EXPERIMENTAL MEASUREMENTS OF SHAPE DEVIATIONS OF MACHINE COMPONENTS

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The paper deals with the analysis of shape deviations, causes of their origin and offers their brief overview. At the same time it points out the methods and possibilities of measurement of shape deviations by means of contact and contactless techniques. The paper focuses also on errors which might influence the measurement results. The main aim of the presented paper is practical measurement of shape deviations by means of the most frequently employed measuring devices. It provides the overview of the particular measured values and presents the view of effectiveness, simplicity and accuracy of the individual measuring methods and devices.

KEYWORDS
tolerance, measurement errors, deviations

1 INTRODUCTION
Measurement of geometrical deviations represents in practice rather significant line of measurement. Such measurements represent 90% of all measurements performed in engineering industry. Demands regarding the employed measuring instruments and procedures are constantly increasing due to continual increase of production tolerances [Mascenik 2014a]. At the same time demands laid on surface quality of products increase. Geometrical tolerances currently range within the scope of micrometric and nanometric values. To assure such qualitative requirement the specialized measuring devices have been credited high prominence which through connection with a computer station offer extensive possibilities of simplification and fast evaluation of surface quality. Uncertainty of measuring by these special measuring devices reaches micrometers and therefore it represents the first-rate yet adequately expensive group of measuring devices [Gaspar 2013].

The presented paper is devoted to analysis of shape deviations in component check and to characteristics of contact and contactless measuring methods as well as to errors influencing the measuring results [Bicejova 2013a]. Special attention is paid to practical measurement and evaluation of the measured shape deviations. The paper presents determination and comparison of the measured values of geometrical deviations with diverse measuring devices and methods [Salokyova 2016a].

2 ANALYSIS OF SHAPE DEVIATIONS IN COMPONENT CHECK
Surface of each component constitutes of functional and free areas. Dimensions determining the functional areas must be tolerated to assure correct function of storing or assembly. Dimensions of free areas lime and determine the component shape yet its observation can be significant from the point of view of function. Magnitude of tolerances of the dimensions is selected to assure their observation under standard production and measuring conditions. These tolerances are determined by means of a joint drawing record [Salokyova 2016b].

Prerequisites of general tolerances and method of their prescription in the drawings are specified by the following standards: STN ISO 2768 standard – 1, includes permitted deviation values regarding the following:

- length dimensions,
- interrupted edges,
- angle dimensions.

STN ISO 2768 standard – 2, specifies general geometrical tolerances regarding the following:

- straightness,
- flatness,
- perpendicularity,
- symmetry,
- circumferential flapping [Halko 2013].

Produced parts cannot be ideal as to accuracy. As to product geometry the shape of actual surface of a workpiece differs more or less from the shape of nominal surface. In fact, dimensions prescribed by the drawing are only theoretical. In production of parts occurred inaccuracies are caused by selected production technology, by production process and by human factor. The actual dimension of the part differs from the ideal one in certain respects. Differences from the nominal shape are referred to as deviations. Prescription of limits and of inaccuracies acceptable in production of parts is determined by tolerances, Tolerances determine just the deviation of actual characteristics from its prescribed nominal dimension [Mascenik 2012]. Each measurement result is error bound. The errors can be expressed as the absolute or the relative ones. The absolute error represents the difference between the measured and actual value of the measured quantity [Bicejova 2016a]. Ratio of absolute error and appertaining conventional actual value of the measured quantity is relative error. The measurement error represents a total value involving a number of partial errors, some of which occur systematically or randomly.

2.1 Sources of Measurement Errors
The most significant sources of measurement errors include the following:

- device errors: refer to errors stemming from imperfection of the applied measuring devices. Some of the errors occurring in production are eliminated; a producer indicates the values of other errors in the form of correction curves; the rest of the errors are indicated by the producer as the maximal permitted ones,
- installation errors: refer to errors stemming from demerits of connection, storage and setting of the measuring instruments and from mutual influence of measuring instruments, etc.,
- errors of method: refer to errors stemming from imperfection of the employed measuring methods,
- observation errors: refer to errors caused by imperfection of an observer,
- calculation errors: refer to errors occurring by processing of the measured values.
3 CONTACT METHODS OF MEASUREMENT DEVIATIONS

3.1 Measured sample

Figure 1 shows the model of a machine part in case of which measurements of geometrical tolerances were performed. The sample was employed in measuring of collinearity between areas 1-2; 3-4, 2-6; 1-5 and perpendicularity between areas 1-4 [Mascenik 2016a].

The measurements were carried out with different measuring devices: SMS Rapid Thomet and contourgraph MarSurf XC 20. Their principle is based on contact measurement. These devices use contact sensors, but their accuracy is different due to principle of activity and to used measuring method [Bicejova 2016b]. The devices use different software for measured value evaluation. The first used measuring device was a 3D coordinate measuring machine Rapid by THOME Präcision, which is a portal SMS for high-speed scanning. It is recommended for measuring of specific elements, in many positions and under various angles. It is characterized by high accuracy, robustness and low demands for maintenance [Smeringaiova 2016].

| Type                        | Rapid Thomet                                      |
|-----------------------------|--------------------------------------------------|
| Measuring features          | Scanning geometrical shapes – circle, cylinder, cone, plane |
|                            | Scanning of curve and common area curves          |
|                            | Self-centering scanning of grooves, holes and hollows |
| Resolution                  | 0.0005 mm                                         |
| Measurement uncertainty in accordance to ISO 10360-2 | 2.2 + (L/350) µm, L – measured length in mm |

Table 1. Features of Rapid device

The first used measuring device was a 3D coordinate measuring machine Rapid by THOME Präcision, which is a portal SMS for high-speed scanning. It is recommended for measuring of specific elements, in many positions and under various angles. It is characterized by high accuracy, robustness and low demands for maintenance [Smeringaiova 2016].

Figure 3. Coordinate Measuring Machines Rapid

The measuring device SMS Rapid, which was used for measurement, was equipped with a measuring software Metrolog XG [Mascenik 2011]. This software requires simple operation and extended graphical menu enables quick and effective measuring even to not trained users after couple of days.

Figure 4. Contourgraph Mar Surf XC 20
The other used measuring device was a countourgraph MarSurf XC 20, which is suitable for quick and simple evaluation of contours, components, tools or jigs. The moving part PCV 200 with replaceable measuring arm enables movement in X-direction (direction of feed) and movement in Z-direction (direction of scanning). In the direction of feed the measuring is done by an incremental sensor and in direction of scanning by an inductive sensor of high accuracy and linearity [Murcinkova 2013].

| Scanning force (Z-axis) | 1 mN – 120 mN |
|------------------------|----------------|
| Resolution (Z-axis) related to sensor tip | 0.5 mm with measuring arm 350 mm long |
| Resolution (Z-axis) related to measuring system | 0.04 µm |
| Positioning accuracy (both X and Z axes) | 1 µm |
| Sensor tip radius | 25 µm |

**Table 2. Features of MarSurf XC 20**

Evaluation and operation is carried out by software MarWin which enables to set scanning parameters as the measuring arm automatic dropping and rising, scanning speed, positioning before and after measuring as well as standard and segment profile scanning [Mascenik 2016b].

4 EVALUATION OF THE MEASURED DEVIATIONS

The first step taken in the measuring was calibration of instruments in order to determine accurate values. Consequently, by means of a scan head of the measuring device Rapid three points in the area 1 and 4 were scanned. The three points were selected to allow the device to define the plane by means of points in Cartesian coordinate system. The software was employed in selection of the geometrical deviation which should be measured – perpendicularity. The measurement result is a measurement record containing the deviation values evaluated by measuring software [Bicejova 2013a].

Collinearity deviation of areas 3 and 4 represented other measured deviation in this case (Fig.5). Deviation value is of 0.001 mm and falls within the tolerance field.

| Measured geometrical deviation | Rapid | MarSurf XC 20 |
|-------------------------------|------|--------------|
| perpendicularity 1 - 4        | 0.011 mm | 0.01 mm |
| collinearity 2 - 6            | 0.005 mm | 0.002 mm |
| collinearity 1 - 5            | 0.005 mm | 0.002 mm |
| collinearity 1 - 2            | 0.014 mm | 0.010 mm |
| collinearity 3 - 4            | 0.001 mm | 0.002 mm |

**Table 3. Overview of the values of measured geometrical deviations**

5 CONCLUSIONS

The measured values of the shape deviations have proved that even in case of diverse types of measuring devices and different measuring methods observed can be negligible measurement deviations which might be the consequence of applied measuring method, of human factor, of environment influence and of measuring period. The term “measuring time” refers to measurement prior to or after calibrations of the respective measuring device [Mascenik 2014]. The aim of the paper was to point out the alternative measurement of perpendicularity and comparison of the measurement results in case of randomly selected component.

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