Systematization of accuracy indices variance when modelling the forming external cylindrical turning process

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Abstract. The article considers the problem of accuracy deviation systematization for external cylindrical turning, proposed a hierarchical approach to the evaluation of these deviations, an approach to the analysis of nesting accuracy metrics, as well as, the common scheme of identification of deviations of the accuracy metrics for party billets in external machining were proposed.

Key words. modeling of the forming process, accuracy metrics hierarchy, identification of deviations, batch work pieces.

1. Introduction
The precision prediction can be attributed to the most important tasks of technological design in today's environment. Objective forecast is required for process parameters selection for unused equipment, and analysis activities to improve the quality of required parameters [1].

The designer specifies the forming accuracy requirements for various parts of even moderate complexity by several tens of indicators. Accuracy metrics of details are regulated by GOST [2]. The analysis of the content has shown that the definitions are focused only on conformity assessment. The entire set of indicators cannot be represented in a single system. None of them expressed in a vector, so if you measure each indicator separately, it is impossible to evaluate them geometrically. However, each of the indicators, one way or another, affects the quality of performance part assignment function. Therefore, for example, a statistical analysis of the process accuracy by one single indicator may not be effective. The more complete description of the set of indicators, the more effective management will be.

Introduction of the quality management system at the enterprises involves the use of processes monitoring, which is necessary to establish quantitative measurable indicators [3] [4]. These include indicators of product quality and process parameters. Therefore, it was decided to use the maximum amount of to obtain a more complete characterization of the process to the task of modeling.

2. Basic part
The goal of modeling is as follows: identifying opportunities for improving the accuracy of the products and reduce the cost of run production jobs processes on the jobs of morphogenesis. The result of the simulation is representation of vectors in each measure of accuracy of all details that are generated during execution of the job in the workplace in a single coordinate system; the distribution of their values in the party, the dynamics of the cost of the process taking into account all additional operations [5].
For solving the problem the assumption was formulated that, in accordance with the contents of the details forming process, the accuracy of each element of the workpiece is characterized by the integral (total) index, which consists of hierarchically nested into each other constituents (nesting is represented in Figure. 1).

![Diagram](image)

**Figure 1. Scheme of components deviation of the measured diameter of the cylindrical element:**
- a) size designation in the drawing;
- b) scheme of the two-point measurement;
- c) element of the deviation profile;
- d) element of the deviation waviness.

As follows from the figure, the appointing of engineer a single measurement to the diametric size point-to-point method will have the following results:
- the actual value of the diameter (Fig. 1. b.) is actually estimated, as the profile deviation and waviness are ignored due to errors in processing, which the designer assumes within the tolerance;
- measured values are derived from the diameter of the adjacent circumference (Fig. 1. c.) deviations of the profile from the adjacent and deviation of the waviness profile (Fig. 1. d).
If the angular coordinates of the profile deviations and the waviness are not specified, the contribution of these deviations in the measurement results is unknown. To sum them up geometrically, it is necessary to introduce a common system of coordinates.

In order to simulate the formation process deviations, it is necessary, moreover, to represent the measured indicator of accuracy of the detail manufactured item as a consequence of successive overlapping components of the total impact factors during the production cycle.

So, scallop’s roughness is a consequence of single tooth contact of the tool with the amount of the allowance. Its value depends on the parameters of the movements, geometry – on the geometry of the tooth in the plan. Core complex billet excessive roughness can cause wrinkling scallops, although symmetrical clamping of elements will not affect the position of the workpiece [6].

Roughness is a part of waviness. Waviness is a periodic deviation from the adjacent line profile. Technologically it is a consequence of the radial or end play of the teeth of milling cutters and grinding wheels, imbalance circles, beating spindles. It must be taken into account when the workpiece positioning the prisms, the cartridges with a small number of clamping elements and a small area of the contact points. Waviness is one of the components of the deviation profile either in the transverse or longitudinal direction.

The profile deviation (nonroundness, crookedness) is a consequence of fluctuations in the allowance due to the deviations of the workpiece, error-based, insufficient rigidity of the movable joints, and non-rigidity of the tool. Each of them contributes to the deviation of the shape.

Size deviation in cross section of detail manufactured item, measured in 2-point scheme, in each point is the sum of the deviations that occur during morphogenesis [7]:

- module adjustment deviation;
- settings for the size deviation;
- adjacent deviation from configuration due to insufficient rigidity;
- shape deviation due to the non-rigidity of the technical system;
- waviness deviation due to the runout of the grinding wheel.

The next levels of the hierarchy are crookedness of the element items axes and the deviation of the relative position of the axes.

The nested variance analysis requires a single technological system of coordinates that characterize the machine tool system as a whole. Usually it is considered to be self-sufficient. But to trace the link between the conditions and the actual value of the deviations, both in morphology and in the measurement, it should be used in both of these processes.

Based on the objectives, inputs include the following initial information:

- in the workplace: code of the workplace; the scheme of machine tool system composition; data on the accuracy of its individual modules; the calculation of the initial position of the modules in the processing coordinate system; selecting controls.

Actual production tasks are performed in a planned restrictions (set optimization process will be done with their account):

- Planned quantity of good parts.
- Acceptance criteria.
- Performance incentives for compliance with quality assurance.
- Required time of delivery of the products.
- Products delivery schedule.
- Incentives indicator for adherence to the delivery schedule.
- Cost limit of job processing
- Incentives indicator for cost reduction.
- The number of blanks in the party.

Next, data for the preparation and enforcement of basic operation production jobs is entered:

- getting machine tooling; input accuracy parameters and time consumption;
- receiving tool; input accuracy parameters and time consumption;
- the receipt of funds control; input time consumption;
- base snap-in; input time consumption;
- calculation of the position of the tooling in the machine coordinate system;
- base tool; input time consumption;
- setting the size in the coordinate system of the machine; input time consumption;
- processing and measurement test parts; input time consumption;
- planning cycle control and regulation control operations;
- coordinate system calculation of the tool in the machine coordinate system;
- calculation of time consumption to complete the operation.

Within a single task accuracy indices of the elements of the machining system are usually considered systematic. Each blank, at the same time, based randomly, and because they are numerous and they are often not identified, it is considered that the indicators of the accuracy of the workpieces are simply unknown. Actually, even if these values are not known to the technologist, in fact, each workpiece is inherent in the full set of indicators. When measuring, they just become known, and identified. Therefore, for efficient simulation, at least random values of each individual parameter that affects the final accuracy of the machining of the part must be specified. These include all accuracy metrics, as well as the hardness and strength of the material machined parts. A condition is made in the task that each of them can meet the requirements of the operating map, but in real life doesn't have to match. Depending on the processing technology in the previous operations, each of them is characterized by a well-defined distribution law in the party with the largest scalar value. And also a well-defined distribution of deviations in the coordinates of the workpiece is typical.

Identification of the party involves procurement structuring and development of indicators for each component. The structure of the workpiece when processing each set consists of supporting and processing complexes. The complexes include separate elements that define a single coordinate plane, and the elements will include structural components, each of which defines the coordinate of a single point of contact.

The first stage of identification is allocation to individual blanks of the highest values of the scalar variance of the indicators, starting with the simplest ones (waviness, profile, size of the adjoining, the axes deviation). Distribution is carried out in the following order:

The source data formation:
- job matching tolerance;
- the share of non-compliant blanks;
- the highest value of the deviation;
- the expectation of the variance in party relative to the middle of the field of tolerance;
- the value of Sigma;
- choice-of-law distribution;
- building distribution curve.
Figure 2. Scheme of modeling process of forming the party preparations in the workplace.
Histogram plotting [8] [9] [10]: intervals formation taking into account the division value of the measuring means; determination of the spacing of the party blanks; calculation of the frequency of exposure interval;

The second stage is the identification of the deviation vector in the coordinate system of the workpiece [5]: setting the coordinate system of the workpiece (origin, axis direction); technological constraints on variations of the distribution of deviations input; setting coordinates of the largest vector value (specific or random distribution); distribution equation construction of variations in workpiece coordinate (if necessary).

According to the results of the identification information model of a single workpiece is formed. Prepared system of the source data is used in the modeling process (Figure 2).

3. Conclusion
Each structural element of the operation model allows to calculate the amount and position deviation. At the end of all forming operation simulation, distribution of the largest (smallest) vectors values of all the variances in the volume of the batch according to the normal Gaussian distribution is formed.

The scope of the technique:
• the most effective method for learning tasks (learning system errors, processes optimization, knowledge testing);
• application techniques in plant cash-flow problems:
• direct tasks (accuracy prediction when entering the dimensions in the technological system; the opportunity to influence the process of manufacturing parts and provide the required parameters taking into account the individual characteristics of the machine);
• inverse tasks (parts, equipment and tooling state diagnosis; analysis of the minimum quality requirements of the party preparations to ensure the required quality details).

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