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MODELS FOR GEOMETRIC PRODUCT SPECIFICATION

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Lucrarea prezintă câteva modele pentru verificarea asistată a geometriei pieselor, în conformitate cu noul concept ISO privind specificațiile geometrice ale produselor. Modelele cuprind elementele fundamentale pe care se pot baza specificațiile geometrice ale reperelor mecanice.

The paper presents some models for assisted inspection with respect to the new Geometrical Product Specification ISO concept. The model is aimed to express the fundamental elements on which the geometrical specification of mechanical parts can be based.

Key words: geometric product specification, geometric tolerances.

1. Introduction

Modeling and representation of geometric tolerances information state the maximum allowable variation of a form or its position from perfect geometry implied on the drawing. Standard geometric tolerances are interpreted according to several fundamental concepts and principles. They are: the size of a feature, the concept of material condition, the maximum material principle, the principle of independency, datum, and tolerance zones. Tolerances are applied to mechanical design to ensure that manufactured parts meet their functional requirements.

2. General terms and definitions

According to [1], geometrical features can be found in three main domains:

- the specification domain, where designers image representations of the future workpiece;
- the physical domain of the workpiece;
- the inspection situation, where a representation of a given workpiece is used through sampling of the workpiece by measuring instruments.

The designer defines a part in terms of fundamental manufacturing features, such as chamfers, through slots, blind slots, etc. – Fig.1. In model-based

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object design, mechanical parts are decomposed in geometrical components which describe various geometric properties of the model – Fig.2.

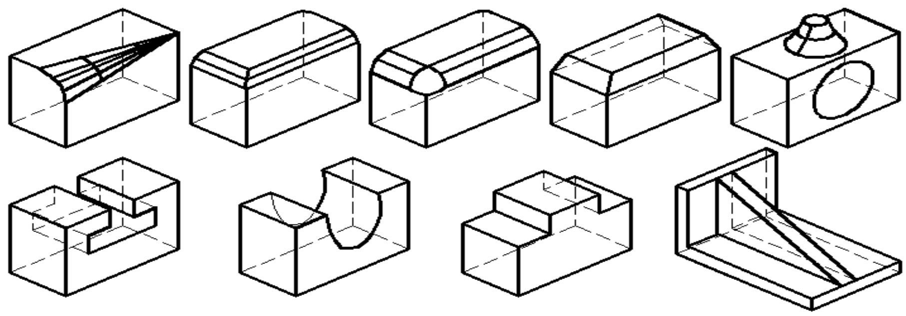


Fig. 1. Manufacturing features.

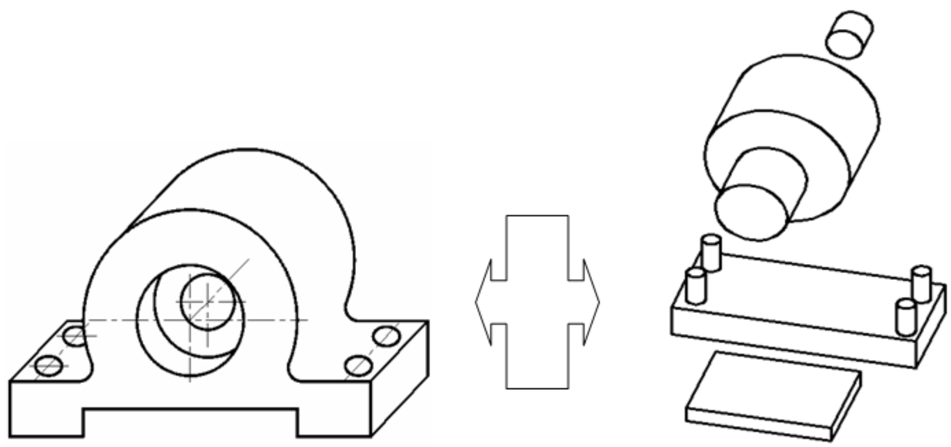


Fig. 2. Decomposing solid models.

SR EN ISO 14660-1 defines the general terms and definitions for geometrical features. This standard is derived from the European standards EN ISO 14660:1999 [2], which defines standardized terminology for geometrical features in each of those three domains.

ISO/TS 17450-1 [3] explain the mathematical basis of the concepts associated with the model. Here are some terms that the standard presents.

- **Geometrical features** – point, line or surface.
- **Integral feature** – surface or line on a surface.
- **Derived feature -** centre point, median line or median surface from one or more integral features. For example, the median line of a cylinder is a derived feature obtained from the cylindrical surface, which is an integral feature. Fig. 3 presents derived features for a cylindrical part oriented on a V-block.

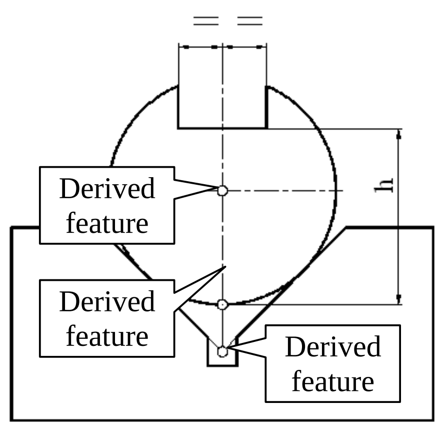


Fig. 3. Derived feature.

- **Feature of size** (Fig. 4) **-** geometrical shape defined by a linear or angular dimension which is a size. The feature of size can be a cylinder, a sphere, two parallel opposite surfaces, a cone or a wedge.

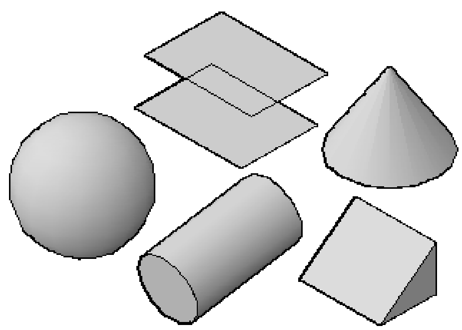


Fig. 4. Feature of size.

- **Nominal integral feature** – theoretically exact integral feature as defined by a technical drawing.
- **Real surface of a workpiece** (Fig. 5) **-** set of features which physically exist and separate the workpiece from the surrounding medium.
- **Extracted integral feature** – approximated representation of the real (integral) feature, obtained by extracting a finite number of points from the real (integral) feature.
- **Ideal feature** – feature defined by a parametric equation.
- **Associated feature** - ideal feature established from a non-ideal model or from a real surface by an association operation.

- **Nominal model** – model of the workpiece of perfect shape defined by the designer (design intent).

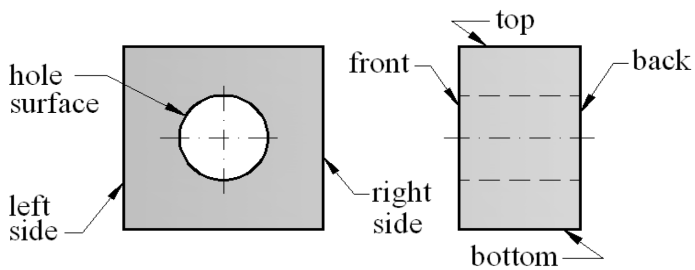


Fig. 5. Real surfaces of a workpiece.

According to [3], the geometrical specification is the design step where the field of permissible deviation of a set of characteristics of a workpiece is stated, accommodating the required functional performance of the workpiece (functional need). It will also define a level of quality in conformance with manufacturing process, the limits permissible for manufacturing and the definition of the conformity of the workpiece – Fig. 6.

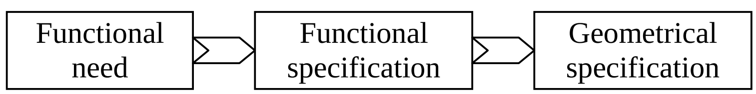


Fig. 6. Functional needs and geometrical specification.

The designer starts to define a workpiece of perfect form with shape and dimensions that fit the functions – the nominal model. This first step establishes a representation with only nominal values that is impossible to product or inspect, because each manufacturing or measuring process has its own variability or uncertainty.

From the nominal geometry, the designer images a model of this real surface which represents the variations that could be expected on the real surface of the workpiece. This model is called the non-ideal model (skin model).

3. Features

According to [2] the nature of geometrical feature is point, line or surface.

The invariance class is a group of ideal features defined by the same invariance degree. The invariance degree is the displacement of the ideal feature.

According to [3], all ideal features belong to one of the seven invariance classes defined in Table 1.

Table 1

The invariance classes.

Invariance class	**Invariance degrees**
complex	none
prismatic	1 translation along a straight line
revolute	1 rotation along a straight line
helical	1 translation along and 1 rotation combined around a straight line
cylindrical	1 translation along and a rotation around a straight line
planar	1 rotation around a straight line and 2 translations in a plane perpendicular to the straight line
spherical	3 rotations around a point

Ideal features are defined by their type (for example, plane, cylinder, torus etc.) and by their characteristics (radius of cylinder, angle between two planes, distance between two axes etc). The size and location are defined by the intrinsic characteristics (for example, diameter) – Table 2, respectively, the situation characteristics (for example, angle or distance between two planes) – Table 3.

Table 2

Examples of intrinsic characteristics of ideal features.

Type	**Examples of intrinsic characteristics**
elliptic curve	length of major and minor axis
torus	generatrix and directrix diameters
cone	apex angle
helical line	helix pitch and radius
cylinder	diameter

Table 3

Examples of situation characteristics.

Location	**Orientation**
point - point distance	straight line - straight line angle
point - straight line distance	straight line – plane angle
point - plane distance	plane – plane angle
straight - straight line distance	
straight line -plane distance	
plane-plane distance	

4. Operations with features

In order to obtain ideal or non-ideal features, specific operations are required:

- **Partition**. In Fig. 7 there are shown a nominal model which is partitioned with several ideal features of type plane.

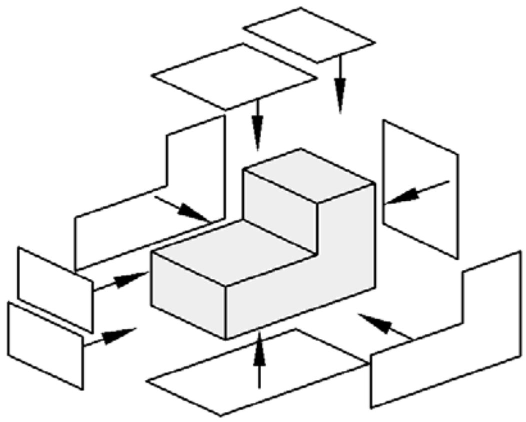


Fig. 7. Decomposition of the nominal model.

- **Extraction.** A feature operation called extraction is used to identify a finite number of elements from a feature – Fig. 8.

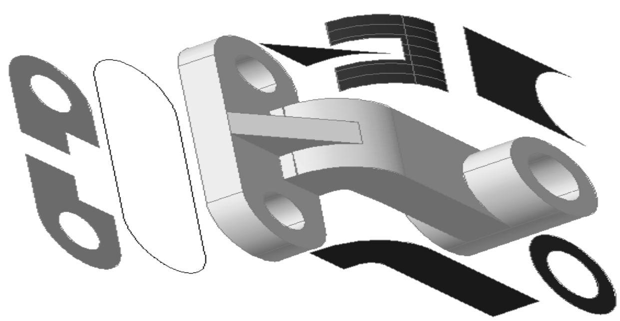


Fig. 8. Extraction.

- **Construction.** The operation is used to build ideal features from other features – Fig. 9. This operation has to respect constraints.

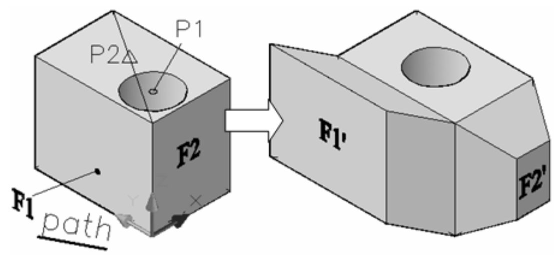


Fig. 9. Construction.

- **Filtration.** The filtration permits the separation of two types of characteristics, according to various filters - for example, the separation of a profile in waviness and roughness - Fig. 10.

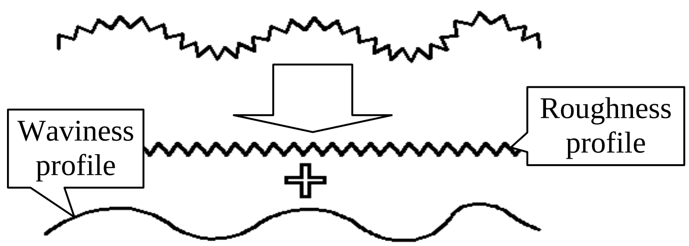


Fig. 10. Filtration.

- **Collection**. A feature operation called collection is used to identify and consider some features together which together play the same functional role. In Fig. 11 two parallel cylinders, CY1 and CY2 are considered together, for building a common datum PL.

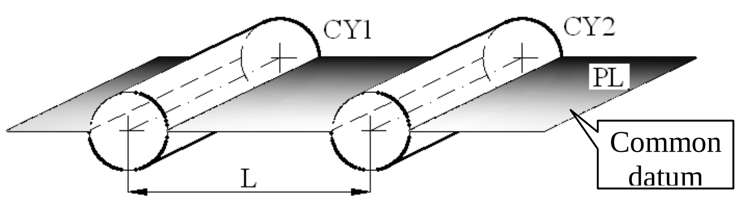


Fig. 11. Collection.

- **Association.** The operation is used to fit ideal features according to specific criteria. In Fig. 12 there are shown the association of ideal cylinder with the non-ideal feature having as criterion “maximize the diameter of the inscribed cylinder”.

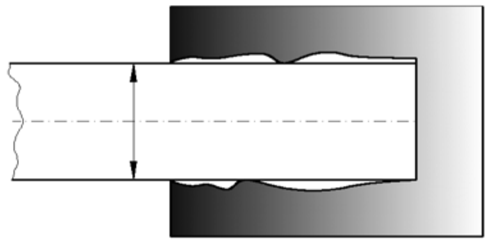


Fig. 12. Association.

5. Specifications

A specification consists in expressing the field of permissible deviation of characteristic of a workpiece as permissible limits [2]. The specifications are specified by dimensions and by zones.

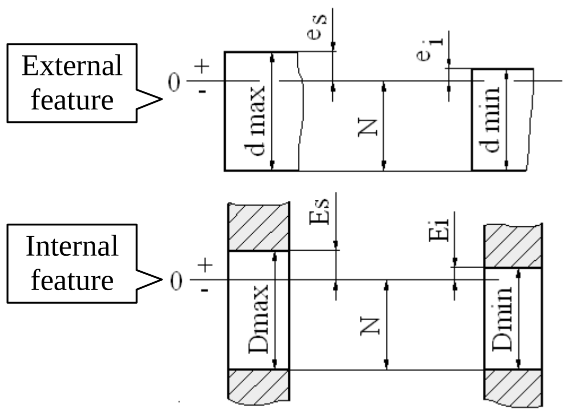


Fig. 13. Specification by dimension.

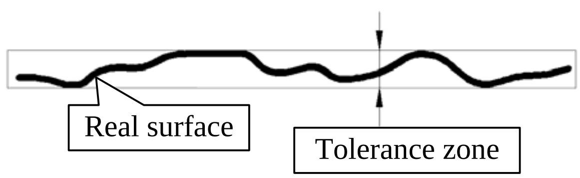


Fig. 14. Specification by zone.

The specification by dimension limits the permissible value of an intrinsic characteristic or of a situation characteristic between ideal features – Fig. 13 (N is the nominal dimension; Dmax, Dmin, dmax, dmin are the limit dimensions; Es, Ei, es, ei are the deviations).

A specification by zone limits the permissible deviation of a non-ideal feature inside a tolerance zone – Fig. 14.

6. Applications

App. 1. Consider an example of orientation tolerance (parallelism between an axis and a plane surface) - Fig. 15.

The specification is the following: by using two planes, parallel to datum A, the orientation tolerance is obtained by evaluation of a characteristic, i.e., the maximum of the distances between each point of the collected feature and one of the two parallel planes; this maximum shall be less than or equal to 0,10.

Table 4 presents the features operations applied.

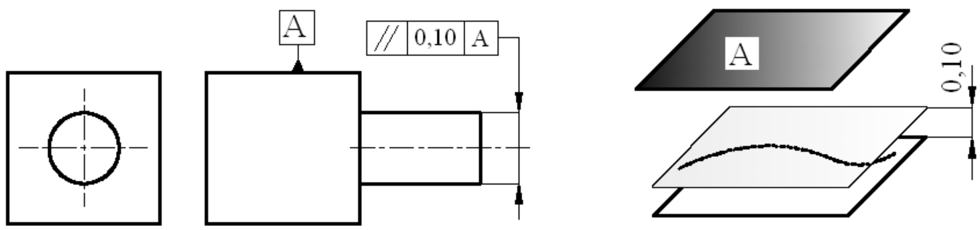
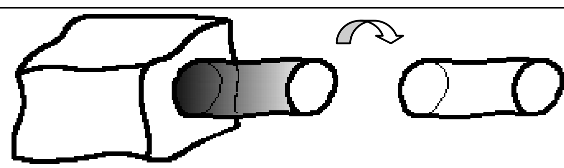
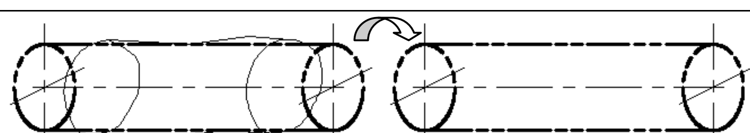
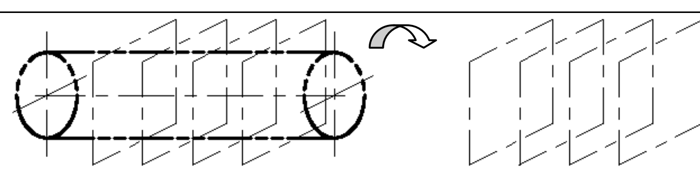
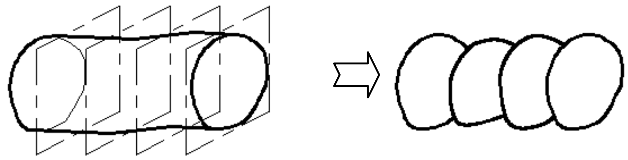
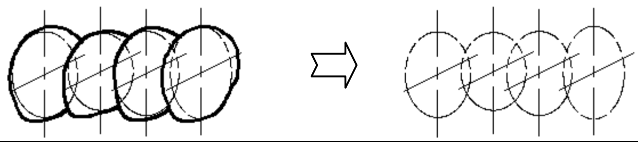
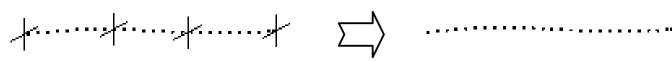


Fig. 15. Parallelism between axis and surface.

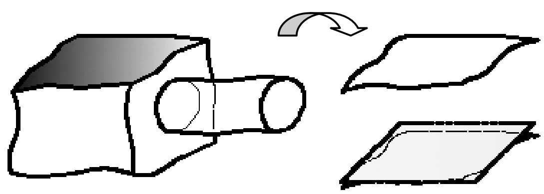
Table 4

Features operations applied for parallelism condition from Fig. 15.

a) the axis of the cylinder is obtained by:	
1. partition, from the non-ideal surface model, of the non-ideal cylindrical surface;	
2. association of ideal feature - type cylinder;	
3. construction of planes perpendicular to associated cylinder's axis;	

4. partition of non-ideal circular lines;	
5. association of ideal feature of type circle;	
6. collection of the centres of the ideal circles .	

b) the datum surface is obtained by:

1. partition, from the non-ideal surface model, of the non-ideal planar surface corresponding to A; 2. association of an ideal feature of type plane.	

c) the axis of the tolerance zone is obtained by association of an ideal feature of type straight line with the collected feature, the situation feature of the straight line is constrained to be parallel to the datum A and the maximum distance between each point of the collection feature and the associated straight line shall be minimum.

App. 2. Consider now an example of form tolerance (cylindricity) - Fig. 16. The features operations applied are presented in Table 5.

The specification is the following: the surface must lie between two coaxial cylindrical surfaces; tolerance is obtained by evaluation of a characteristic, i.e., the maximum of the distances between each point of the partitioned feature and one of the two cylindrical surface; this maximum shall be less than or equal to 0,40/2.

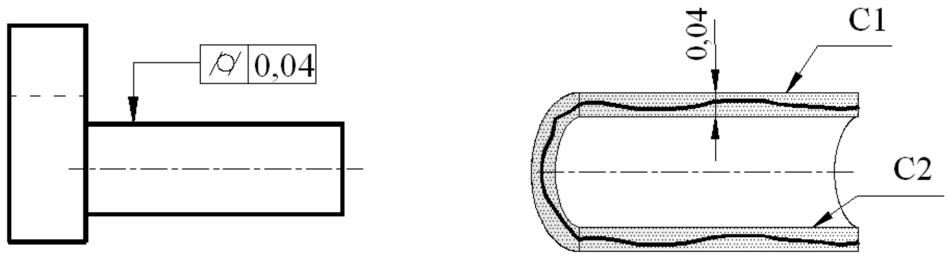
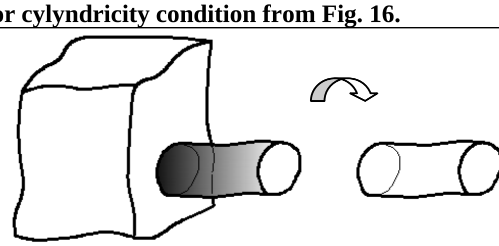
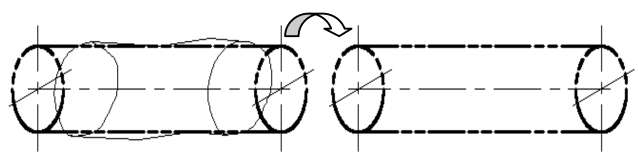
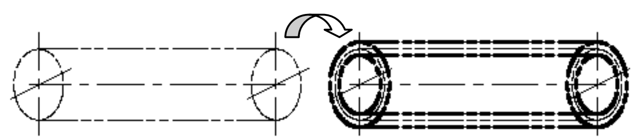


Fig. 16. Cylindricity.

Table 5

Features operations applied for cylyndricity condition from Fig. 16.

a) partition of the non-ideal cylindrical surface, from the non-ideal surface model;	
b) extraction cylinder surface – digital representation of the real partition surface. Extraction operation consists in obtaining a representative set of points on the real surface (extraction strategies are defined by ISO/TS 12180-2:2003).	
c) association of ideal feature - type cylinder, in order to obtain the median cylinder of the tolerance zone;	
d) construction of two coaxial cylindrical surfaces which limits the tolerance zone.	

7. Conclusions

The model proposed should serve as a basis for revising and completing the existing standards according to a unified and systematic approach, in order to provide a non-ambiguous Geometric Product Specification GPS language, to be used and understood by people involved in design, manufacturing and inspection. The model also provides a formalization of the concepts, in order to facilitate standardization inputs. The impact should be an accurate work, shorter design time, less iteration and hence lower cost.

R E F E R E N C E S

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