# NEW STANDARDS IN THE FIELD OF GEOMETRICAL PRODUCT SPECIFICATIONS

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**ABSTRACT**: The essential tool for improving product quality and reducing manufacturing costs is the implementation of standards relating to a product. The main group of ISO standards are the standards related to Geometrical Product Specifications (GPS), where the requirements for detail geometrical characteristics that determine the execution of the functional purpose of the products are given. The purpose of this paper is to present the new standards of geometrical dimensioning and tolerancing of linear sizes, accuracy of form, as well as orientation and position of surfaces and axes. There are indicated problems associated with the implementation of the standards under consideration in Bulgaria and the ways to rectify them.

**KEY WORDS**: geometrical product specification (GPS), ISO, standards, geometrical characteristics, tolerancing.

## 1 INTRODUCTION

It is impossible to manufacture workpieces without deviations from the nominal shape. Production parts always have deviations in terms of size, form, orientation and location. When these deviations are too large, the usability of the workpiece for its purpose will be impaired. During manufacturing process, attempts are made to keep these deviations as small as possible, in order to avoid the impairment of usability - production is too expensive and the product is difficult to be sold.

In general, competition forces use all possibilities for economic production, including those resulting from current advances in technology. Therefore, it is necessary that the drawing tolerances define the workpieces completely, i.e. each property (size, form, orientation and location) must be toleranced. Only under these circumstances the manufacturer is able to choose the most economic production method, e.g. depending on the number of pieces to be produced and the production methods available.

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## 2 REVIEW OF STANDARDS RELATED TO GEOMETRIC DEVIATIONS

Standardization of geometric deviations in the International Organization for Standardization is carried out by the Technical Committee 213 and at national level in the Republic of Bulgaria by the TC 28 "Metrology". TC 213 developed and approved over 128 standards. Most of these standards are accepted as Bulgarian state standards. ISO/TC 213 is creating the new technical language entrusted to bridge the gap between design, manufacturing and verification through a corpus of standards going under the name of Geometrical Product Specification and Verification (GPS) Standards. The main purpose of these standards is to guarantee information consistency through a new technical language based on mathematical definitions. This kind of approach overcomes the traditional expert based on the system of Geometrical Dimensioning and Tolerancing (GD&T), which has characterized the industrial world after World War II (Ricci,2012)

Geometrical Product Specification and Verification (GPS) is an international standard system, covering all the issues related to product manufacturing, ranging from the design phase to the metrological principles and practices for their verification.

The aim of GPS standards framework is to grant coherence to all data generated along product lifecycle, in order to enable the information age industry to be more cost effective.

This aim is pursued through the definition of a new rigorous language based on mathematics that relies on the concepts of operations, operators and uncertainties. It enables harmonization of information into the global scale of a manufacturing industry. Such a language, completely based on mathematics, enables information consistency, but still needs to be encapsulated into an integrated information system to spread into industrial practice as it often turns out to be too complicated to be used directly. GPS language allows the development of next generation Product Lifecycle Management software that is intended to fully exploit the potential provided by improvements in the field of measuring instruments and informatics for production management (Ricci, 2012).

The concept of Geometrical Product Specifications and Verification includes (Durakbasa,2011):

- several types of standards, some of which dealing with fundamental rules of specification, others dealing with global principles and definitions and still others dealing directly with geometric characteristics;
- different geometric characteristics such as size, distance, angle, form, location, orientation, roughness;
- workpiece characteristics as a result of different manufacturing processes and the characteristics of specific machine elements that occur at several steps of the product life cycle, i.e. in the development of a product, its design, manufacturing, metrology, quality assurance, etc.

Geometrical Product Specifications are a means of transforming a function dependent on the requirements to the produced details and parts based on:

- mathematical rules and methods;
- consideration of macro- and micro geometry;
- possibilities for measuring quantities, toleranced quantities in particular;
- evaluation of uncertainty.

ISO 14405-1 (ISO/DIS 14405-1.2,2011) is the first standard that addresses the whole issue of size properly and gives a thorough and long overdue classification of the different ways in which the size can be defined. It also provides tools which enable size to be defined in different ways in a specification when necessary.

The diagram given in Figure 1 presents the relations between several types of characteristics relative to the size of a feature. The type of size can be indicated on the drawing by a specification modifier for controlling the feature (Table 1). Figure 2 and Figure 3 show examples of the use of some specification modifiers.

The new edition of ISO 5459 (ISO 5459: 2011) applies to new concepts and terms that have not been used in previous ISO GPS standards. The previous version of ISO 5459 dealt only with planes, cylinders and spheres being used as data. There is a need to consider all types of surfaces, which are increasingly used in industry. The definitions of classes of surfaces as given are exhaustive and unambiguous. This Standard provides tools to express location or orientation constraints, or both, for a tolerance zone. It does not provide information about the relationship between data or data systems and functional requirements or applications.

These concepts are described in detail in (ISO/TR 14638,2012) (ISO 17450-1,2011), and (ISO 17450-2,2012). It is recommended to refer to these standards when using ISO 5459. This Standard specifies the terminology, rules and methodology for the indication and understanding of data and data systems in technical product documentation. It also provides explanations to assist the user in understanding the concepts involved. In Table 2, the symbols used to set the data for the assessment of deviations are given. In standard, 10 rules how to clarify the selection and designation of the data for assessment of deviations are given. Practical application requires extensive preparation of all participants in the production process, such as designers, technicians and metrologists.

## 3 NEW PRINCIPLES, RULES AND APPLICATION OF THE NEW APPROACH

The following principles and rules are adopted with the new approach to the GPS standards (Henzold, 2006):

### 3.1 Independency principle, ISO 8015 (ISO 8015,2011) (applied at present when "ISO 8015" is indicated by drawing a title box intended by ISO TC 213 to become the default rule without indication)

Each requirement must be indicated and respected (no hidden rules, for example the envelope requirement must be respected for each feature of size);

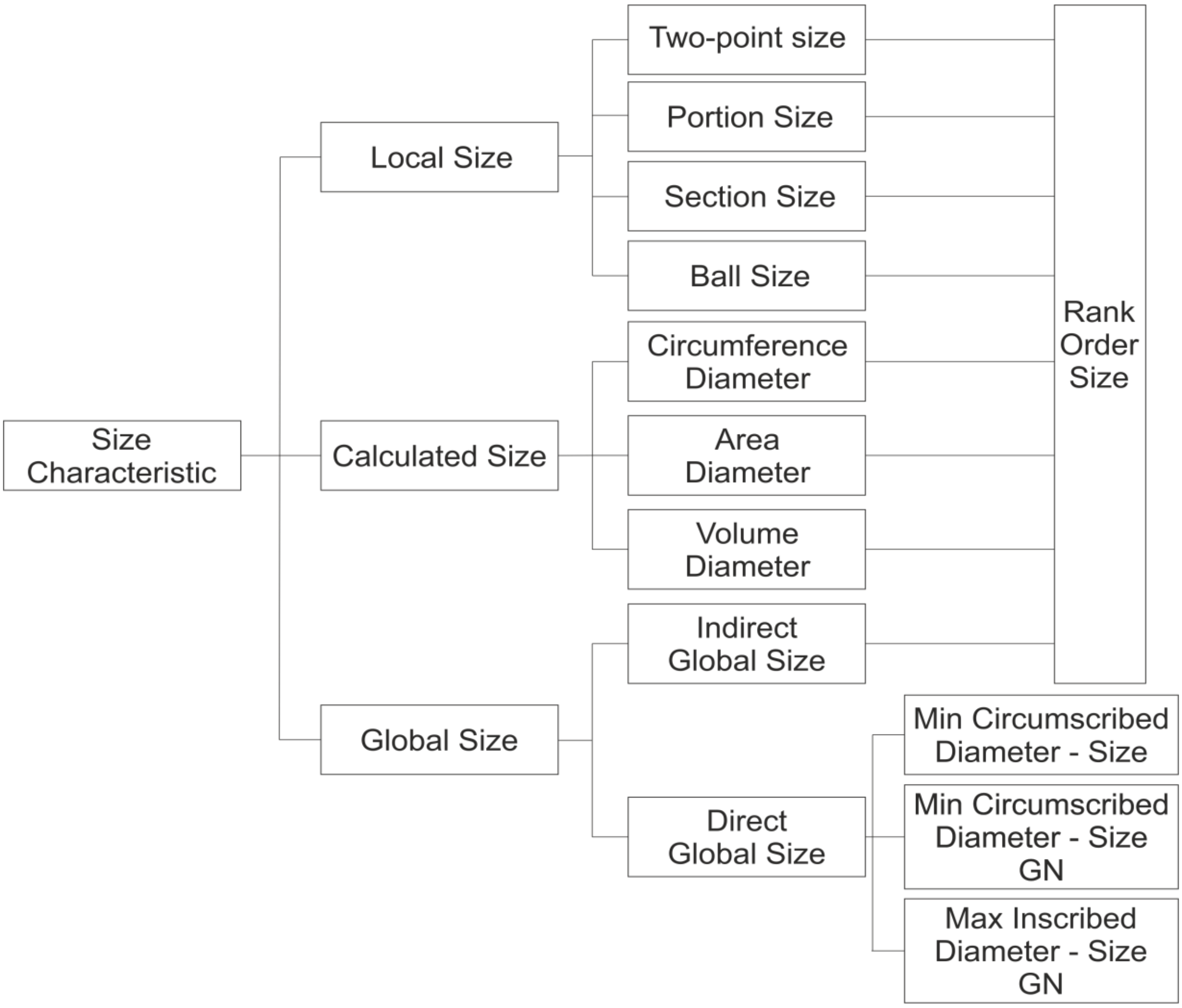


**Figure 1. Overview diagram for size (ISO/DIS 14405-1, 2011**

## 3.2 Drawing definitive principle, ISO 14 659 (ISO 14 659,2009)

What is not specified, is not required. The specification may be directly indicated or may be given by a reference to a default (ISO standard default, national standard default, company standard default);

## 3.3 Operator principle, ISO TS 17 450-1&2

Definition of specifications by a set of successive operations;

## 3.4 Duality principle, ISO TS 17 450-1&2

From the specification operator the verification operator is derived;

## 3.5 Uncertainty principle, ISO TS 17 450-2

From the difference between the specification operator and the verification operator the measurement uncertainty is derived. The specification operator may have a specification uncertainty and a correlation uncertainty;

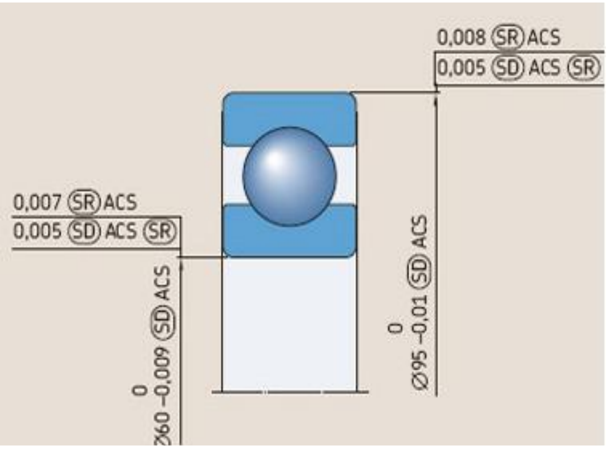


**Figure 2. Example of the use of a specification modifier for bearings**

**Table 1. Specification modifiers for linear size**

| Modifier | Description | Define |
|---|---|---|
| (LP) | Two-point size |  |
| (LS) | Ball size Local size defined by a sphere |  |
| (GG) | Section size With Least square association criteria |  |
| (GX) | Section size Maximum inscribed association criteria |  |
| (GN) | Section size Minimum circumscribed association criteria |  |
| (CC) | Circumference diameter(calculated size) | $D = \frac{L}{\pi}$ |
| (CA) | Area diameter (calculated size) | $D = \sqrt{\frac{4A}{\pi}}$ |
| (CV) | Volume diameter (calculated size) | $d = \sqrt{\frac{4V}{\pi \times L}}$ |
| (SX) | Maximum rank- order size | Dmax |
| (SN) | Minimum rankorder size | Dmin |
| (SA) | Average rank-order size | Dm |
| (SM) | Median rank-order size | - |
| (SD) | Mid-range rank-order size | - |
| (SR) | Range rank-order size | - |

### 3.6 Conformance rules, ISO 14253-1 (ISO 14253-1,2013)

Measurement uncertainty goes to the debit of the measuring party, if not otherwise specified;

### 3.7 Decimal rule, ISO 14659

After the last digit of dimensions and tolerances indicated zero is applied (no rounding);

### 3.8 Reference temperature, ISO 1(ISO 1,2003)

(20 ° C applies);

### 3.9 Specification interpretation rule, ISO 14 659.

The standard is applied in force at the time of drawing (specification) issue.

The new approach with its sophisticated terms and definitions is relevant for:

- Programming measuring instruments (like coordinate measuring machines);
- Defining very small tolerances;
- Precisely evaluating measurement uncertainty.

**Table 2. Specification symbols**

| Symbol | Description |
|---|---|
| [PD] | Pitch diameter |
| [MD] | Major diameter |
| [LD] | Minor diameter |
| [ACS] | Any cross section |
| [ALS] | Any longitudinal section |
| [CF] | Contacting feature |
| [DV] | Variable distance(for common data) |
| [PT] | (situation feature of type) Point |
| [SL] | (situation feature of type) Straight line |
| [PL] | (situated feature of type) Plane |
| >< | For orientation constraint only |
| Ⓟ | Projected(for secondary or tertiary data) |
| Ⓛ | Least material requirement |
| Ⓜ | Maximum material requirement |

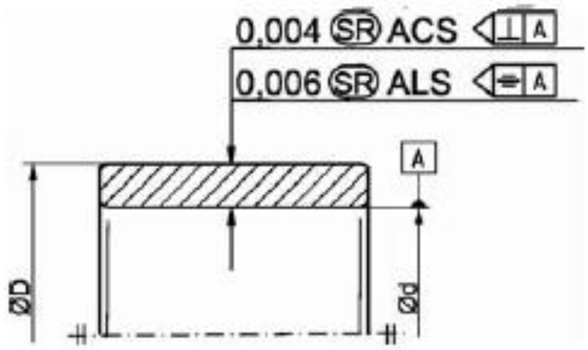


**Fig. 3. Example of the use of a specification modifier for cylindrical surface**

## 4 CONCLUDING REMARKS

Incompletely toleranced drawings lead up to: questions for the production-planning engineer, questions for the manufacturing engineer, questions for the inspection engineer, reworking, defects and damages. Only completely toleranced drawings enable the production of workpieces to be as precise as necessary and as economic as possible. This is necessary for competition.

There are no clear rules for designers about the possibilities for measuring of a defined size. The difference between local and global sizes is not clarified. It is necessary to develop guidelines for application of the types of sizes. It is also necessary for metrologists to have clear instructions prepared about the types of sizes and the ways of measurement.

For measuring internal cylindrical surfaces three-point measuring scheme can be used, but in the standard discussed, the symbol for defining this measuring method is missing.

There are some questions so as to how to proceed in assessing the function-related geometrical tolerancing as follows:

### 4.1 Tolerancing of orientation, location and run-out:

- Which features are related to each other by the function?
- Is the general geometrical tolerance sufficient or not (e.g. ISO 2768-2) (ISO 2768-2, 2002)? Does one feature determine orientation or location and may it therefore serve as a datum?
- Is it appropriate to specify a common tolerance zone and thereby avoid the specification of a datum?
- Is it appropriate to specify a data system or data targets?
- Which characteristics shall be toleranced?
- Is Ⓜ, Ⓛ, Ⓡ, Ⓟ or Ⓕ appropriate?
- What is the magnitude of tolerance?

### 4.2 Tolerancing of form:

- Which characteristic shall be toleranced?
- Is Ⓔ appropriate and sufficient or not? Is the general geometrical tolerance sufficient or not (e.g. ISO 2768-2)? Is the form deviation already limited sufficiently by a tolerance of orientation or location or total run-out or not?
- What is the magnitude of the tolerance?

### 4.3 Type of tolerance:

- Fits: Ⓔ;
- Clearance fits but there is no kinematics: Ⓜ (in this case Ⓔ is often not needed);
- Geometrical ideal form within the material required - L;
- Weight limitation: thickness tolerance (maximum thickness);
- Interference fit, kinematics, optics, electrical contacts, measuring contacts: geometrical tolerances regardless of other tolerances;
- Threaded holes, holes for center pins Ⓟ;
- Flexible parts: Ⓕ, ISO 10579-NR (ISO 10579-NR,2013).

It is often the case (e.g. with clearance fits associated with the maximum material requirement Ⓜ) that the features are of the same type functional priority with regard to being chosen as a datum. Then, each of them may be chosen as a datum.

The geometric specification according to the current ISO-GPS standards is an essential tool for obtaining products of lower cost and improved quality.

Implementation of the ISO-GPS standards is a fundamental requirement for an organization to be able to develop a competitive tolerance design, but it must go together with a preliminary training and an efficient application, and also with awareness on the part of the firm management about its advantages and competitive contributions.

The GPS standards have been introduced in Bulgaria in English. which is a serious obstacle to the understanding and correct implementation of the new symbols which in turn leads to their current limited use in practice.

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## 7 NOTATION

The following symbols are used in this paper:
ISO – International Organization for Standardization;
TC - Technical committee;
TS - Technical specification;
GPS – Geometrical product specifications;
GD&T - Geometrical Dimensioning and Tolerancing.
$A_t$ = total area.