THE APPLICATION OF NEW RULES OF GPS IN STRUCTURAL PRODUCT REQUIREMENT

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Abstract
The approach of the constructer and designer of the products and its components is based on the restrictions which are conditioned by model layout of geometric elements. The designer has to know the principles of GPS perfectly in order to be able to order geometric and proportional tolerances correctly. Moreover, he should have inevitable requirements and experience of tolerances production and measurement. When the designer orders important parameters and proportions, their boundary deviations and tolerances, he gives primary impulse to the way in which these parameters will be produced and controlled afterwards. The aim of the contribution is to show how a designer can noticeably contribute to the optimisation of control operations by the application of new requirements according to the standard EN ISO 1101.

Key words: *GPS; documentation; geometrical tolerances, designer.*

INTRODUCTION

The basic rule of the design realisation in the technical documentation is the relationship demarcation between length size and its deviation (which are the results of production and can be found out by measuring), and geometrical tolerances. The geometrical tolerances determine the characteristics of every geometrical feature, i. e. size, shape, direction and position. The definition of the tolerance zone from the point of view of its shape and size, and of its assignment to the assessed shape of geometrical feature has to be unambiguous, so that the regulation of every geometrical tolerance was unambiguous. The way of the control of tolerated feature depends on the definition of the tolerance zone. This is the reason why it is important to understand correctly the definitions of individual geometrical characteristics unambiguously stated by standards and to learn how to order them on drawings correctly (*Broncek, Handbook of Designer 1, 2015; Draganovska, Materials Science Forum, 2014; Broncek, Materials Science Forum, 2015*). But deciding about optimal tolerances is not easy. Firstly, the tolerance always has to have a relation to the function of part, and secondly, the stated tolerances have to be manufactorable. Thirdly, we have to be able to do unambiguous and repeatable measurement of all tolerances. The designer has to know perfectly the principles of GPS in order to be able to order geometrical and dimensional tolerances. Moreover, the designer should be aware of necessary requirements and experiences related to manufacturing and measurement of tolerances.
Geometrical product specification (GPS) is overall term for a group of international standards and determines basic relations between size tolerances and geometrical tolerances. GPS include the standards which are related to construction requirements, but also to their proper manufacturing process and product verification for the assessment of correct shape, or more precisely for the assessment of the correct geometry. One of the basic standards of GPS is the standard EN ISO 1101 which is the standard of geometrical tolerance and which determines basic requirements for use of geometrical tolerance when creating technical drawing documentation. In the framework of the inspection, the standard was completely restructured and fundamentally extended with new parts (e.g. the part about filters, filtration in GPS). New concepts, terms and definitions (e.g. theoretically exact feature TEF, connected feature, or specification element) are applied in the revised edition of the standard of the year 2017. These concepts, terms and definitions were not used in the previous editions of the standard, but nowadays they are valid for the definitions of geometrical features in the set of GPS standards. In the following part of the article, we would like to briefly introduce several changes and examples which are

included in this standard and which are related mainly to its application when ordering geometrical tolerances on drawings.

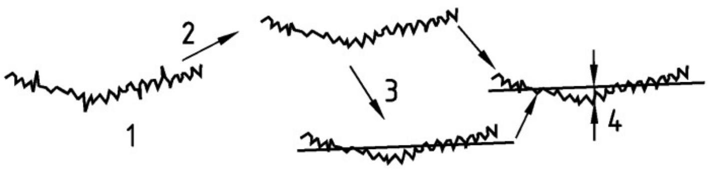
The main changes introduced by the standard EN ISO 1101 are:

- Tools for a specification of the tolerated feature filtration have been added and a line type for an illustration has been selected.
- Tools for tolerance of associated features have been added.
- Tools for shape characteristics specification by determination of referential feature and specified parameter assignment have been added.
- Tools which specify restrictions of the tolerance zone have been added.

The aim of the contribution is to show how a designer can noticeably contribute to the optimisation of control operations by the application of new requirements according to the standard EN ISO 1101.

MATERIALS AND METHODS

The GPS specification for GPS characteristics has to be stated in the technical documentation of a product. The GPS characteristics enable the determination of the deviations (of texture, shape, orientation and location) and the proportions having regard to the ideal features. The deviations of texture and shape are determined from one non-ideal feature. The deviations of orientation and location are situational characteristics which are determined from two non-ideal features. The proportion is a proper characteristic which is determined from one non-ideal feature. Figure 1 shows the GPS characteristics of shape for plane surface. The shape of characteristic is expressed as basic characteristic which is a situational characteristic between non-ideal feature and ideal feature, i. e. maximal distance between the smoothed feature and the plane.



Key
1 non-ideal feature
2 filtration
3 association
4 basic characteristic

Fig. 1 Example of determining GPS characteristics

The workpiece or feature is to be considered acceptable/good when the specification is fulfilled. Only that which is explicitly required in the technical product documentation shall be taken into account. The actual GPS specification stated in the technical product documentation defines the measurand. On a drawing, the geometrical tolerances are indicated in a tolerance indicator (tolerance frame vertically divided into two or more parts). The data in the tolerance frame are always ordered from left to right and the content of individual parts is explained in Figure 2.

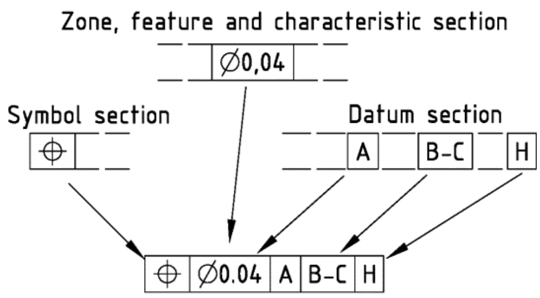


Fig. 2 Example of data arrangement in tolerance indicator

Table 1 shows the tolerance features which can be used in the second part of the tolerance indicator, in a different grouping and order for a zone, for a tolerated feature and characteristic. All specification features are optional besides those of them which determine the width of the tolerance zone. In the following part of the article, we briefly state the analysis of certain requirements which are used to control specific functions of the products. Filter specification stated in the part of the tolerance indicator is optional specification feature. The ordering of the filtration of tolerated feature is marked by specification combination which is composed of two elements. The first element of the order marks the type of the specified filter and the second element contains the nesting index, value of boundary wavelength λc or filter characteristics. The boundary wavelength λc and the filter type describe the features of the filter (characteristics of the filter or transfer function).

Tab. 1 Specification elements in the tolerance zone, feature and characteristic section of tolerance indicator [1]

Tolerance zone					Tolerance feature				Characteristic		Material condition and state
Shape	Width and extent	Combination	Specified offset	Constrain	Filter type	Filter indices	Associated. toleranced feature	Derived feature	Association	Parameter	
ϕ	0.02	CZ	UZ+0,2	OZ	G	0.8	Ⓒ	Ⓐ	C CE CI	P	Ⓜ
$S\phi$	0.02-0,01	SZ	UZ-0,3	VA	S	-250	Ⓖ	Ⓟ	G GE GI	V	Ⓛ
	0.1/75		UZ+0.1:+0,2	> <	Etc.	0.8 -250	Ⓝ	Ⓟ 25	X	T	Ⓡ
	0.1/75x75		UZ+0.1:-0,3			500	Ⓣ	Ⓟ 32-7	N	Q	Ⓕ
	0.2/ϕ4		UZ-0.1:-0,3			-15	Ⓧ				
	0.2/75x30°					500 -15					

According to the norm ISO 16610-21, the boundary wavelength represents 50% of the transfer characteristic. It means that the value of depicted frequency is considered to be permeable for boundary wavelength exactly 50%. The difference is principally given by 3 different characteristics of the filter, i.e. the bottom permeability, the top permeability and the filter permeability band. When we want to measure a shape, we use mainly the filtration with the bottom. The transmission band (band pass filter) has to be marked by the basic length of filters (in mm) which are separated by a hyphen "-". For the same filter type (G- Gauss' filter) a long-wave pass filter 0,25 is written first and then short-wave pass filter 8 is written afterwards (Figure 3). The tolerated features are all lines at the surface which are parallel to the datum A.

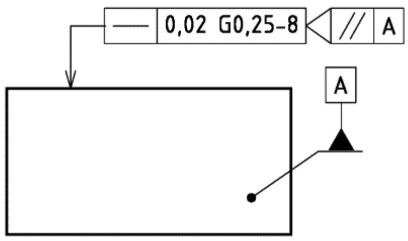


Fig. 3 Example of the specification for geometrical shape deviation – linearity with the given band pass filter for a filter type – Gaussian filter

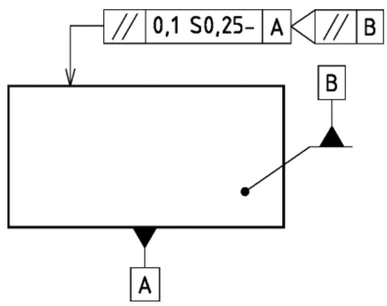


Fig. 4 Example of the specification of linearity tolerance zone when using long-wave spline filter

The example of the collinearity tolerance zone order when using long-wave spline filter is visualized on Figure 4. The specification S in the part of the tolerance indicator indicates that the spine filter is ordered. The value 0,25 represents the bound 0,25 mm. We are talking about a long-wave pass filter, because the hyphen "-" follows the value. While using this filter, the wavelengths shorter than cut-off value are removed. This is the reason why the specification refers to the feature which has been fil-

tered with a 0,25 mm long wave spline filter. The plane cross point indicator placed beside the tolerance indicator marks, that the specification is related to the line features parallel to the datum B. It means that every individual filtered line has to be parallel to the datum A and has to be located in the tolerance zone defined as the space between two lines 0,1 mm apart. The nesting index for open features, e. g. straight line, plane, cylinder in an axial direction, is stated in mm. The nesting index for closed features, e. g. cylinder in a peripheral direction, is stated in UPR – undulations per revolution. The units shall not be indicated.
Figure 5 shows the example of the specification for shape geometrical deviation – circularity. The specification G in the tolerance indicator element marks that ordered Gaussian filter and indication N determine the specification of the smallest circumscribed referential element/feature. The tolerated feature is considered to be closed and nesting index is stated in the values of UPR (undulation per revolution), because we are talking about the circularity specification. The value of 50% stands for 50% UPR and because a hyphen "-" follows the value UPR and it is a long-wave pass filter which removes short wavelengths (higher UPR numbers). This is the reason why the specification order is related to the feature which has been filtered with the help of 50 UPR Gaussian long-wave pass filter. The notation in the tolerance indicator element shows that every individual filtered circumferential profile line has to be located in the tolerance zone defined as the space between two concentric circles with 0,02 mm radius difference.
When we order the requirement for the feature which is open in two directions, e. g. a plane, we can order filters (various) for each direction. The plane cross-line indicator for a direction mark, in which the first stated filter should be used, is stated as the tolerance indicator. In order to separate two filter indications "x" is used. The second filter, which is related to the closed feature, is applied in the perpendicular direction to the first filter direction. For the function which is open in one direction and closed in the second direction, e. g. cylinder, the filter indicator for open direction has to be directed before filter indicator determined for the closed direction.

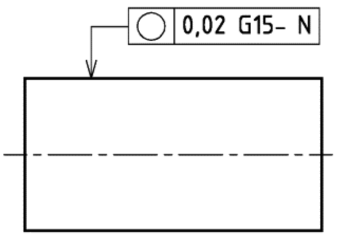


Fig. 5 Example of a specification for shape geometrical deviation – roundness specification

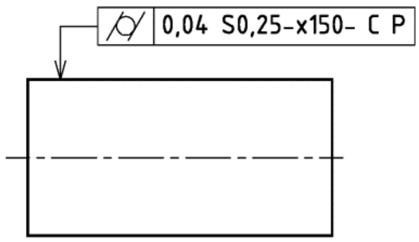


Fig. 6 Example of shape geometrical deviation specification – cylindricity specification

Figure 6 shows the example of the specification of shape geometrical deviation – cylindricity specification which is related to the profile point height (indicator P) in regard to the referential cylinder. The referential cylinder is associated by the method minimax (indicator C – Chebyshev) after the application of a long-wave spline filter with boundary values 0,25 mm in the axial direction and 150 UPR in the circumferential direction.
In the mechanical engineering enterprises, there is a standard requirement that the constructional solution has to be appropriate even from the technological point of view. Analogically, the requirement on the metrologicality of the construction should be applied to the construction, too. It means that the measuring operations when the quality control are realisable and appropriate from the point of view of the accuracy of the measurement and from the economical point of view. The designer can considerably contribute to the optimisation of the control operations by applying new requirements according to the standard EN ISO 1101. The decision, which measuring method or which measuring device will be applied for the given control operation, is based on the requirements which are included in the technical (manufacturing) documentation. The way how the constructer orders important parameters and proportions, their boundary deviations and tolerances gives the primary impulse to how these parameters will be controlled (*Kohar, Communications, 2014; Fabian, Communications, 2014; Martinec,*

2015; Mazinova, 2015; Stupavsky, Materials Science Forum, 2014). This enables the designer to predetermine the form and the content of the control operations. These statements are confirmed in the following part with the help of specific example.

RESULTS AND DISCUSSION

The aim of the experimental measurement was to measure and evaluate the deviation of proportions and geometrical shape deviations on a functional surface of a rotary component with the diameter ϕ 46,545 mm (Figure 7). The forging made of the material 16MnCr5 is an intermediate product for the component manufacture. The surface of the component should be modified by a nitriding and shaped by grinding afterwards. The ordered tolerance of proportions – or diameter is ±0,025 mm and shape deviation tolerance is ordered by cylindricity 0,02 mm.

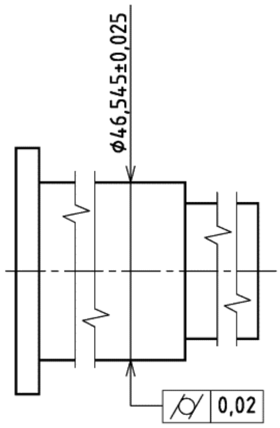


Fig. 7 The order of the proportions requirement and the specification for shape geometrical deviation - cylindricity

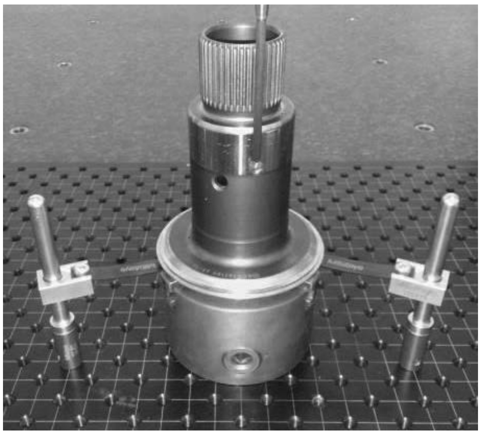


Fig. 8 The picture of 3D coordinate measuring machine CMM

The experiments were realized on the 3D coordinate measuring machine (CMM) from the company Zeiss with the help of the passive scanning probe which cooperates with the software Calypso. The evaluation of the measurement results gained on the machine CMM, which were measured on the same workpiece and under the same measurement conditions, can be considerably different which depends on the use of different methods of the results evaluation of the measurement by measuring software. The external diameter was measured by continuous method by scanning of the profile surface. An ideal geometrical feature – cylinder was affiliated to the gained profile by selected approximation method.

Tab. 2 Selected results from measurement of the proportion and geometrical deviation of cylindricity

Name	Actual dimension (mm)	Nominal dimension (mm)	Difference (mm)
Dimension specification			
Cylinder diameter method GG	46.5204	46.5450	-0.0246
Cylinder diameter method GN (E)	46.5305	46.5450	-0.0145
2-point diameter max.	46.5343	46.5450	-0.0107
Cylindricity specification			
Cylindricity method G	0.0115	0	0.0115
Cylindricity method N	0.0122	0	0.0122
Cylindricity method C	0.0112	0	0.0112

The approximation methods: the smallest squares method – G, the packaging surface method – E and two-point method were used to evaluate the proportions. The proportions were removed from the referential feature by the methods G and E, and the referential feature was used in a two-point method to determinate its centre. The geometrical deviation of cylindricity was evaluated from the surface profile we had taken by these methods: the smallest squares method – G (LSCY), the smallest circumscribed cylinder method (MCCY) and the minimal zone method (MZCY). Table 2 shows certain results from the protocol of the measurement of the proportions and cylindricity. The implementation of individual measurement principles serves to the comparison of the results of measurement for the examination of the pertinence of correct requirement order according to the appropriate method.

CONCLUSIONS

From the analysis of processed values data follows, that different results were achieved by the application of individual approximation methods of geometrical features affiliation. The smallest external diameter deviation values were recognised when using two-point method (method of tangent features). While the evaluation of shape geometrical feature – cylindricity that the smallest geometrical deviation values were recognised when applying the minimal zone method MZCY. By the conclusion reflection about (the objectivity) the appropriateness of the use of particular measurement method we are able to state that, while the selection of the particular method for referential geometrical feature determination (reference circle), we have to take into consideration mainly the supposed function of the evaluated surface.

The established results point to the fact, that measurement and evaluation methods influence the final measured value. This is the reason, why it is important that the designer orders appropriate method of measurement and evaluation of measured parameter values on the drawing documentation to the order of parameter specification.

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