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Geometrical Product Specification (GPS) — Geometrical tolerancing — Maximum material requirement (MMR) and least material requirement (LMR)

[Revision of first edition (ISO 2692:1988) and its Amendment 1:1992]

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

ICS 01.100.20

ISO/CEN PARALLEL ENQUIRY

The CEN Secretary-General has advised the ISO Secretary-General that this ISO/DIS covers a subject of interest to European standardization. **In accordance with subclause 5.1 of the Vienna Agreement, consultation on this ISO/DIS has the same effect for CEN members as would a CEN enquiry on a draft European Standard.** Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month FDIS vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

Pour accélérer la distribution, le présent document est distribué tel qu'il est parvenu du secrétariat du comité. Le travail de rédaction et de composition de texte sera effectué au Secrétariat central de l'ISO au stade de publication.

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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 or 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 3.

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

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

ISO 2692 cancels and replaces ISO 2692:1985 and ISO 2692:1985/Amd. 1:1992 of which it constitutes a technical revision.

Annexes A, B and C are for information only.

Introduction

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 link 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 standard to the GPS matrix model see annex C.

This International Standard covers some frequently occurring workpiece functional cases in design and tolerancing. “Assembleability” is covered by maximum material requirement, MMR, and e.g. “minimum wall thickness” of a part covered by least material requirement, LMR. Maximum and least material requirement combines two independent tolerance requirements into one collective requirement which more accurate simulate the intended function of the workpiece. In some cases of both MMR and LMR the reciprocity requirement, RPR, can be added.

About maximum material requirement, MMR:

The assembly of parts depends on the combined effect of:

a) the extracted size (of one or more “features of size”), and
b) geometrical deviation of the (extracted) features and their derived features

such as e.g. 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. largest bolt and smallest hole) and when the geometrical deviations (e.g. 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 extracted sizes of the assembled features of size are furthest from their maximum material sizes (e.g. smallest shaft and largest hole) and when the geometrical deviations (e.g. form, orientation and location deviations) of the features of size and their derived features are zero. From the above, it follows that if the extracted sizes of a mating part do not reach their maximum material size, the indicated geometrical tolerance of the features of size and their derived feature may be increased without endangering the assembly of the other part. It also follows that if the geometry is perfect it allows the extracted sizes may be increased without endangering the assembly.

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

About least material requirement, LMR:

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

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 the maximum material virtual condition or least material virtual condition respectively.

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

General information about terminology and figures

The terminology and tolerancing concepts in this International Standard is updated to conform to GPS terminology as in ISO 286-1, ISO 14405, ISO 14660-1, ISO 14660-2, ISO/TS 17450-1 and others.

Geometrical Product Specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR)

1 Scope

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

The use of these requirements is to control specific functions of workpieces where there is a mutual dependence of size and geometry, for fulfilling the function assembly of parts (for maximum material requirement) and e.g. for fulfilling the function minimum wall thickness (for least material requirement). However the maximum material requirement and least material requirement may be used to fulfill other functional design requirements.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

ISO 1101:— [2)], *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out*.

ISO 5459:1981 [1)], *Technical drawings — Geometrical tolerancing — Datums and datum-systems for geometrical tolerances*.

ISO 14405:— [3)], *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:— [3)], *Geometrical Product Specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*.

3 Terms and definitions

For the purpose of this International Standard, the terms and definitions given in ISO 286-1, ISO 14405, ISO 14660-1, ISO 14660-2, ISO/TS 17450-1 and the following apply.

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1) Under revision

2) To be published. Revision of ISO 1101:1983

3) To be published

3.1
feature of size

[see ISO 14660-1, 2.2]

3.2
extracted local size

[see ISO 14660-2, 3.5 and 3.6]

3.3
derived feature

[see ISO 14660-1, 2.1.2]

3.4
integral feature

[see ISO 14660-1, 2.1.1]

3.5
maximum material condition
MMC
state of the considered extracted feature in which the feature of size is everywhere at that limit of size where the material of the feature is at its maximum, e.g. minimum hole diameter and maximum shaft diameter

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

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

NOTE 3 In this International Standard a specific definition of the extracted size is not needed for the unambiguous use of the maximum material condition, MMC.

3.6
maximum material size
MMS
dimension defining the maximum material condition of a feature

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

NOTE 1 Maximum material size, MMS, can be defined by default or by several special definitions of the extracted size (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 for the unambiguous use of maximum material size, MMS.

3.7
least material condition
LMC
state of the considered extracted feature in which the feature of size is everywhere at that limit of size where the material of the feature is at its minimum, e.g. maximum hole diameter and minimum shaft diameter

NOTE 1 The term least material condition, LMC, is used in this International Standard to point out, 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 concerned.

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

NOTE 3 In this International Standard a specific definition of the extracted size is not needed for the unambiguous use of the least material condition, LMC.

3.8
least material size
LMS
dimension defining the least material condition of a feature

See Figures A.2, A.3, A.4, A.6, A.7, A.10 and A.11.

NOTE 1 Least material size, LMS, can be defined by default and several special definitions of the extracted size (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 for the unambiguous use of least material size, LMS.

3.9
maximum material virtual size
MMVS
size generated by the collective effect of the maximum material size , MMS, (sum for external and difference for internal features) 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 Expressed by equations, MMVS is:
For external features of size: MMVS = MMS + geometrical tolerance
For internal features of size: MMVS = MMS – geometrical tolerance

3.10
maximum material virtual condition
MMVC
state of associated feature of maximum material virtual size, MMVS

See Figures A.2, A.3, A.4, A.6, A.7, A.10 and A.11.

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 (according to ISO 1101 and ISO 5459) of the associated feature when the geometrical tolerance is a orientation tolerance (Figure A.3). Maximum material virtual condition, MMVC, includes a location constraint (according to ISO 1101 and ISO 5459) of the associated feature when the geometrical tolerance is a location tolerance (see Figure A.4).

3.11
least material virtual size
LMVS
size generated by the collective effect of the least material size, LMS, (difference for external and sum for internal features) of the 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 Expressed by equations MMVS is:
For external features of size: LMVS = LMS – geometrical tolerance
For internal features of size: LMVS = LMS + geometrical tolerance

3.12
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 thefeature.

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

3.13
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 limit the non ideal feature from the outside material side.

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

NOTE 2 See also 4.2.

3.14
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 limit the non ideal feature from the inside material side.

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

NOTE 2 See also 4.3.

3.15
reciprocity requirement
RPR
additional requirement for a feature of size used as an addition to the maximum material requirement or the least material requirement to indicate that the size tolerance are enlarged with 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 size and of the geometrical tolerance concerned of interrelated features. These requirements can be applied only 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 For the time being, only features of size of type cylinder and type two opposite parallel plane surfaces are considered by this edition of ISO 2692 Consequently, the only possible derived features are median lines and median surfaces.

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

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

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

When **no** modifiers Ⓛ, Ⓜ and Ⓡ are applied to the datum, the 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 independant requirements:

a) one for the upper limit of the local size (see Rules a.1 and a.2),
b) one for the lower limit of the local size (see Rules b.1 and b.2),
c) one for the surface non-violation of the MMVC (see Rule c),

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

When the maximum material requirement, MMR, 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 frame, then it specifies for the surface(s) (of the feature of size):

Rule a.1) that for external features, the extracted local size shall be smaller than the maximum material size, MMS

NOTE 1 This rule may be altered by the indication of reciprocity requirement, RPR, with the symbol Ⓡ after the symbol Ⓜ. See clause 5 and Figure A.1.

Rule a.2) that for internal features, the extracted local size shall be larger than the least material size, LMS

NOTE 2 This rule may be altered by the indication of reciprocity requirement, RPR, with the symbol Ⓡ after the symbol Ⓛ. See clause 5 and Figure A.1.

Rule b.1) that for external features, the extracted local size shall be larger than least material size, LMS (see Figures A.2a, A.3a, A.4a, A6a, A.7a, A.10 and A.11)

Rule b.2) that for internal features, the extracted local size shall be smaller than maximum material size, MMS (see Figures A.2b, A.3b, A.4b, A.6b, A.7b, A.10 and A.11)

Rule c) that the maximum material virtual condition, MMVC, of the toleranced feature of size 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 3 Use of other constraints on size at maximum material condition, MMC, e.g. envelope requirement Ⓔ or the Taylor Principle may result in superfluous requirements, not necessary for the function of the feature(s) (assembleability). Use of these other constraints and definitions for size will reduce the technical and economical advantage of maximum material requirement, MMR

NOTE 4 The indication 0 Ⓜ has the same meaning as envelope requirement, Ⓔ

Rule d) that the toleranced features of size (when more than one) are controlled by the same tolerance indication, or when the geometrical tolerance of the derived feature is orientation or location, the maximum material virtual conditions, MMVC, of the toleranced feature(s) are in theoretical exact location(s) and orientation(s) relative to each other and to the datum(s) (see Figures A.6, A.7, A.10 and A.11).

4.2.2 Maximum Material Requirement for datum features

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

e) one for the surface non-violation of the MMVC (see Rule e),
f) one for MMS when there is no geometrical tolerance or when there is a geometrical tolerance not followed by the symbol Ⓜ (see Rule f),
g) one for MMS when there is a geometrical tolerance of form followed by the symbol Ⓜ (see Rule g),

When the maximum material requirement, MMR, is indicated on drawings by the symbol Ⓜ placed after the datum letter(s) in the tolerance frame, then it specifies for the surface(s) (of the feature of size):

Rule e) that the maximum material virtual condition, MMVC, of the datum feature shall not be violated by the extracted (integral) datum feature from which the datum is derived (see Figures A.6 and A.7).

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

Rule f) that the size of the maximum material virtual condition, MMVC, of the datum feature is the maximum material size, MMS, when the datum feature has **no** geometrical tolerance, or has a geometrical tolerance **not** followed by the symbol Ⓜ (see Figure A.6).

NOTE 2 Expressed as an equation MMVS is:
For external and internal features of size: MMVS = MMS ± 0 = MMS

Rule g) that the size of the maximum material virtual condition, MMVC, of the datum feature is maximum material size, MMS, + or – the geometrical tolerance (+ (plus) for external features of size; - (minus) for internal features of size), when the datum feature has a geometrical tolerance of form and this tolerance is followed by the symbol Ⓜ (see Figure A.7).

NOTE 3 Expressed as equations MMVS is:

For external features of size: MMVS = MMS + geometrical tolerance

For internal features of size: MMVS = MMS – geometrical tolerance

NOTE 4 This possibility is only applicable for geometrical tolerances of form for the related datum feature

4.3 Least material requirement, LMR

4.3.1 Least material requirement for toleranced features

The least material requirement, LMR, indicated on the drawing by the symbol Ⓛ placed after the geometrical tolerance of the derived feature of the size (toleranced feature) in the tolerance frame. Least material requirement, LMR, is **only** relevant in combination of a size for a feature of size with a location tolerance for its derived feature

To be fully in control of e.g. the minimum wall thickness, the symbol Ⓛ shall be applied to the tolerancing of the features on both sides of the wall. Least material requirement, LMR can be implemented in two different ways:

- The location tolerance for the two different sides of the wall can refer to the same datum axis or datum system (see Figure A.8). Ⓛ applies for the two toleranced features.

- The location tolerance of the derived feature for one of the sides of the wall can refer to the derived feature of the other as the datum. In this case the tolerance for the toleranced feature **and** the datum letter shall be followed of the symbol Ⓛ (see Figure A.9).

NOTE 1 This possibility only applies if the features on the two sides are features of size.

The symbol Ⓛ specifies:

Rule h) When applied to the toleranced feature the extracted local sizes of the feature shall be:

h.1) Larger than least material size, LMS, for external features
h.2) Smaller than maximum material size, MMS, for internal features

Rule j) When applied to the toleranced feature the extracted local sizes of the feature shall be:

j.1) Smaller than maximum material size, MMS, for external features (se Figures A.5a, A.8 and A.9)
j.2) Larger than least material size, LMS, for internal features (see Figures A.5b and A.8)

Rule k) When applied to the toleranced feature, the least material virtual condition, LMVC, shall be fully contained within the material of the extracted toleranced feature of size (see Figures A.5, A.8 and A.9).

NOTE 2 Use of other constraints on size at least material condition, LMC, e.g. envelope requirement Ⓔ or the Taylor Principle will result in superfluous requirements, not necessary for the function of the feature(s) (minimum wall thickness). Use of these other constraints and definitions for size will reduce the technical and economical advantage of least material requirement, LMR.

Rule m) The least material virtual condition(s), LMVC, of the involved features, is (are) in theoretical exact location(s) and orientation(s) relative to each other and to the datum(s) (see Figures A.8 and A.9).

4.3.2 Least material requirement for related datum features

The least material requirement, LMR, indicated on the drawing by the symbol Ⓛ placed after the datum letter in the tolerance frame.

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

Rule n) When applied to the datum, the least material virtual condition, LMVC, shall be fully contained within the material of the extracted datum feature (see Figure A.9).

4.3.3 Size of least material vitual condition, LMVC, of a related datum feature

The size of the least material virtual condition, LMVC, of the related datum feature is:

Rule o) Least material size, LMS, when the related datum feature has no geometrical tolerance or a geometrical tolerance of form followed by the symbol Ⓛ (see Figure A.9).

Rule p) Least material size, LMS, + or – (for external features of size –, for internal features of size +) the geometrical tolerance, when the related datum feature has a geometrical tolerance of form and this tolerance is followed by the symbol Ⓛ.

NOTE 1 Expressed as equations LMVS is:

For external features of size:	LMVS = LMS – geometrical tolerance
For internal features of size:	LMVS = LMS + geometrical tolerance

NOTE 2 This possibility is only applicable for geometrical tolerances of form for the related datum feature

In this case, (p), the datum triangle shall be connected to that geometrical tolerance frame from which the least material virtual condition, LMVC, of the datum feature is controlled.

5 Reciprocity requirement, RPR

5.1 General

Reciprocity requirement, RPR, is indicated on drawings as an additional requirement to maximum material requirement, MMR, or least material requirement, LMR, by the symbol Ⓡ placed after the symbol Ⓜ or the symbol Ⓡ placed after the symbol Ⓛ. Reciprocity requirement is only applicable for the toleranced feature. The additional requirement, RPR, is altering the tolerance for size of the feature of size in the collective requirements MMR and LMR. By RPR the size can take full advantage of the MMVC and the LMVC.

5.2 Reciprocity requirement, RPR, and maximum material requirement, MMR

The reciprocity requirement, RPR, indicated on drawings by the symbol Ⓡ placed after the symbol Ⓜ placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance frame, alters the maximum material requirement for the surface(s) (of the feature of size) in the following way (see Figure A.1b):

- Rule a) is not valid
- Rules b) to d) are still valid

NOTE 1 The reciprocity requirement is inherent in the tolerance indication "0 Ⓜ"

NOTE 2 The reciprocity requirement, RPR, allows an increase in the size tolerance, when the geometrical deviation does not take full advantage of the maximum material virtual condition, MMVC.

5.3 Reciprocity requirement, RPR, and least material requirement, LMR

The reciprocity requirement, RPR, indicated on drawings by the symbol Ⓡ placed after the symbol Ⓛ. placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance frame, alters the least material requirement for the surface(s) (of the feature of size) in the following way:

- Rule h) is not valid
- Rules j) to m) are still valid

NOTE 1 The reciprocity requirement is inherent in the tolerance indication "0 Ⓛ"

NOTE 2 The reciprocity requirement, RPR, allows an increase in the size tolerance, when the geometrical deviation does not take full adva/ntage of the least material virtual condition, LMVC.