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Geometrical product specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)

Spécification géométrique des produits (GPS) — Tolérancement géométrique — Exigence du maximum de matière (MMR), exigence du minimum de matière (LMR) et exigence de réciprocité (RPR)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 2692 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This second edition cancels and replaces the first edition (ISO 2692:1988), which has been technically revised. It also incorporates the Amendment ISO 2692:1988/Amd.1:1992.

Introduction

0.1 General

This International Standard is a Geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences the chain links 1, 2 and 3 of the chain of standards on size of linear “features of size” and form, orientation or location of derived features based on “features of size”.

For more detailed information of the relation of this International Standard to the GPS matrix model, see Annex C.

This International Standard covers some frequently occurring workpiece functional cases in design and tolerancing. The “maximum material requirement”, MMR, covers “assembleability” and the “least material requirement”, LMR, covers, for example, “minimum wall thickness” of a part. Each requirement (MMR and LMR) combines two independent tolerance requirements into one collective requirement, which more accurately simulates the intended function of the workpiece. In some cases of both MMR and LMR, the “reciprocity requirement”, RPR, can be added.

0.2 Information about maximum material requirement, MMR

The assembly of parts depends on the combined effect of:

a) the size (of one or more extracted features of size), and

b) the geometrical deviation of the (extracted) features and their derived features, such as the pattern of bolt holes in two flanges and the bolts securing them.

The minimum assembly clearance occurs when each of the mating features of size is at its maximum material size (e.g. the largest bolt size and the smallest hole size) and when the geometrical deviations (e.g. the form, orientation and location deviations) of the features of size and their derived features (median line or median surface) are also at their maximum. Assembly clearance increases to a maximum when the sizes of the assembled features of size are furthest from their maximum material sizes (e.g. the smallest shaft size and the largest hole size) and when the geometrical deviations (e.g. the form, orientation and location deviations) of the features of size and their derived features are zero. It therefore follows that if the sizes of one mating part do not reach their maximum material size, the indicated geometrical tolerance of the features of size and their derived features may be increased without endangering the assembly to the other part.

This assembly function is controlled by the maximum material requirement. The collective requirement is indicated on drawings by the symbol Ⓜ.

0.3 Information about least material requirement, LMR

The least material requirement is designed to control, for example, the minimum wall thickness, thereby preventing breakout (due to pressure in a tube), the maximum width of a series of slots, etc. It is indicated on drawings by the symbol Ⓛ. The least material requirement is also characterised by a collective requirement for the size of a feature of size, the geometrical deviation of the feature of size (form deviations) and the location of its derived feature.

0.4 Information about reciprocity requirement, RPR

The reciprocity requirement is an additional requirement, which may be used together with the maximum material requirement and the least material requirement in cases where it is permitted — taking into account the function of the toleranced feature(s) — to enlarge the size tolerance when the geometrical deviation on the actual workpiece does not take full advantage of, respectively, the maximum material virtual condition or the least material virtual condition.

The reciprocity requirement is indicated on the drawing by the symbol Ⓡ.

0.5 General information about terminology and figures

The terminology and tolerancing concepts in this International Standard have been updated to conform to GPS terminology, notably that in ISO 286-1:1998, ISO 14405:—, ISO 14660-1:1999, ISO 14660-2:1999 and ISO/TS 17450-1:2005.

Geometrical product specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)

1 Scope

This International Standard defines the maximum material requirement, the least material requirement and the reciprocity requirement, and specifies their applications.

These requirements are used to control specific functions of workpieces where size and geometry are interdependent, e.g. to fulfil the functions “assembly of parts” (for maximum material requirement) and “minimum wall thickness” (for least material requirement). However, the maximum material requirement and least material requirement are also used to fulfil other functional design requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 286-1:1988, *ISO system of limits and fits — Part 1: Bases of tolerances, deviations and fits*

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

ISO 5459:—[1], *Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum-systems*

ISO 14405:—[2], *Geometrical Product Specifications (GPS) — Dimensional tolerancing — Linear sizes*

ISO 14660-1:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

ISO 14660-2:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 2: Extracted median line of a cylinder and a cone, extracted median surface, local size of an extracted feature*

ISO/TS 17450-1:2005, *Geometrical Product Specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

1) To be published. (Revision of ISO 5459:1981)

2) To be published.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 286-1:1998, ISO 14405:—, ISO 14660-1:1999, ISO 14660-2:1999, ISO/TS 17450-1:2005 and the following apply.

3.1
feature of size
geometrical shape defined by a linear or angular dimension which is a size

[ISO 14660-1:1999]

3.2
derived feature
centrepoint, median line or median surface from one or more integral features

[ISO 14660-1:1999]

3.3
integral feature
surface or line on a surface

NOTE An integral feature is intrinsically defined.

[ISO 14660-1:1999]

3.4
maximum material condition
MMC
state of the considered extracted feature, where the feature of size is at that limit of size where the material of the feature is at its maximum everywhere, e.g. minimum hole diameter and maximum shaft diameter

NOTE 1 The term maximum material condition, MMC, is used in this International Standard to indicate, at ideal or nominal feature level (see ISO/TS 17450-1 and ISO 14660-1 respectively), which upper or lower limit of the requirement is concerned.

NOTE 2 The size of the extracted feature at maximum material condition, MMC, can be defined by default, or by several special definitions of the size of the extracted feature (see ISO 14405 and ISO 14660-2).

NOTE 3 The maximum material condition, MMC, as defined in this International Standard, can be used unambiguously with any definition of size of the extracted feature.

3.5
maximum material size
MMS
l_{MMS}
dimension defining the maximum material condition of a feature

See Annex A.

NOTE 1 Maximum material size, MMS, can be defined by default or by one of several special definitions of the size of the extracted feature (see ISO 14405 and ISO 14660-2).

NOTE 2 In this International Standard, maximum material size, MMS is used as a numerical value, therefore no specific definition of the extracted size is needed to permit unambiguous use of maximum material size, MMS.

3.6
least material condition
LMC
state of the considered extracted feature, where the feature of size is at that limit of size where the material of the feature is at its minimum everywhere, e.g. maximum hole diameter and minimum shaft diameter

NOTE 1 The term least material condition, LMC, is used in this International Standard to indicate, at the ideal or nominal feature level (see ISO/TS 17450-1 and ISO 14660-1 respectively), which end (upper or lower) of the requirement is concerned.

NOTE 2 The size at least material condition, LMC, can be defined by default or by several special definitions of the size of extracted feature (see ISO 14405 and ISO 14660-2).

NOTE 3 The least material condition, LMC, as defined in this International Standard, can be used unambiguously with any definition of size of the extracted feature.

3.7
least material size
LMS
l_{LMS}
dimension defining the least material condition of a feature

See Annex A.

NOTE 1 Least material size, LMS, can be defined by default or by one of several special definitions of the size of the extracted feature (see ISO 14405 and ISO 14660-2).

NOTE 2 In this International Standard, least material size, LMS, is used as a numerical value, therefore no specific definition of the extracted size is needed to permit unambiguous use of least material size, LMS.

3.8
maximum material virtual size
MMVS
l_{MMVS}
size generated by the collective effect of the maximum material size, MMS, of a feature of size and the geometrical tolerance (form, orientation or location) given for the derived feature of the same feature of size

NOTE 1 Maximum material virtual size, MMVS, is a parameter for size used as a numerical value connected to maximum material virtual condition, MMVC.

NOTE 2 For external features, MMVS is the sum of MMS and the geometrical tolerance, whereas for internal features, it is the difference between MMS and the geometrical tolerance.

NOTE 3 The MMVS for external features of size, $l_{MMVS,e}$, is given by Equation (1):

$$l_{MMVS,e} = l_{MMS} + \delta \quad (1)$$

and the MMVS for internal features of size, $l_{MMVS,i}$, is given by Equation (2):

$$l_{MMVS,i} = l_{MMS} - \delta \quad (2)$$

where

l_{MMS} is the maximum material size

δ is the geometrical tolerance.

3.9
maximum material virtual condition
MMVC
state of associated feature of maximum material virtual size, MMVS

See Annex A.

NOTE 1 Maximum material virtual condition, MMVC, is a perfect form condition of the feature.

NOTE 2 Maximum material virtual condition, MMVC, includes an orientation constraint (in accordance with ISO 1101 and ISO 5459) of the associated feature when the geometrical tolerance is a orientation tolerance (see Figure A.3). Maximum material virtual condition, MMVC, includes a location constraint (in accordance with ISO 1101 and ISO 5459) of the associated feature when the geometrical tolerance is a location tolerance (see Figure A.4).

3.10
least material virtual size
LMVS
l_{LMVS}
size generated by the collective effect of the least material size, LMS, of a feature of size and the geometrical tolerance (form, orientation or location) given for the derived feature of the same feature of size

NOTE 1 Least material virtual size, LMVS, is a parameter for size used as a numerical value connected to least material virtual condition, LMVC.

NOTE 2 For external features, LMVS is the difference between LMS and the geometrical tolerance, whereas for internal features, it is the sum of LMS and the geometrical tolerance.

NOTE 3 The LMVS for external features of size, $l_{LMVS,e}$, is given by Equation (3):

$$l_{LMVS,e} = l_{LMS} - \delta \tag{3}$$

and the MMVS for internal features of size, $l_{LMVS,i}$, is given by Equation (4):

$$l_{LMVS,i} = l_{LMS} + \delta \tag{4}$$

where

l_{LMS} is the least material size

δ is the geometrical tolerance

3.11
least material virtual condition
LMVC
state of associated feature of least material virtual size, LMVS

See Figures A.5, A.8 and A.9.

NOTE 1 Least material virtual condition, LMVC, is a perfect form condition of the feature.

NOTE 2 Least material virtual condition, LMVC, includes a location constraint (in accordance with ISO 1101 and ISO 5459) of the associated feature when the geometrical tolerance is a location tolerance (see Figure A.5).

3.12
maximum material requirement
MMR
requirement for a feature of size, defining a geometrical feature of the same type and of perfect form, with a given value for the intrinsic characteristic (dimension) equal to MMVS, which limits the non-ideal feature on the outside of the material

NOTE 1 Maximum material requirement, MMR, is used to control the assembleability of a workpiece.

NOTE 2 See also 4.2.

3.13
least material requirement
LMR
requirement for a feature of size, defining a geometrical feature of the same type and of perfect form, with a given value for the intrinsic characteristic (dimension) equal to LMVS, which limits the non-ideal feature on the inside of the material

NOTE 1 Least material requirements, LMR, are used in pairs, e.g. to control the minimum wall thickness between two symmetrical or coaxially located similar features of size.

NOTE 2 See also 4.3.

3.14
reciprocity requirement
RPR
additional requirement for a feature of size used as an addition to the maximum material requirement, MMR, or the least material requirement, LMR to indicate that the size tolerance is increased by the difference between the geometrical tolerance and the actual geometrical deviation

4 Maximum material requirement, MMR and least material requirement, LMR

4.1 General

The maximum material requirement, MMR, and the least material requirement, LMR, take into account the mutual relationship of the size and the geometrical tolerance of interrelated features. These requirements can be applied exclusively in order to combine requirements for the size of features of size and the geometrical tolerance for the derived feature(s) of the feature(s) of size.

NOTE 1 This edition of this International Standard only covers features of size of type cylinder and type two opposite parallel plane surfaces. Consequently, the only possible derived features are median lines and median surfaces.

When maximum material requirement, MMR, or least material requirement, LMR, is specified, the two requirements (size and geometrical tolerance) are transformed into one collective requirement. The collective requirement concerns only the integral feature, which in this International Standard relates to the surface(s) of the feature(s) of size(s).

NOTE 2 In the past, the maximum material requirement, MMR, was referred to as the maximum material principle, MMP.

When no modifiers (Ⓛ, Ⓜ, Ⓡ) are applied to the toleranced feature, the definitions of size of extracted feature in ISO 14405 and ISO 14660-2 apply.

When no modifiers (Ⓛ, Ⓜ, Ⓡ) are applied to the datum, ISO 5459 applies.

4.2 Maximum material requirement, MMR

4.2.1 Maximum material requirement for toleranced features

The maximum material requirement for toleranced features results in four independent requirements:

a) a requirement for the upper limit of the local size [see Rules A 1) and A 2)];

b) a requirement for the lower limit of the local size [see Rules B 1) and B 2)];

c) a requirement for the surface non-violation of the MMVC (see Rule C);

d) a requirement for when more than one feature is involved (see Rule D).

When the maximum material requirement, MMR, applies to the toleranced feature, it is indicated on drawings by the symbol Ⓜ placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance indicator.

In this case, it specifies for the surface(s) (of the feature of size) the following rules.

— **Rule A** The extracted local sizes of the toleranced feature shall be:

  1) equal to or smaller than the maximum material size, MMS, for external features;

  2) equal to or larger than the maximum material size, MMS, for internal features.

NOTE 1 This rule can be altered by the indication of reciprocity requirement, RPR, with the symbol Ⓡ after the symbol Ⓜ (see Clause 5 and Figure A.1).

— **Rule B** The extracted local sizes of the toleranced feature shall be:

  1) equal to or larger than the least material size, LMS, for external features [see Figures A.2 a), A.3 a), A.4 a), A.6 a), A.7 a), A.10 and A.11];

  2) equal to or smaller than the least material size, LMS, for internal features [see Figures A.2 b), A.3 b), A.4 b), A.6 b), A.7 b), A.10 and A.11].

— **Rule C** The maximum material virtual condition, MMVC, of the toleranced feature shall not be violated by the extracted (integral) feature (see Figures A.2, A.3, A.4, A.6, A.7, A.10 and A.11).

NOTE 2 Use of other constraints on size at maximum material condition, MMC, e.g. envelope requirement Ⓔ (previously also known as the Taylor Principle), can result in superfluous requirements, not necessary for the function of the feature(s) (assembleability). Use of other such constraints and size definitions reduces the technical and economic advantage of maximum material requirement, MMR.

NOTE 3 The indication 0 Ⓜ has the same meaning as envelope requirement Ⓔ when the geometrical specification is a form tolerance.

— **Rule D** When the toleranced features (in cases of more than one features) are controlled by the same tolerance indication, or when the geometrical specification is orientation or location, the maximum material virtual condition(s), MMVC(s), of the toleranced feature(s) are in theoretical exact location(s) and orientation(s) relative to each other and to the datum(s), as applicable (see Figures A.6, A.7, A.10 and A.11).

4.2.2 Maximum material requirement for related datum features

The maximum material requirement for datum features results in three independent requirements:

a) a requirement for the surface non-violation of the MMVC (see Rule E);

b) a requirement for MMS when there is no geometrical tolerance or when there is a geometrical tolerance not followed by the symbol Ⓜ (see Rule F);

c) a requirement for MMS when there is a geometrical tolerance of form followed by the symbol Ⓜ (see Rule G).

When the maximum material requirement, MMR, applies to the datum feature, it is indicated on drawings by the symbol Ⓜ placed after the datum letter(s) in the tolerance indicator.

NOTE 1 The use of Ⓜ after the datum letter is only possible if the datum is obtained from a feature of size.

NOTE 2 When maximum or least material requirement applies to all elements of the collection of surfaces of a common datum, the corresponding sequence of letters identifying the common datum are indicated within parentheses (see Figure A.12). When maximum or least material requirement applies only to one element of the collection of surfaces