will be presented as weight coefficients w_{ij} used to determine assessment indexes of machine tool structure. Application of weight coefficients w_{ij} during the calculation of assessment indexes will enable considering the distribution of machining tasks in the working space of a machine tool.

The scope of tests was a numerically controlled toolmaker's lathe TL1 by HAAS. It enabled carrying out all operations designated for universal lathes. Maximum distance between centres was equal to 762 mm at swing diameter over bed equal to 406 mm. The lathe as a standard was equipped with a three-jaw chuck Samchully FTC-190H (length of jaws – 43 mm).

Based on the rule of lathe's turning area division to elementary zones with the consideration of the working space size and the size of a standard chuck, a division of the assessed lathe's working space was conducted to six representative elementary zones (A-F) which contain 85% of all workpieces from the analysed group. In the next step, normalisation of weight coefficients w_{ij} was conducted interpreting them as probability of the appearance of cutting forces in these fields (Fig. 1.).

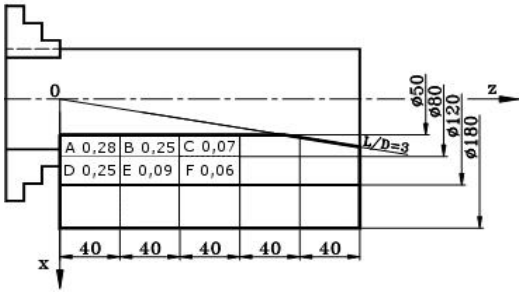

Fig. 1. Normalised weight coefficients in representative elementary machining zones (A-F)

3. ASSESSMENT INDEXES

For the assessment oof lathe structure properties indexes defined in article (Skoczyński & Krzyżanowski, 2002) were used. They represent qualitative and quantitative influence of a given property on operational characteristics of a machine tool.

They enable conducting total and partial assessment of selected machine tool characteristics. Additionally, these indexes allow comparing the values of determined indexes with reference values.

In the adopted assessment method (Skoczyński & Krzyżanowski, 2002) several indexes were chosen. Global index W_g was used to assess properties of the structure, taking into account machining tasks performed by a lathe in the entire working space. It is defined as weighted mean of assessment index values obtained based on measurements of geometric deviations, form deviations and surface roughness conducted on a group of machined parts which with their dimensions fall into representative areas of lathe working space. While local assessment index W_{ij} was determined in each of selected representative machining zones. In relation to deviations these indexes had various values corresponding to quantitative values of one of ISO tolerance classes.

To achieve independent assessment of static, dynamic and geometrical properties of a machine tool, global and partial indicators were introduced (Skoczyński, 2001). To assess static properties of a lathe, global W_g^s and local W_{ij}^s indicators were used. In assessing form errors, indicators W_g^k and W_{ij}^k, correspondingly, were used. Roughness was assessed with the use of global indicators W_g^c and local W_{ij}^c.

4. TESTING RESULTS

Testing of lathe operation according to ISO 1708:1989 is carried out in finishing machining conditions. Workpieces should be made from easily machined steel or cast iron. Therefore test pieces for experiments were made from C45 steel. Their dimensions were fitted to machining possibilities inside representative elementary zones (Fig. 1) with the consideration of the available machining chuck. Turning with the smallest allowance was carried out on a surface which was used as reference surface during the assessment of static properties.

The realisation of such assessment required carrying out geometry measurements of the workpieces obtained as a result of cutting tests. Static properties were assessed based on changes in turning diameter deviations caused by the action of loads connected with cutting of various samples at stepwise varying cutting depth (Fig. 2). Local assessment indexes were defined for cutting depth of 0.5 mm. Table 1 contains calculation results.

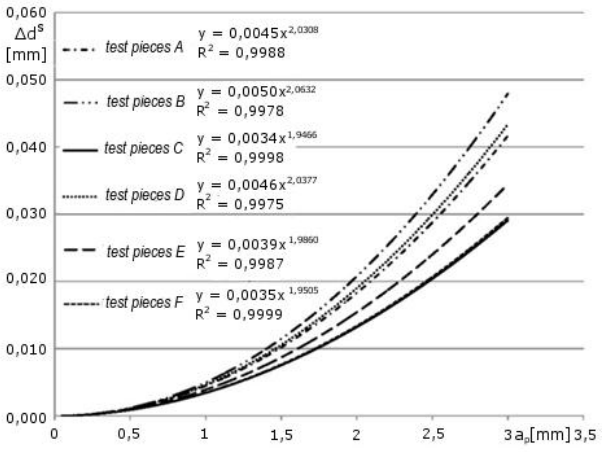

Fig. 2. Relationship between diameter deviation Δd^s of various test pieces from cutting depth a_p, determined in relation to reference cylindrical surface diameters of each piece.

Global assessment index for the structure and operational characteristics of the lathe was determined. It measured W_g = 4.59, which means that the tested lathe allows achieving an average of 5th ISO tolerance class in the entire analysed working space. In particular elementary machining areas local indexes did not exceed the value of 7, while the most negative impact on this result was the roughness of machined surfaces. From the assessed properties' point of view, the lowest index values were caused by static stiffness of the lathe, i.e. it had the most favourable influence on geometric and form accuracy.

Partial and global indicators	Representative elementary machining fields					
	A	B	C	D	E	F
W_{ij}^s	2,85	3,03	2,37	2,59	2,31	2,13
W_{ij}^k	4,23	4,29	4,48	4,65	3,89	4,43
W_{ij}^c	5,34	5,04	3,91	6,25	6,16	5,5
W_g^s	2,71					
W_g^k	4,35					
W_g^c	5,48					

Tab. 1. Comparison of assessment indicator values

Considering the fact that requirements connected with machining accuracy achieved on lathes for all operations fit in ISO tolerance class range from IT6 to IT12 it was found that the tested lathe fulfils all mandatory requirements connected to machining accuracy.

4. CONCLUSIONS

The applied method allows assessing the properties of machine tool structure and its operational features without the need of knowledge about the relationships between these properties and constructional configuration of its components, but based on machining tests on specially selected test pieces.

The method takes into account the character of machining tasks and machine tool load states connected to them, method of workpiece fixing and types of representative machining operations. The determination of partial assessment indexes in elementary machining zones enables identifying such lathe structure configurations, for which it does not fulfil the requirements connected to the achievable machining accuracy.

The proposed method and the established indexes and criteria can be implemented in evaluation procedures of various machine tools, but they need a particular adaptation to a specific type of machine. In this study the method was employed to test NC lathes. Experience gained in the course of the tests will be applied in working out manufacturer- and user-independent recommendations concerning the prototype tests. It can also be a theoretical basis for the standardization of acceptance tests in the area of evaluation of test piece machining accuracy.

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