Proceedings of the 16th International Conference on Manufacturing Systems – ICMaS
ISSN 1842-3183
University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

GEOMETRIC PRODUCT SPECIFICATION FOR TOLERANCE ANALYSIS

Ionel SIMION, Adrian GHIONEA

Abstract: *This paper presents a generalized model for assisted inspection of form tolerances with respect to the new Geometrical Product Specification ISO concept. The model is aimed to expressing the fundamental elements on which the geometrical specification of mechanical parts can be based. The model was inserted and used in LANDIM program* [1].

Key words: *Geometric Product Specification, Geometric Tolerances, LANDIM.*

1. INTRODUCTION

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.

Modelling and representation of geometric tolerances information state the maximum allowable variation of a form or its position from perfect geometry implied on the drawing.

ISO/TS 17450-1 [2] provides a model for geometrical specification and verification and define the corresponding concepts. It also presents some examples of application to ISO 1101 [4], regarding flatness, perpendicularity and location tolerances.

This paper presents a generalized model for assisted inspection of form tolerances with respect to the new Geometrical Product Specification (GPS) ISO concept. The model was inserted and used in LANDIM program [1] for vectorial and statistic tolerances.

2. SPECIFICATION

A specification consists in expressing the field of permissible deviation of characteristic of a workpiece as permissible limits [3]. The specifications are specified by dimensions and by zones.

The specification by dimension limits (Fig. 1) the permissible value of an intrinsic characteristic or of a

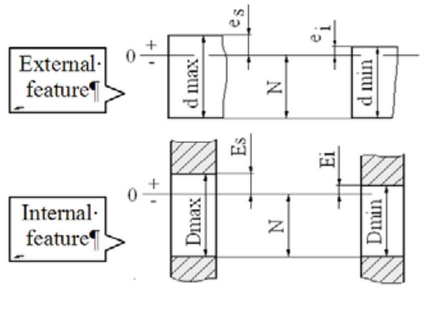


Fig. 1. Specification by dimension.

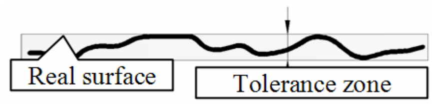


Fig. 2. Specification by zone.

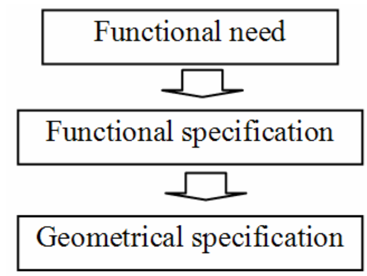


Fig. 3. Functional need and geometrical specification.

situation characteristic between ideal features - Fig. 1 (*N* is the nominal dimension; *Dmax*, *Dmin*, *dmax*, *dmin* are the limit dimensions; *Es*, *Ei*, *es*, *ei* are the deviations).

A specification by zone (Fig. 2) limits the permissible deviation of a non-ideal feature inside a tolerance zone.

According to [2], 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. 3).

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 [3] 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 [2], all ideal features belong to one of the seven invariance classes defined in Table 1.

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).

ISO/TS 17450-1 [2] explain the mathematical basis of the concepts associated with the model. Here are some terms that the standard presents:

Table 1

The invariance classes

Invariance class	Invariance degrees
Complex	none
Pprismatic	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

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

- *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. Figure 4 presents derived features for a cylindrical part oriented on a V-block.
- *Feature of size* - 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.
- *Nominal integral feature* – theoretically exact integral feature as defined by a technical drawing.
- *Real surface of a workpiece* - 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 parameterized equation.
- *Associated feature* - ideal feature established from a non-ideal model or from a real surface through an association operation.
- *Nominal model* – model of the workpiece of perfect shape defined by the designer (design intent).

In order to obtain ideal or non-ideal features, specific operations are required [6]:

- *Partition***.** A nominal model is partitioned with several ideal features of type plane.
- *Extraction***.** A feature operation called extraction is used to identify a finite number of elements from a feature.
- *Construction.* The operation is used to build ideal features from other features (Fig. 5). This operation shell respect constraints.

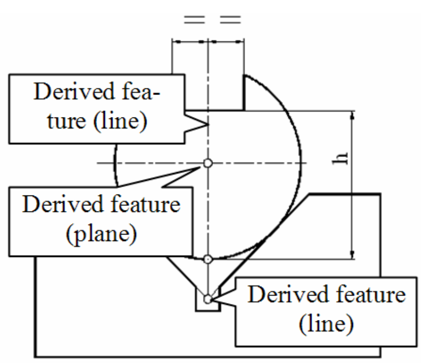


Fig. 4. Derived features.

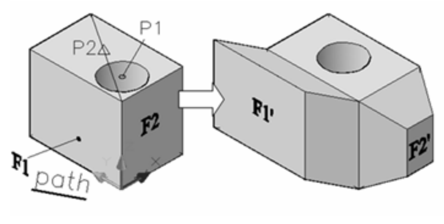


Fig. 5. Construction.

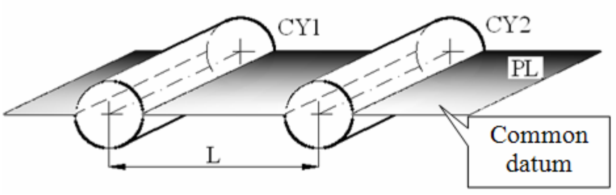


Fig. 6. Collection.

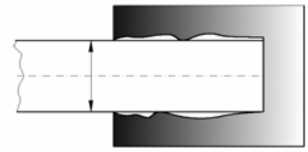


Fig. 7. Association.

- *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.
- *Collection.* A feature operation called collection is used to identify and consider some features together which together play and functional role. In Fig. 6 two parallel cylinders, CY1 and CY2 are considered together, for building a common datum PL.
- *Association.* The operation is used to fit ideal features according to specific criteria. In Fig. 7 there are shown the association of ideal cylinder with the non-ideal feature having criteria "maximize the diameter of the inscribed cylinder".

4. GENERALIZED MODEL FOR ASSISTED INSPECTION OF FORM TOLERANCES

Form tolerance is one of the most generally geometric tolerances. Inspection of form tolerance includes more other tolerances (Fig. 8).

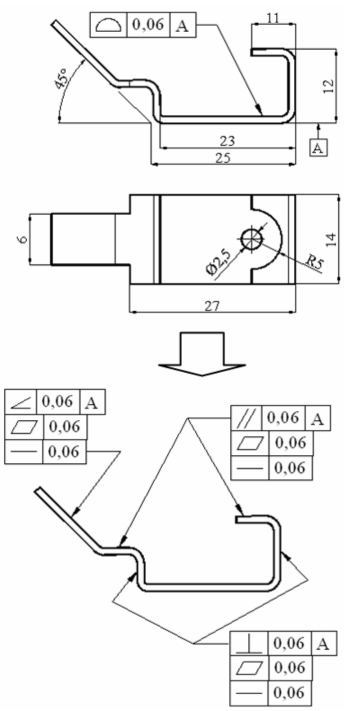


Fig. 8. Form tolerance – example.

4.1. Form tolerance inspection

Consider an example of generally form surface tolerance (Fig. 9). The specification is the following: the surface must lie between two offset 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 reference surface; this maximum shall be less than or equal to 0.40/2.

The features operations applied are presented in Table 4.

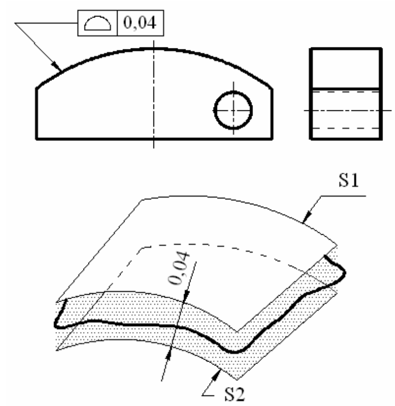
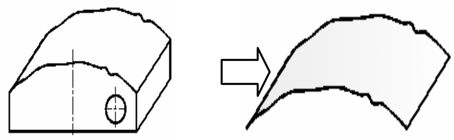
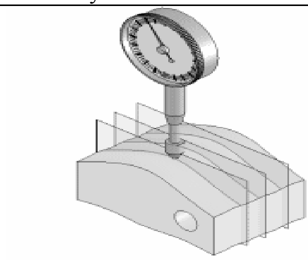
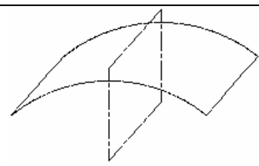
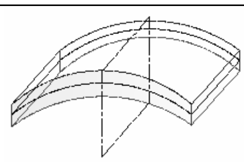


Fig. 9. Form surface tolerance.

Table 4

Features operations applied for form tolerance condition.

1. Partition of the non-ideal surface, from the non-ideal surface model.

2. Extraction 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).

3. Association of ideal feature - type surface, in order to obtain the median surface of the tolerance zone.

4. construction of two offset surfaces who limits the tolerance zone.


4.2. Application. Cylindricity tolerance.

Consider now an example of cylindricity tolerance (Fig. 10). 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.

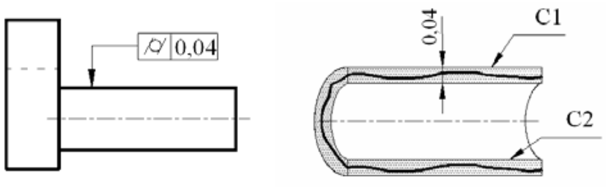
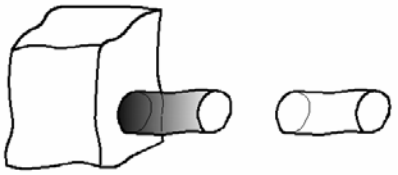
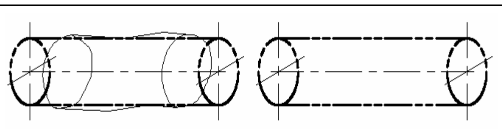
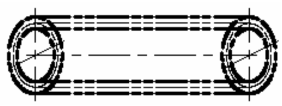


Fig. 10. Cylindricity tolerance.

Table 5

Features operations applied for form tolerance condition.

1. Partition of the non-ideal cylinder, from the non-ideal surface model.

2. Extraction cylinder – 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 [5]).
3. Association of ideal feature - type surface, in order to obtain the median surface of the tolerance zone.

4. construction of two offset surfaces who limits the tolerance zone.


10. CONCLUSION

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 lower cost.

REFERENCES

[1] Grant CEEX (2006). Programul de cercetare de excelență, Modulul 1. Proiecte de cercetare-dezvoltare complexe: *Lanțuri de dimensiuni spațiale tratate vectorial şi statistic, metoda de îmbunătățire funcțional tehnologică a produselor - LANDIM,* (Excelence research program, Module 1. Complex research developing programs: *3D dimension chains vectorially and statistically treated, method of functonal and technological improveent of products - LANDIM*), Phases I and II.

[2] *** ISO/TS 17450-1:2005, *Geometrical Product Specifications (GPS) - General Concepts*.

[3] *** EN ISO 14660-1:1999, *Geometrical Product Specifications (GPS) - Geometrical features*.

[4] *** ISO 1101:2004, *Geometrical Product Specifications (GPS) - Geometrical tolerancing - Tolerances of form, orientation, location and run-out.*

[5] *** ISO/TS 12180-2:2003, *Geometrical Product Specifications (GPS) - Cylindricity*.

[6] Simion, I., (2005), *AutoCAD 2005 for engineers*, TEORA USA Publishing House, ISBN 978-973-20-1046-4, New York.

Authors:

PhD, Ionel SIMION, Professor, Head of Department, University Politehnica of Bucharest, Descriptive Geometry and Engineering Graphics Department, 313 Splaiul Independenței, Bucharest, Romania,

E-mail: isimion@geom.desc.pub.ro.

PhD, Adrian GHIONEA, Professor, University Politehnica of Bucharest, Machines and Manufacturing Systems Department, 313 Splaiul Independenței, Bucharest, Romania,

E-mail: ghionea@imst.msp.pub.ro.