

Analytical Determination of Error from Static Adjustment of Boring Heads Cutting Part During Combined Machining of Holes

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Abstract—In the publication is presented analytical studies about an analyze of of boring heads cutting part accuracy for combined tools for machining holes by cutting and burnishing. It was found that the accuracy of the static size of the tool when using triangular and square inserts is determined by tolerances of inserts sides. When using round inserts, static radius error depends only on insert radius error. The conclusions drawn show that by determining appropriate tolerances for elements of fixtures, the specified accuracy of the processed parts is ensured.

Keywords—error, accuracy, boring, holes

I. INTRODUCTION

The accuracy of the dimensions obtained in combined machining by cutting and burnishing of holes from hydro- and pneumatic cylinders largely depends on the accuracy of the cutting elements of the boring tool [1].

Analyzing the accuracy of machining when using tools with square, triangular and round inserts is essential for the process of static adjustment of the technological system in boring and burnishing of holes. [2],[3]. Using dimensional analysis to assess the influence of the geometric parameters of the tool on the accuracy, it is possible to minimize errors from combined machining of holes [4].

II. MATERIALS AND METHODS

The diametrical size of the boring head is determined by the position of the cutting elements. In modern metal-cutting tool designs, soldering of the cutting inserts is increasingly rare, preferring the use of non-returnable, mechanically fixed inserts. In this case, the accuracy of the diametrical size of the tool will be determined by the accuracy of the insert and the accuracy of the position of the socket for its installation [5],[6].

Fig. 1 schematically shows the installation of a square non-returnable insert in the boring head housing and the dimensional chain determining the static radius of the tool A_{Σ} [7],[8]. By projecting the dimensional chain onto an axis parallel to A_{Σ} , an expression for determining its size can be obtained.

$$A_{\Sigma} = A_T + a(\sin\chi'_r + \cos\chi'_r) + r(\sin\chi'_r + \cos\chi'_r - 1) \quad (1)$$

where: A_T – is the size of the tool body;

a – the width of the insert;

r – the radius of curvature at the tip of the insert;

Assuming that for each individual tool $A_T = \text{const}$ from formula (1) the following expression for the static radius error can be obtained:

$$\omega_{\Sigma} = T_a(\sin\chi'_r + \cos\chi'_r) + Tr(\sin\chi'_r + \cos\chi'_r - 1) \quad (2)$$

From the dependence (2) it follows that the accuracy of the static size of the tool is determined by the tolerances of the width a and the radius r , as well as by the auxiliary setting angle χ'_r . [9] The degree of influence of these three factors on the accuracy of the tool is different. The influence of the width of the insert and the radius of curvature can be compared by the ratio of their transmission coefficients ξ_a and ξ_r [10]:

$$\frac{\xi_a}{\xi_r} = \frac{\sin\chi'_r + \cos\chi'_r - 1}{\sin\chi'_r + \cos\chi'_r} \quad (3)$$

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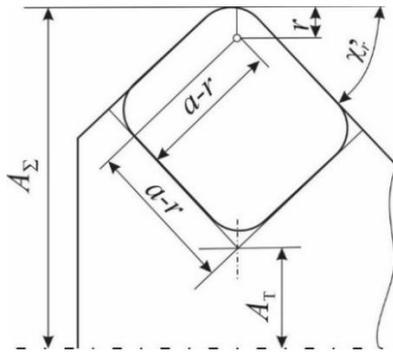


Fig. 1. Dimensioning square insert

The graphical dependence for $(\xi_a)/\xi_r$ as a function of the auxiliary setting angle χ_r' is shown in Fig. 2. It can be seen from it that the influence of the radius of curvature error is significantly weaker than that of the width of the insert, reaching its maximum at $\chi_r' = 45^\circ$ [11].

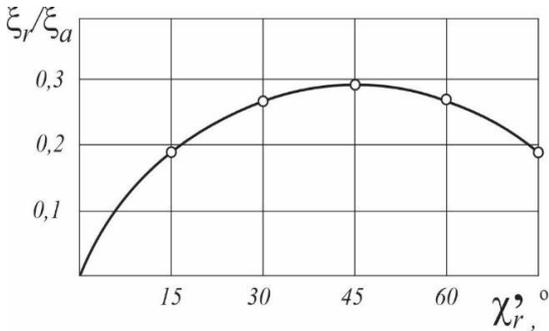


Fig. 2. Dependence of the ratio of the transmission coefficients ξ_a and ξ_r on the auxiliary setting angle

To express the influence of the auxiliary setting angle on the accuracy of the tool, it is convenient to rework formula (2) by setting $T_r = kTa$. This yields:

$$\frac{\omega_\Sigma}{T_a} = (1+k) (\sin\chi_r' + \cos\chi_r') - k \quad (4)$$

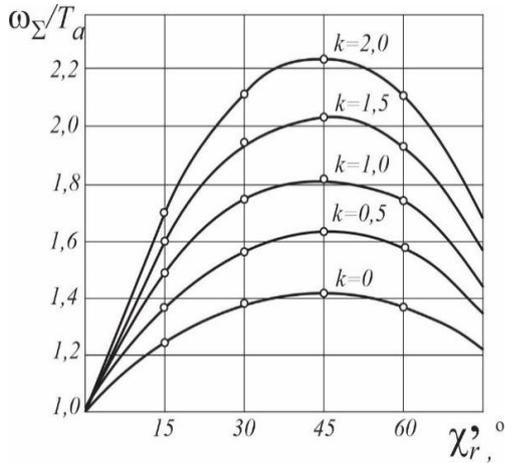


Fig. 3. Dependence of the ratio $(\omega_\Sigma)/Ta$ on the auxiliary setting angle χ_r'

Dependence (4) is presented graphically in Fig. 3. It can be seen that with increasing χ_r' from 0° to 45° the total error of the static radius of the tool grows and reaches its maximum at $\chi_r' = 45^\circ$. The intensity of the increase in the total error is the smallest at $Tr=0$ and increases with increasing Tr .

An analogous expression for the error of the static radius of the tool can be translated for other shapes of the non-flowable plate.

Fig. 4 shows schematically the establishment of a triangular, and Fig. 5 - of a round insert.

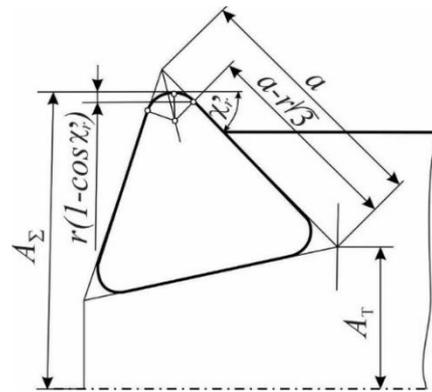


Fig. 4. Dimensioning triangle insert

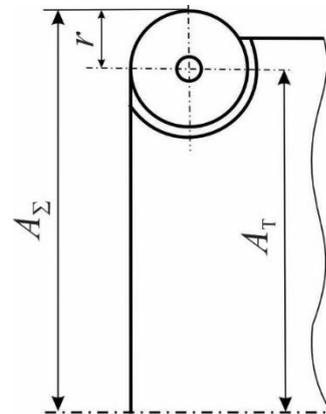


Fig. 5. Dimensioning round insert

The expressions for the static radius of the tool and its error in these two cases will have the form:

For triangle insert

$$A_\Sigma = A_T + a \quad (5)$$

$$\omega_\Sigma = \sin\chi_r' + Tr (\sqrt{3}\sin\chi_r' + \cos\chi_r') \quad (6)$$

For round insert:

$$A_\Sigma = A_T - r \quad (7)$$

$$\omega_\Sigma = Tr \quad (8)$$

For round non-returnable inserts, the static radius error of the tool depends only on the error of the insert radius.

For triangular inserts, as well as for square inserts, the static radius error depends on three parameters: the insert

size a , the radius of curvature r and the auxiliary setting angle χ'_r .

To compare the insert size a and the radius of curvature r , the ratio of their transmission coefficients is used:

$$\frac{\xi_r}{\xi_a} = \frac{\sqrt{3}\sin\chi'_r + \cos\chi'_r - 1}{\sin\chi'_r} \quad (9)$$

III. RESULTS AND DISCUSSION

Graphically, the dependence (9) is shown in Fig. 6.

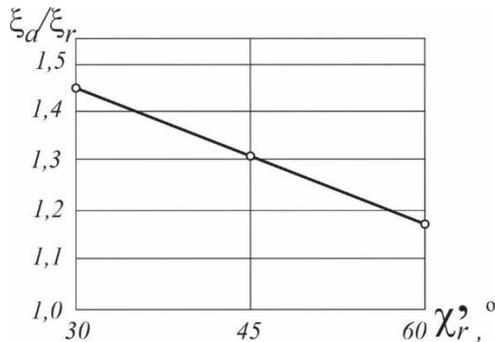


Fig. 6. Dependence of the ratio of the transmission coefficients ξ_a and ξ_r on the auxiliary setting angle

The influence of the auxiliary setting angle on the static radius error is expressed by the dependence:

$$\frac{\omega_\Sigma}{T_a} = \sin\chi'_r + k(\sqrt{3}\sin\chi'_r + \cos\chi'_r - 1) \quad (10)$$

The dependence (10) is presented graphically in Fig. 7.

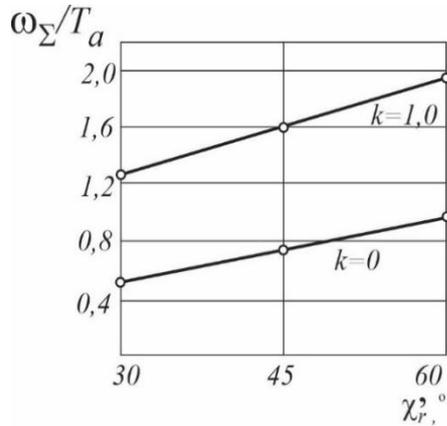


Fig. 7. Dependence of the ratio $(\omega_\Sigma)/T_a$ on the auxiliary setting angle χ'_r

With the increase in the auxiliary setting angle χ'_r in the range from 30° to 60° , the error of the static radius of the tool increases. The absolute increase in the error increases r with increasing χ'_r [12,13].

In the course of the technological process, the size of the static radius changes. The factors that influence it are: elastic deformations arising from the cutting force between the support surfaces of the boring head and the insert;

thermal deformations; dimensional wear of the cutting insert.

The first two factors are insignificant for the boring heads of the considered class.

The dimensional wear of the tool is a systematic factor that changes the static radius in the course of the technological process. The intensity of its influence can be estimated from the process accuracy diagram. Fig. 8 shows an example of the accuracy diagram of a stable technological process.

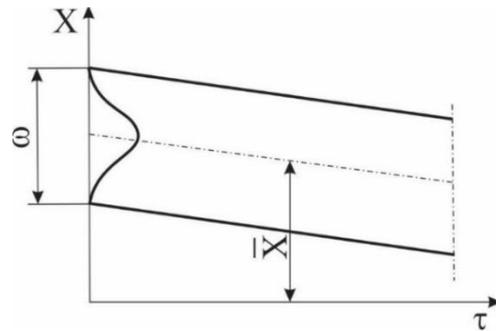


Fig. 8. Accuracy diagram of a stable technological process

The influence of dimensional wear on dimensional formation is expressed by the linear regression equation for the average size of the machined parts:

$$\bar{X} = \tilde{a} + \tilde{b}\tau \quad (11)$$

From equation (11) it follows that for a certain period of time, $\Delta\tau$, of operation at one setup, the change in the static size of the tool, $\Delta\bar{X}$, as a result of dimensional wear will be:

$$\Delta\bar{X} = \tilde{b}\Delta\tau \quad (12)$$

The error for one part of the batch, $\Delta\bar{X}_{det}$, can be determined by replacing $\Delta\tau$ in formula (12) with the time spent on cutting, T_{det} , during its processing.

$$\Delta\bar{X}_{det} = \tilde{b} \cdot T_{det} \quad (13)$$

IV. CONCLUSIONS

Analytical relationships have been obtained to determine the influence of the geometric parameters of cutting carbide inserts with different configurations (triangular, square, round) on the static adjustment during boring. These, together with the magnitude of the dimensional wear of the inserts, can serve as a basis for creating a mathematical model of the accuracy of the combined hole machining process[14].

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