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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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# Contents

Page

Foreword.....	iv
Introduction .....	v
1 Scope .....	1
2 Normative references .....	1
3 Terms and definitions.....	2
4 Maximum material requirement, MMR and least material requirement, LMR.....	5
4.1 General.....	5
4.2 Maximum material requirement, MMR.....	5
4.3 Least material requirement, LMR.....	7
5 Reciprocity requirement, RPR.....	9
5.1 General.....	9
5.2 Reciprocity requirement and maximum material requirement .....	9
5.3 Reciprocity requirement and least material requirement.....	9
Annex A (informative) Examples of tolerancing with $\text{M}$ , $\text{L}$ and $\text{R}$ .....	10
Annex B (informative) Concept diagram.....	29
Annex C (informative) Relation to the GPS matrix model.....	30
Bibliography .....	31

## 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  $\text{M}$ .

### 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  $\text{L}$ . 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:—<sup>1)</sup>, *Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum-systems*

ISO 14405:—<sup>2)</sup>, *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*

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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

$\delta$  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

$\delta$  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  $\text{Ⓜ}$  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  $\text{Ⓜ}$  after the symbol  $\text{Ⓜ}$  (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  $\text{Ⓢ}$  (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  $\text{0 Ⓜ}$  has the same meaning as envelope requirement  $\text{Ⓢ}$  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  $\text{Ⓜ}$  (see Rule F);
- c) a requirement for MMS when there is a geometrical tolerance of form followed by the symbol  $\text{Ⓜ}$  (see Rule G).

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

NOTE 1 The use of  $\text{Ⓜ}$  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

of a common datum, the sequence of letters identifying the common datum is not indicated within parentheses, and the requirement applies only to the feature identified by the letter placed just before the modifier.

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

- **Rule E** The maximum material virtual condition, MMVC, of the related 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).
- **Rule F** The size of the maximum material virtual condition, MMVC, of the related datum feature is the maximum material size, MMS, when the related datum feature has no geometrical tolerance, or has a geometrical tolerance of form not followed by the symbol  $\text{M}$  (see Figure A.6).

NOTE 3 In this case, the MMVS for external and internal features of size,  $l_{\text{MMVS}}$ , is given by Equation (5):

$$l_{\text{MMVS}} = l_{\text{MMS}} \pm 0 = l_{\text{MMS}} \quad (5)$$

where

$l_{\text{MMS}}$  is the maximum material size.

- **Rule G** The size of the maximum material virtual condition, MMVC, of the related datum feature is the maximum material size, MMS, plus (for external features of size) or minus (for internal features of size) the geometrical tolerance, when the datum feature has a geometrical tolerance of form and this tolerance is followed by the symbol  $\text{M}$  (see Figure A.7).

NOTE 4 In this case, the MMVS for external features of size is as given in Equation (1), and the MMVS for internal features of size is as given in Equation (2). See 3.8, Note 3.

NOTE 5 This possibility is only applicable for geometrical tolerances of form for the related datum feature.

In the case of Rule G, the datum triangle shall be connected to that geometrical tolerance indicator from which maximum material virtual condition, MMVC, of the datum feature is controlled.

## 4.3 Least material requirement, LMR

### 4.3.1 Least material requirement for toleranced features

When the least material requirement, LMR, applies to the toleranced feature, it is indicated on the drawing by the symbol  $\text{L}$  placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance indicator.

EXAMPLE To fully control the minimum wall thickness, the symbol  $\text{L}$  is applied to the tolerancing of the features on both sides of the wall. Least material requirement, LMR can be implemented in two different ways, as follows.

- 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). In this case,  $\text{L}$  applies to 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 are followed by the symbol  $\text{L}$  (see Figure A.9).

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

When the least material requirement, LMR, applies to the toleranced feature, it specifies for the surface(s) (of the feature of size) the following rules.

- **Rule H** The extracted local sizes of the tolerated feature shall be:
  - 1) equal to or larger than the least material size, LMS, for external features;
  - 2) equal to or smaller than the least material size, LMS, for internal features.
- **Rule I** The extracted local sizes of the tolerated feature shall be:
  - 1) equal to or smaller than the maximum material size, MMS, for external features [see Figures A.5 a), A.8 and A.9];
  - 2) equal to or larger than the maximum material size, MMS, for internal features [see Figures A.5 b) and A.8].
- **Rule J** The least material virtual condition, LMVC, of the tolerated feature shall not be violated by the extracted (integral) feature (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  $\ominus$  (previously also known as the Taylor Principle), can result in superfluous requirements, not necessary for the function of the feature(s) (minimum wall thickness). Use of other such constraints and size definitions for size reduces the technical and economic advantage of LMR.

- **Rule K** When more than one tolerated features are controlled by the same tolerance indication, or when the geometrical specification is orientation or location, the LMVC(s) of the tolerated feature(s) 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

When the least material requirement, LMR, applies to the datum feature, it is indicated on the drawing by the symbol  $\textcircled{L}$  placed after the datum letter in the tolerance indicator.

NOTE 1 The use of  $\textcircled{L}$  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 of a common datum, the sequence of letters identifying the common datum is not indicated within parentheses, and the requirement applies only to the feature identified by the letter placed just before the modifier.

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

- **Rule L** The least material virtual condition, LMVC, of the related datum feature shall not be violated by the extracted (integral) datum feature from which the datum is derived (see Figure A.9).
- **Rule M** The size of the least material virtual condition, LMVC, of the related datum feature is the least material size, LMS, when the related datum feature has no geometrical tolerance, or has a geometrical tolerance of form not followed by the symbol  $\textcircled{L}$  (see Figure A.5).

NOTE 3 In this case, the LMVS for external and internal features of size,  $l_{LMVS}$ , is given by Equation (6):

$$l_{LMVS} = l_{LMS} \pm 0 = l_{LMS} \tag{6}$$

where

$l_{LMS}$  is the least material size.

- **Rule N** The size of the least material virtual condition, LMVC, of the related datum feature is the least material size, LMS, minus (for external features of size) or plus (for internal features of size) the geometrical tolerance, when the datum feature has a geometrical tolerance of form and this tolerance is followed by the symbol  $\textcircled{L}$  (see Figure A.9).

NOTE 4 In this case, the LMVS for external features of size is as given in Equation (3), and the LMVS for internal features of size is as given in Equation (4). See 3.10, Note 3.

NOTE 5 This possibility is only applicable for geometrical tolerances of form for the related datum feature.

In the case of Rule N, the datum triangle shall be connected to that geometrical tolerance indicator 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  $\textcircled{R}$  placed after the symbol  $\textcircled{M}$ , or the symbol  $\textcircled{R}$  placed after the symbol  $\textcircled{L}$ . Reciprocity requirement is only applicable for the toleranced feature.

The additional requirement, RPR alters the size tolerance of the feature of size in the collective requirements MMR and LMR. By means of RPR, the size can take full advantage of the MMVC and the LMVC. RPR allows for the choice of distribution of variation allowance between dimensional and geometrical tolerances based on manufacturing capabilities.

NOTE Reciprocity requirement can express the same workpiece functions as the indication "0  $\textcircled{M}$ ".

### 5.2 Reciprocity requirement and maximum material requirement

The reciprocity requirement, RPR, indicated on drawings by the symbol  $\textcircled{R}$  placed after the symbol  $\textcircled{M}$  [itself placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance indicator], alters the maximum material requirement for the surface(s) (of the feature of size) in the following ways [see Figure A.1 b)]:

- Rule A is not valid.
- Rules B to D are still valid.

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

### 5.3 Reciprocity requirement and least material requirement

The reciprocity requirement, RPR, indicated on drawings by the symbol  $\textcircled{R}$  placed after the symbol  $\textcircled{L}$  [itself placed after the geometrical tolerance of the derived feature of the feature of size (toleranced feature) in the tolerance indicator], alters the least material requirement for the surface(s) (of the feature of size) in the following ways [see Figures A.5 e) and A.5 f)]:

- Rule H is not valid.
- Rules I to K are still valid.

NOTE The reciprocity requirement, RPR, allows an increase in the dimensional tolerance when the geometrical deviation does not take full advantage of the least material virtual condition, LMVC.

## Annex A (informative)

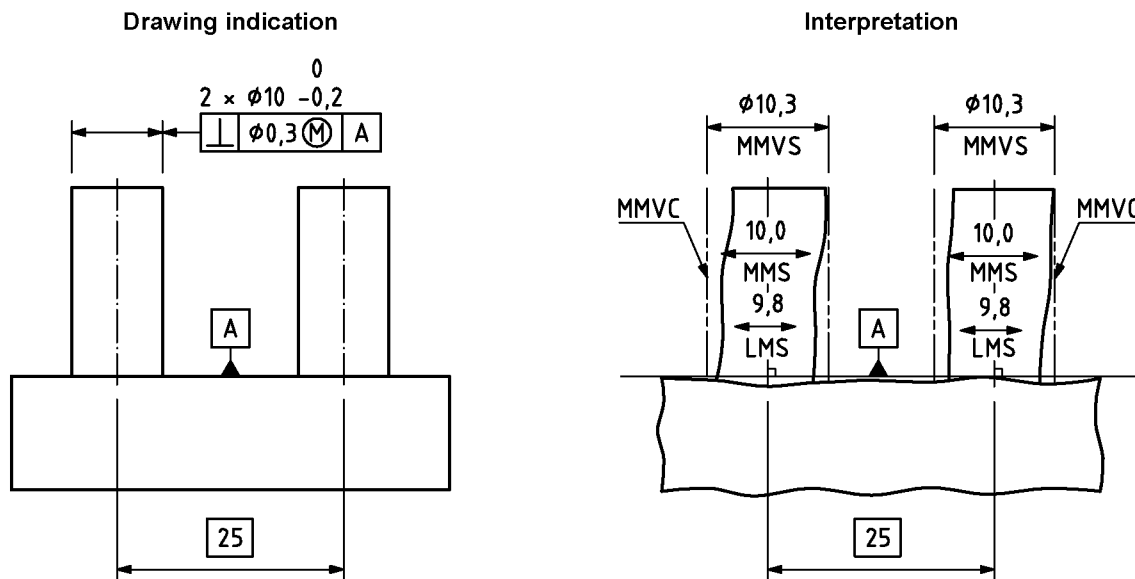
### Examples of tolerancing with $\text{M}$ , $\text{L}$ and $\text{R}$

The figures in this International Standard are intended only as illustrations to aid the user in understanding the maximum material requirement, the least material requirement and the reciprocity requirement. In some instances, figures provide added details for emphasis; in other instances, figures have deliberately been left incomplete. Numerical values of dimensions and tolerances have been given for illustrative purposes only.

For uniformity in this International Standard, all dimensions are given in millimetres and all figures are in first angle projection.

It should be understood that the third angle projection method could equally well have been used without prejudice to the principles established. For the definitive presentation (proportions and dimensions) of symbols for geometrical tolerancing, see ISO 7083:1983.

Dimensions in millimetres



The intended function of the part illustrated in Figure A.1 a) is an assembly with a plate with two holes 25 mm apart. The holes are required to be perpendicular to the contact surface of the plate.

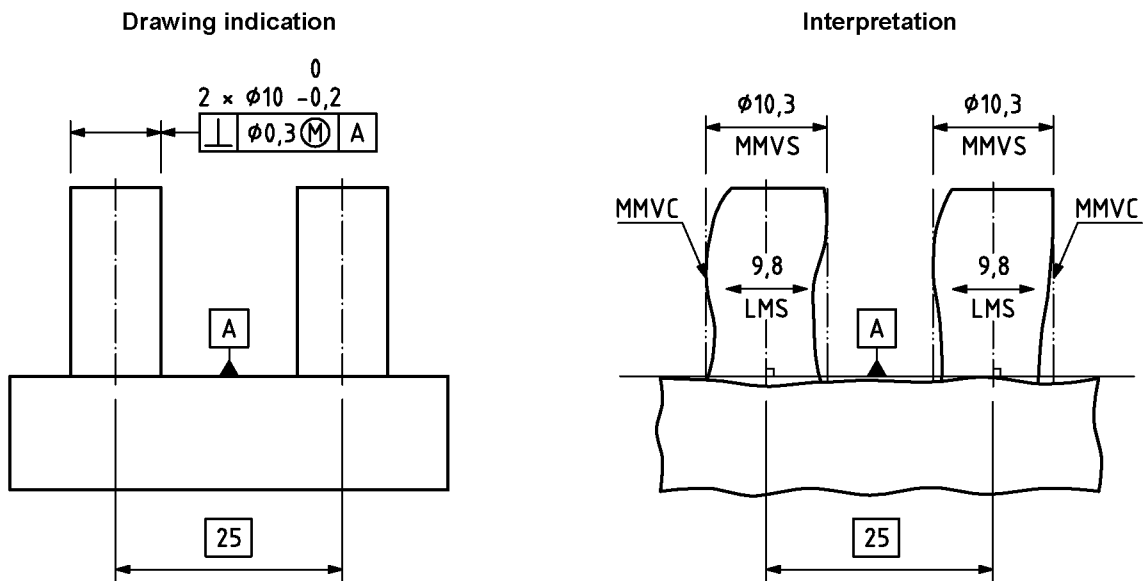
The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature of the tolerated pins shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 10,3 mm (see Rule C, 3.8 and 3.9).
- b) The extracted feature of the tolerated pins shall have everywhere a local diameter larger than LMS = 9,8 mm [see Rule B 1) and 3.5] and smaller than MMS = 10,0 mm [see Rule A 1) and 3.3].
- c) The location of the two MMVCs is theoretically correct — at a distance 25 mm relative to each other and theoretically correct perpendicular to the datum A [see Rule D and 3.7 NOTE 2].

**a) Example of MMR without RPR for two external cylindrical features based on size and perpendicularity (orientation) requirements**

Figure A.1 (continued)

Dimensions in millimetres



The intended function of the part illustrated in Figure A.1 b) is an assembly with a plate with two holes 25 mm apart. The holes are required to be perpendicular to the contact surface of the plate.

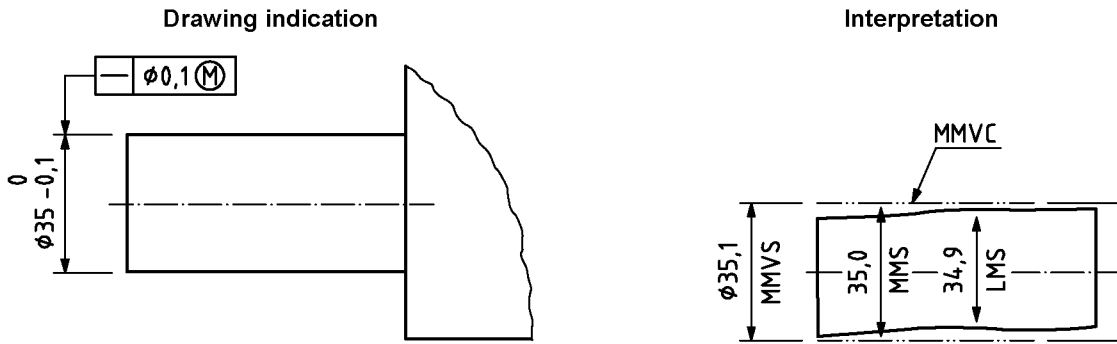
The interpretation is based on the following rules and definitions given in this International Standard.

- The extracted feature of the tolerated pins shall not violate the maximum material virtual condition, MMVC, which has the diameter  $MMVS = 10,3$  mm (see Rule C and 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the tolerated pins shall have everywhere a local diameter larger than  $LMS = 9,8$  mm [see Rule B 1) and 3.5]. The RPR requirement allows the size tolerance to increase.
- The location of the two MMVCs is theoretically correct — at a distance 25 mm relative to each other and theoretically correct perpendicular to the datum A (see Rule D and 3.7 NOTE 2).

**b) Example of MMR with RPR for two external cylindrical features based on size and perpendicularity (orientation) requirements**

**Figure A.1 — Examples of MMR for two external cylindrical features based on size and perpendicularity (orientation) requirements**

Dimensions in millimetres



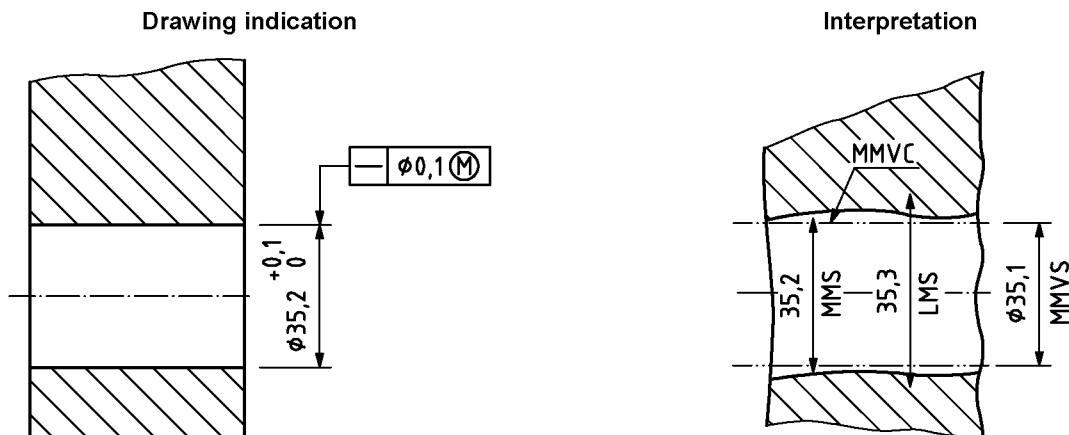
The intended function of the part toleranced in Figure A.2 a) could be a clearance fit with a hole of the same length as the toleranced cylindrical feature.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter larger than LMS = 34,9 mm (see Rule B 1) and 3.5) and smaller than MMS = 35,0 mm [see Rule A 1) and 3.3].
- c) The orientation and location of the MMVC are not controlled by any external constraints (see 3.7 NOTE 2).

**a) Example of MMR for an external cylindrical feature based on size and form (straightness) requirements**

Dimensions in millimetres



The intended function of the part toleranced in Figure A.2 b) could be a clearance fit with a shaft of the same length as the toleranced cylindrical feature.

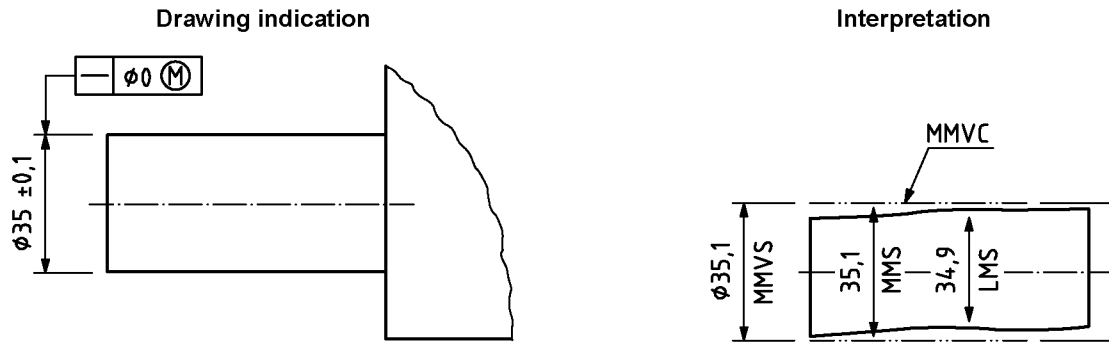
The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS = 35,2 mm [see Rule A 2) and 3.3].
- c) The orientation and location of the MMVC are not controlled by any external constraints (see 3.7 NOTE 2).

**b) Example of MMR for an internal cylindrical feature based on size and form (straightness) requirements**

**Figure A.2 (continued)**

Dimensions in millimetres



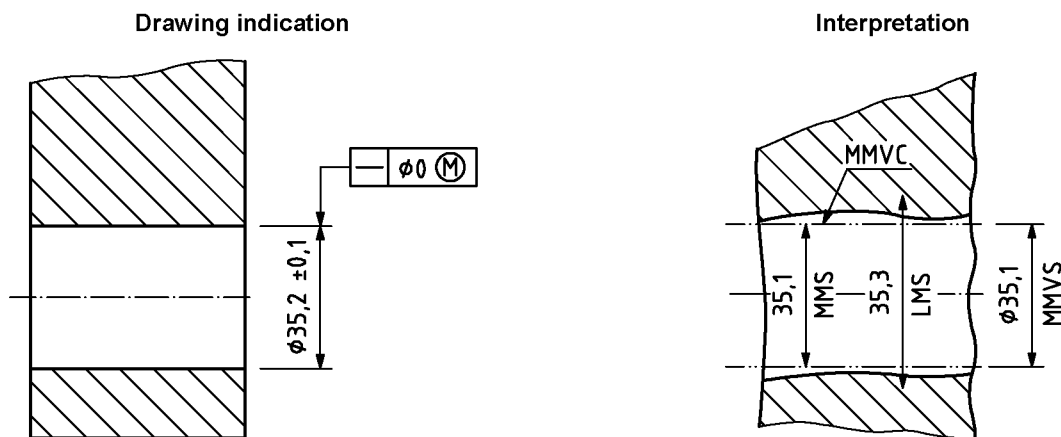
The intended function of the part toleranced in Figure A.2 c) could be a clearance fit with a hole of the same length as the toleranced cylindrical feature.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter larger than LMS = 34,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 35,1 mm [see Rule A 1) and 3.3]. The difference between Figures A.2 c) and A.2 a) is in the specification of the local diameter, in this case MMS.
- c) The orientation and location of the MMVC are not controlled by any external constraints (see 3.7 NOTE 2).

**c) Example of MMR [with 0 (M)] for an external cylindrical feature based on size and form (straightness) requirements**

Dimensions in millimetres



The intended function of the part toleranced on Figure A.2 d) could be a clearance fit with a shaft of the same length as the toleranced cylindrical feature.

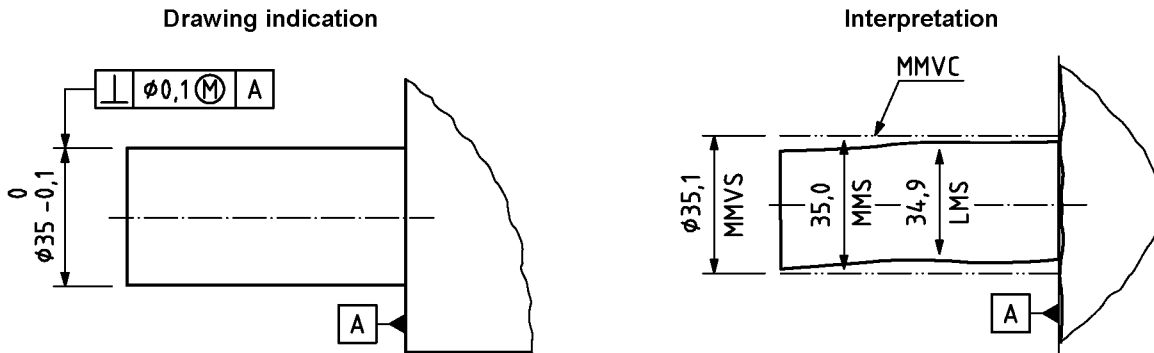
The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS = 35,1 mm [see Rule A 2) and 3.3]. The difference between Figures A.2 d) and A.2 b) is in the specification of the local diameter, in this case MMS.
- c) The orientation and location of the MMVC are not controlled by any external constraints (see 3.7 NOTE 2).

**d) Example of MMR [with 0 (M)] for an internal cylindrical feature based on size and form (straightness) requirements**

**Figure A.2 — Examples of MMR for a cylindrical feature based on size and form (straightness) requirements**

Dimensions in millimetres



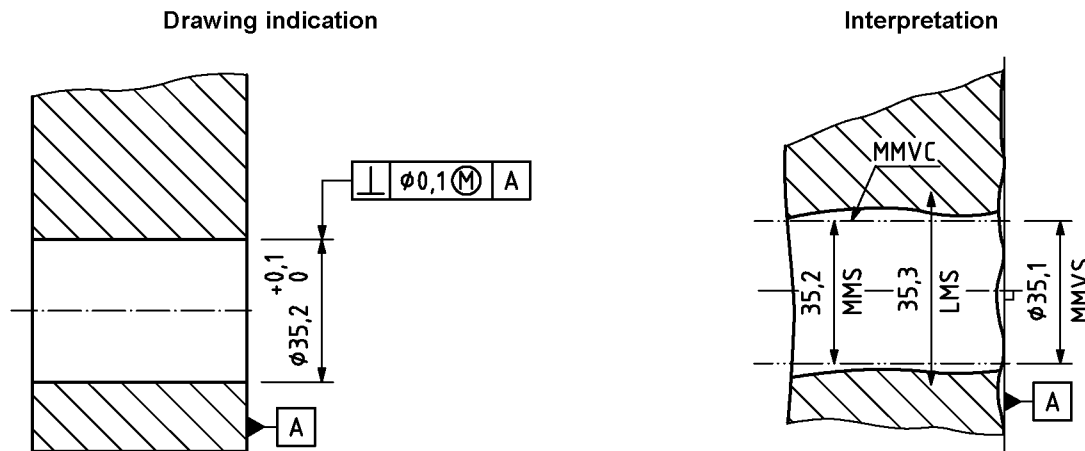
The intended function of the part toleranced in Figure A.3 a) could be an assembly with a part as shown in Figure A.3 b), where the functional requirement is that the two planar faces shall be in contact and the pin shall fit into the hole at the same time.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter larger than LMS = 34,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 35,0 mm [see Rule A 1) and 3.3].
- c) The orientation of the MMVC is perpendicular to the datum and the location of the MMVC is not controlled by any external constraints (see Rule D and 3.7 NOTE 2).

**a) Example of MMR for an external cylindrical feature based on size and orientation (perpendicularity) requirements**

Dimensions in millimetres



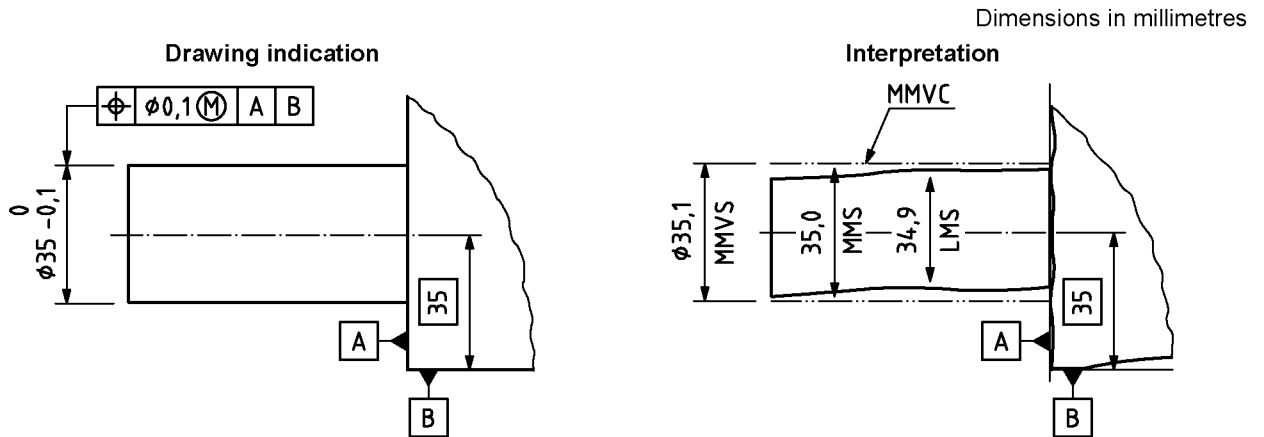
The intended function of the part toleranced in Figure A.3 b) could be an assembly with a part as shown in Figure A.3 a), where the functional requirement is that the two planar faces shall be in contact and the pin shall fit into the hole at the same time.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS = 35,2 mm [see Rule A 2) and 3.3].
- c) The orientation of the MMVC is perpendicular to the datum and the location of the MMVC is not controlled by any external constraints (see Rule D and 3.7 NOTE 2).

**b) Example of MMR for an internal cylindrical feature based on size and orientation (perpendicularity) requirements**

**Figure A.3 — Examples of MMR for a cylindrical feature based on size and orientation (perpendicularity) requirements**

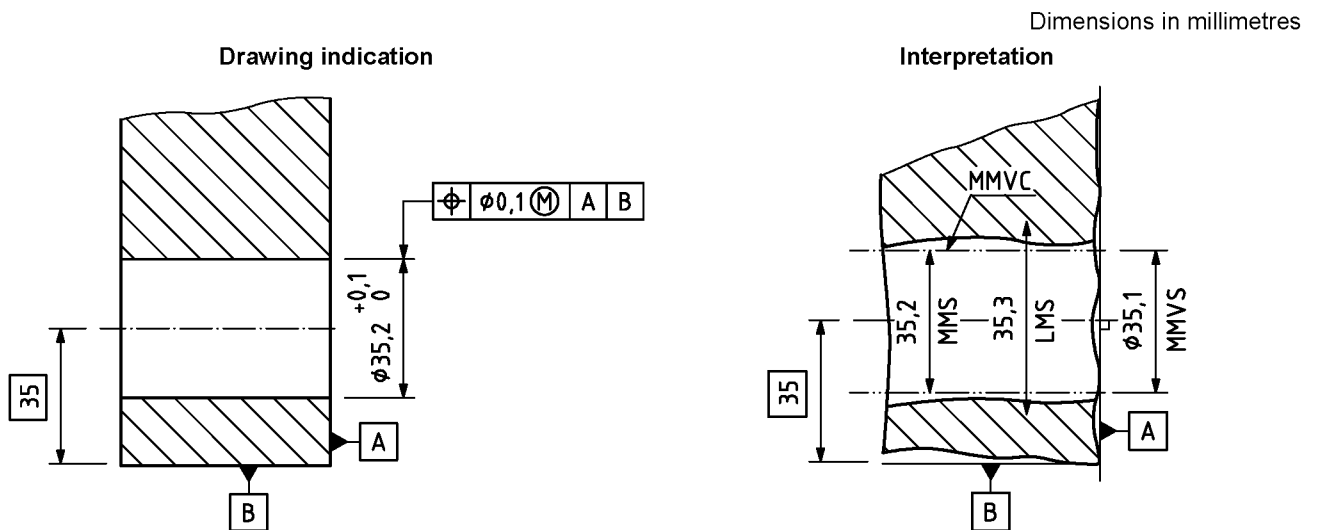


The intended function of the part toleranced in Figure A.4 a) could be an assembly with a part as shown in Figure A.4 b), where the functional requirement is that the two planar faces A shall be in contact, the two planar faces B shall both simultaneously be in contact with a plane (on a part not shown).

The interpretation is based on the following rules and definitions given in this International Standard.

- The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.8 and 3.9).
- The extracted feature shall have everywhere a local diameter larger than LMS = 34,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 35,0 mm [see Rule A 1) and 3.3].
- The orientation of the MMVC is perpendicular to datum A and the location of the MMVC is in a theoretically exact position 35 mm from datum B (see Rule D and 3.7 NOTE 2).

**a) Example of MMR for an external cylindrical feature based on size and location (position) requirements**



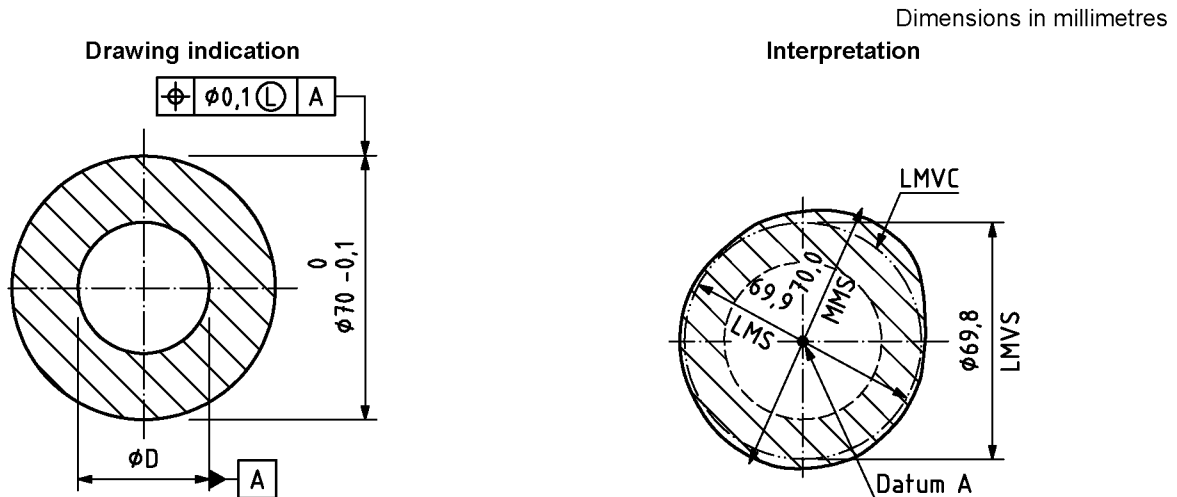
The intended function of the part toleranced in Figure A. 4b) could be an assembly with a part as shown in Figure A.4 a), where the functional requirement is that the two planar faces A shall be in contact, the two planar faces B shall both simultaneously be in contact with a plane (on a part not shown).

The interpretation is based on the following rules and definitions given in this International Standard.

- The extracted feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS = 35,2 mm [see Rule A 2) and 3.3].
- The orientation of the MMVC is perpendicular to datum A and the location of the MMVC is in a theoretically exact position 35 mm from datum B (see Rule D and 3.7 NOTE 2).

**b) Example of MMR for an internal cylindrical feature based on size and location (position) requirements**

**Figure A.4 — Examples of MMR for a cylindrical feature based on size and location (position) requirements**



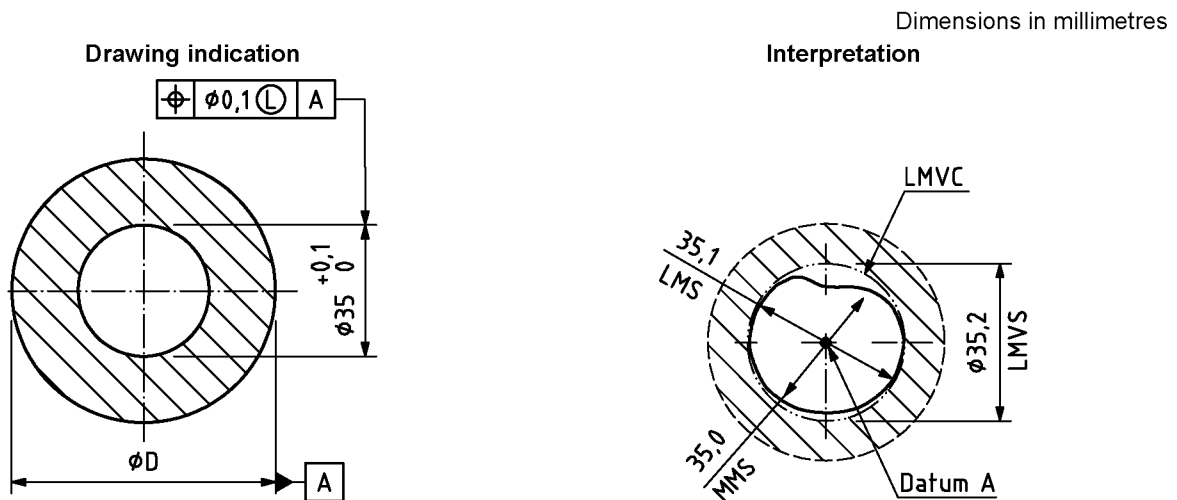
Position and coaxiality/concentricity can be used with the same meaning in this case.

This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The least material virtual condition, LMVC, which has the diameter LMVS = 69,8 mm, shall be fully contained in the material (see Rule J, 3.7 and 3.8).
- b) The extracted feature shall have everywhere a local diameter smaller than MMS = 70,0 mm [see Rule I 1) and 3.3] and larger than LMS = 69,9 mm [see Rule H 1) and 3.5].
- c) The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

**a) Example 1 of least material requirement for one external feature of size with another concentric internal feature of size as the datum**



Position and coaxiality/concentricity can be used with the same meaning in this case.

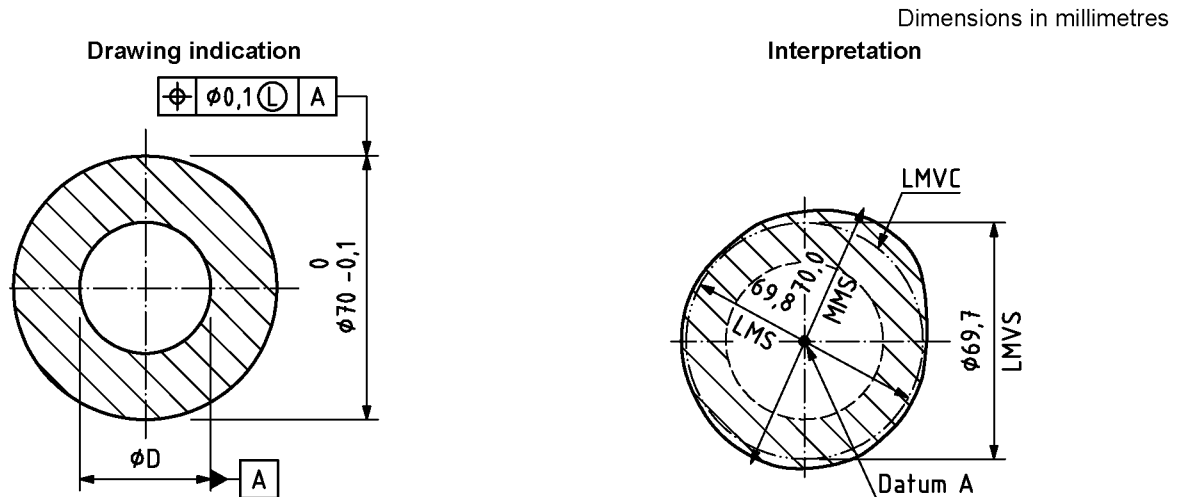
This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The least material virtual condition, LMVC, which has the diameter LMVS = 35,2 mm, shall be fully contained in the material (see Rule J, 3.7 and 3.8).
- b) The extracted feature shall have everywhere a local diameter larger than MMS = 35,0 mm [see Rule I 2) and 3.3] and smaller than LMS = 35,1 mm [see Rule H 2) and 3.5].
- c) The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

**b) Example 1 of least material requirement for one internal feature of size with another concentric external feature of size as the datum**

**Figure A.5 (continued)**



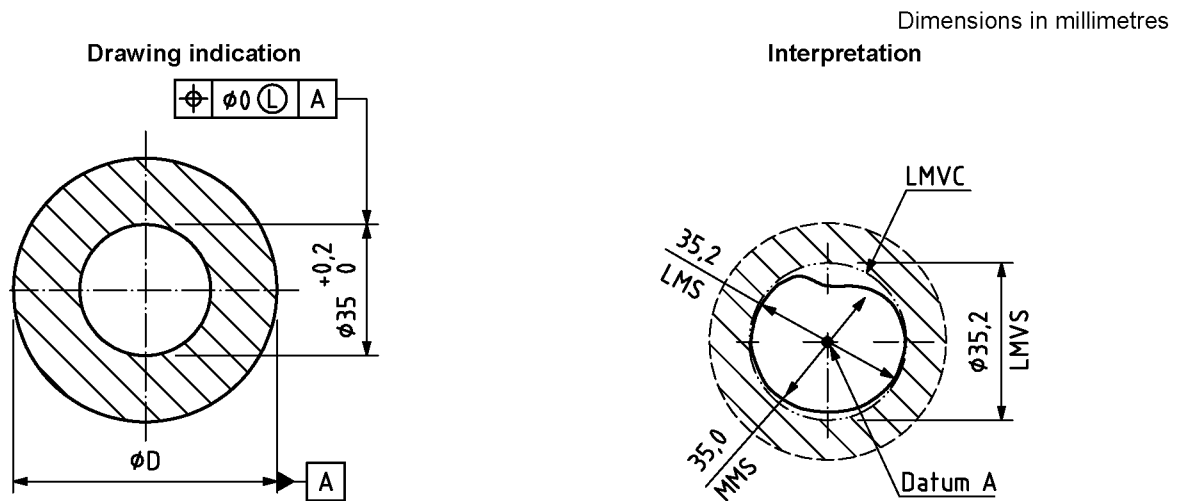
Position and coaxiality/concentricity can be used with the same meaning in this case.

This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- The least material virtual condition, LMVC, which has the diameter LMVS = 69,8 mm, shall be fully contained in the material (see Rule J, 3.7 and 3.8).
- The extracted feature shall have everywhere a local diameter smaller than MMS = 70,0 mm [see Rule I 1) and 3.3] and larger than LMS = 69,8 mm [see Rule H 1) and 3.5]. The difference between Figures A.5 c) and A.5 a) is in the specification of the local diameter, in this case to LMS.
- The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

**c) Example 2 of least material requirement for one external feature of size with another concentric internal feature of size as the datum**



Position and coaxiality/concentricity can be used with the same meaning in this case.

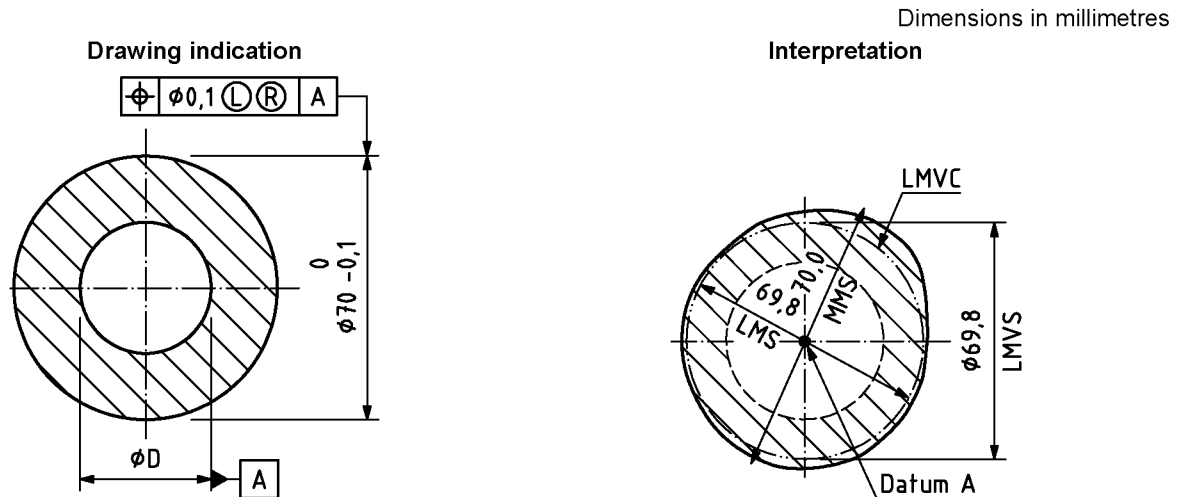
This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- The least material virtual condition, LMVC, which has the diameter LMVS = 35,2 mm, shall be fully contained in the material (see 4.3.1, Rule J, 3.7 and 3.8).
- The extracted feature shall have everywhere a local diameter larger than MMS = 35,0 mm [see Rule I 2) and 3.3] and smaller than LMS = 35,2 mm [see Rule H 2) and 3.5]. The difference between Figures A.5 d) and A.5 b) is in the specification of the local diameter, in this case to LMS.
- The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

**d) Example 2 of least material requirement for one internal feature of size with another concentric external feature of size as the datum**

**Figure A.5 (continued)**



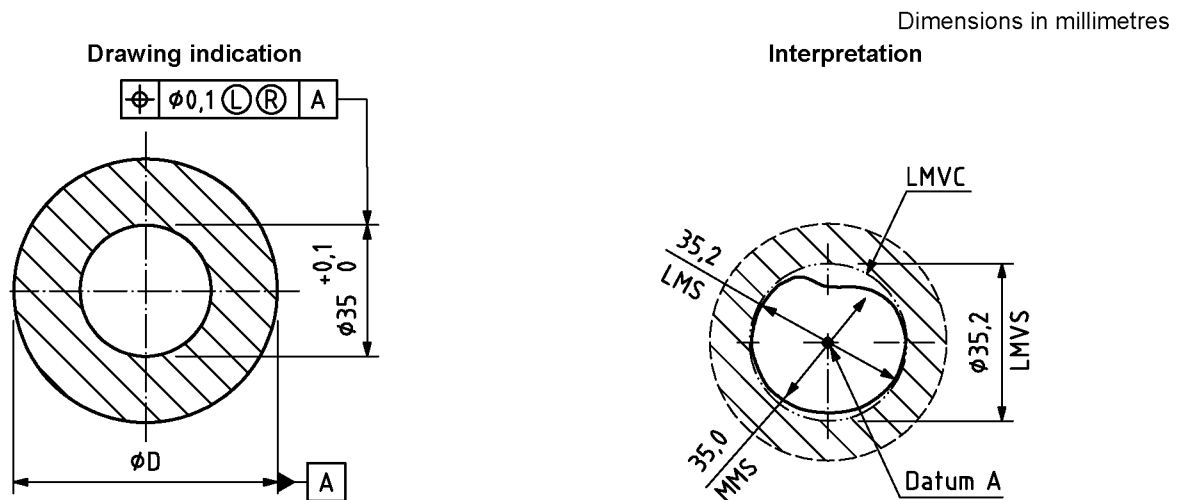
Position and coaxiality/concentricity can be used with the same meaning in this case.

This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The least material virtual condition, LMVC, which has the diameter LMVS = 69,8 mm, shall be fully contained in the material (see Rule J, 3.7 and 3.8).
- b) The extracted feature shall have everywhere a local diameter smaller than MMS = 70 mm [see Rule I 1) and 3.6]. The RPR allows the size tolerance limit to decrease from LMS (local diameter may be smaller than 69,9 mm, down to LMVS).
- c) The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

**e) Example of least material and reciprocity requirements for one external feature of size with another concentric internal feature of size as the datum**



Position and coaxiality/concentricity can be used with the same meaning in this case.

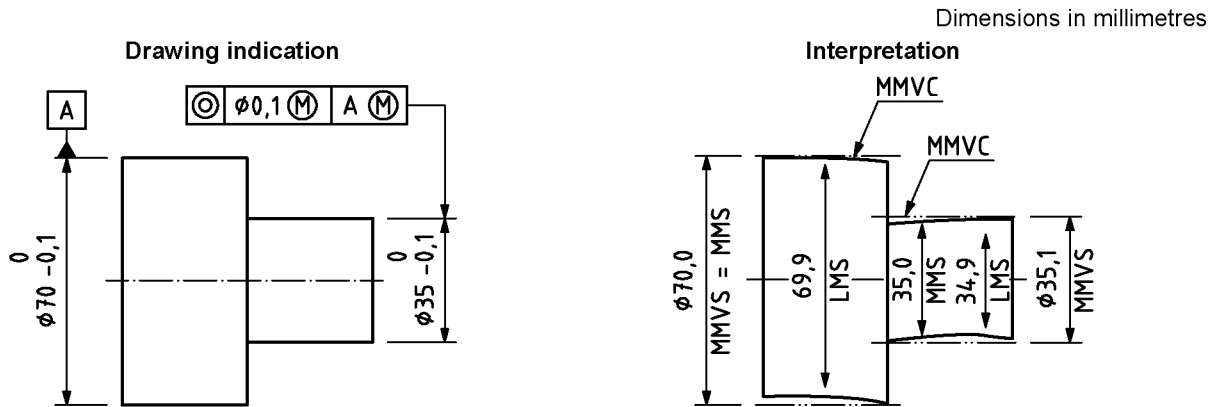
This figure only illustrates some rules for least material requirement. This drawing indication is incomplete and does not control the minimum wall thickness. The least material requirement is missing on the other feature. Therefore it is not possible to indicate a function.

The interpretation is based on the following rules and definitions given in this International Standard.

- a) The least material virtual condition, LMVC, which has the diameter LMVS = 35,2 mm, shall be fully contained in the material [see Rule J, 3.7 and 3.8).
- b) The extracted feature shall have everywhere a local diameter smaller than MMS = 35 mm [see Rule I 2) and 3.6]. The RPR allows the size tolerance limit to increase beyond LMS (local diameter may be larger than 35,1 mm, up to LMVS).
- c) The orientation of the LMVC is parallel to the datum and the location of the MMVC is in a theoretically exact position coaxial with datum A (see Rule K and 3.9 NOTE 2).

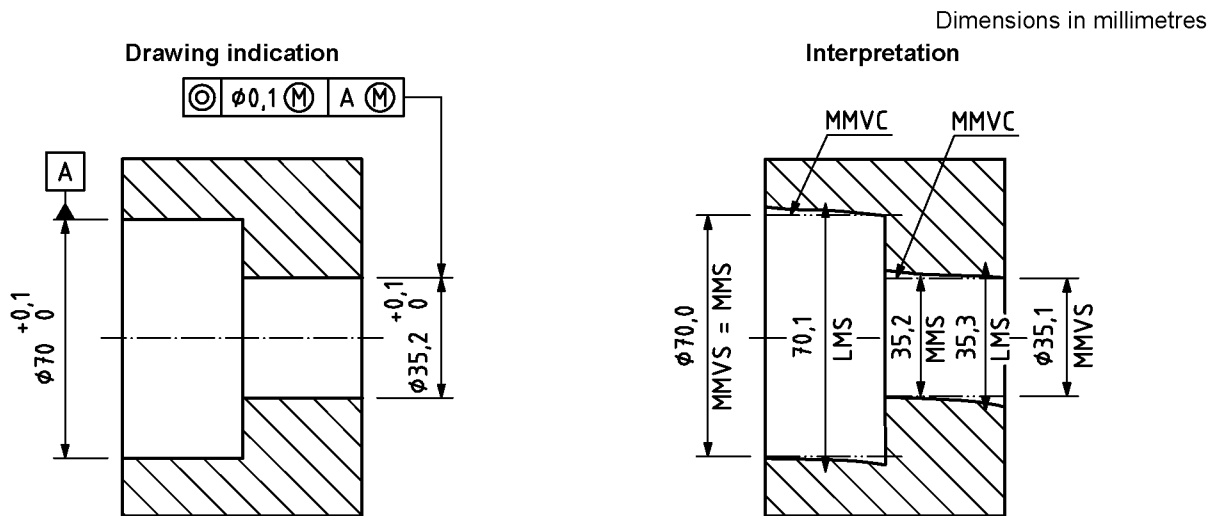
**f) Example of least material and reciprocity requirements for one internal feature of size with another concentric external feature of size as the datum**

**Figure A.5 — Examples of use of LMR for one feature of size with another concentric feature of size as the datum**



The intended function of the part toleranced in Figure A.6 a) could be an assembly with a part similar to that of Figure A.6 b). The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature of the toleranced feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
  - b) The extracted feature of the toleranced feature shall have everywhere a local diameter larger than LMS = 34,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 35,0 mm [see Rule A 1) and 3.3].
  - c) The location of the MMVC is coaxial to the axis of the MMVC of the datum feature (see Rule D and 3.7 NOTE 2).
  - d) The extracted feature of the datum feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = MMS = 70,0 mm (see Rule F, 3.6, 3.7 and 3.7 NOTE 1).
  - e) The extracted feature of the datum feature shall have everywhere a local diameter larger than LMS = 69,9 mm [see Rule B 1), 3.5].
- a) Example of MMR for an external cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement — as the datum and also with MMR**

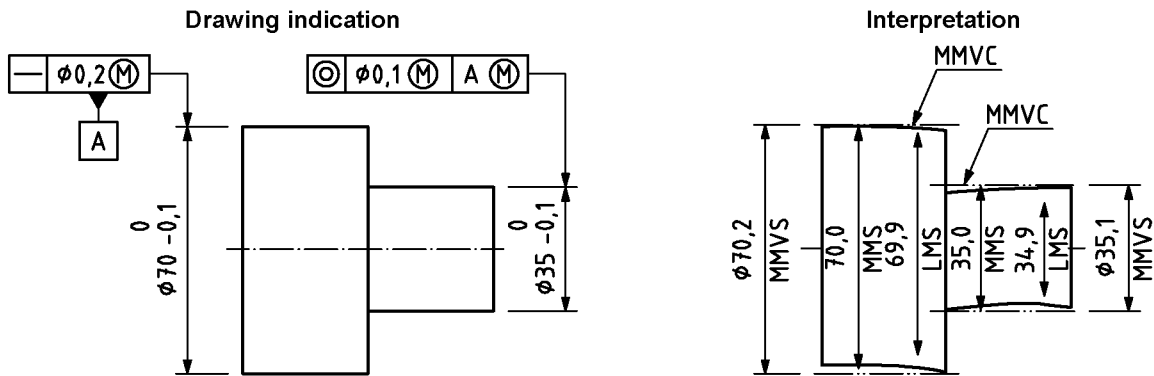


The intended function of the part toleranced in Figure A.6 b) could be an assembly with a part similar to that of Figure A.6 a). The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature of the toleranced feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
  - b) The extracted feature of the toleranced feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS = 35,2 mm [see Rule A 2) and 3.3].
  - c) The location of the MMVC is coaxial to the axis of the MMVC of the datum feature (see Rule D and 3.7 NOTE 2).
  - d) The extracted feature of the datum feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = MMS = 70,0 mm (see Rule F, 3.6, 3.7 and 3.7 NOTE 1).
  - e) The extracted feature of the datum feature shall have everywhere a local diameter smaller than LMS = 70,1 mm [see Rule B 2) and 3.5].
- b) Example of MMR for an internal cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement — as the datum and also with MMR**

**Figure A.6 — Examples of MMR for a cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement — as the datum and also with MMR**

Dimensions in millimetres

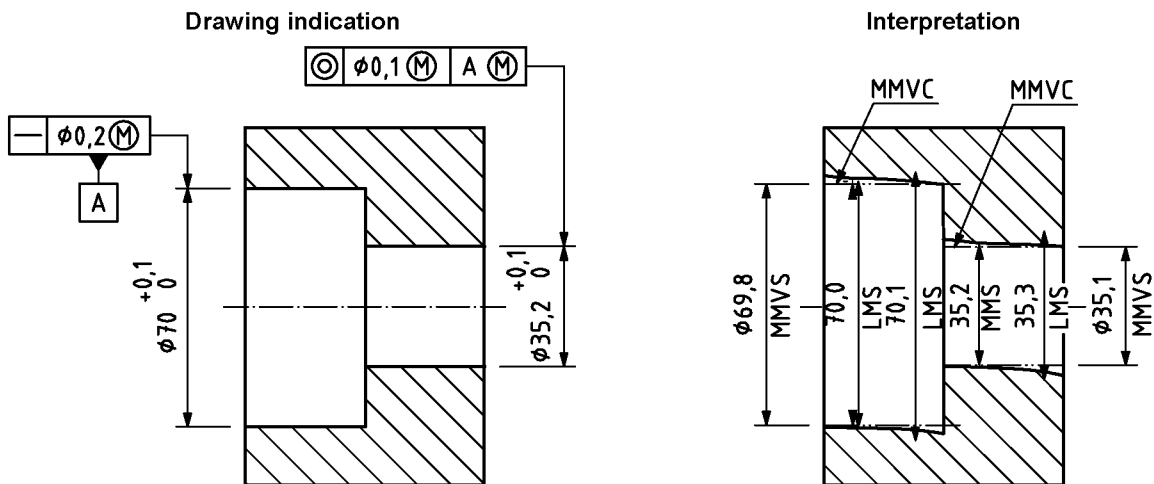


The intended function of the part toleranced in Figure A.7 a) could be an assembly with a part similar to that of Figure A.7 b). The interpretation is based on the following rules and definitions given in this International Standard.

- a) The extracted feature of the toleranced feature shall not violate the MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature of the toleranced feature shall have everywhere a local diameter larger than LMS = 34,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 35,0 mm [see Rule A 1) and 3.3].
- c) The location of the MMVC is coaxial to the axis of the MMVC of the datum feature (see Rule D and 3.7 NOTE 2).
- d) The extracted feature of the datum feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 70,2 mm (see Rule G, 3.6, 3.7 and 3.7 NOTE 1).
- e) The extracted feature of the datum feature shall have everywhere a local diameter larger than LMS = 69,9 mm [see Rule B 1) and 3.5] and smaller than MMS = 70,0 mm [see Rule A 1) and 3.3].

**a) Example of MMR for an external cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement and a form tolerance — as the datum and also with MMR**

Dimensions in millimetres



The intended function of the part toleranced in Figure A.7 b) could be an assembly with a part similar to that of Figure A.7 a). The interpretation is based on the following rules and definitions given in this International Standard.

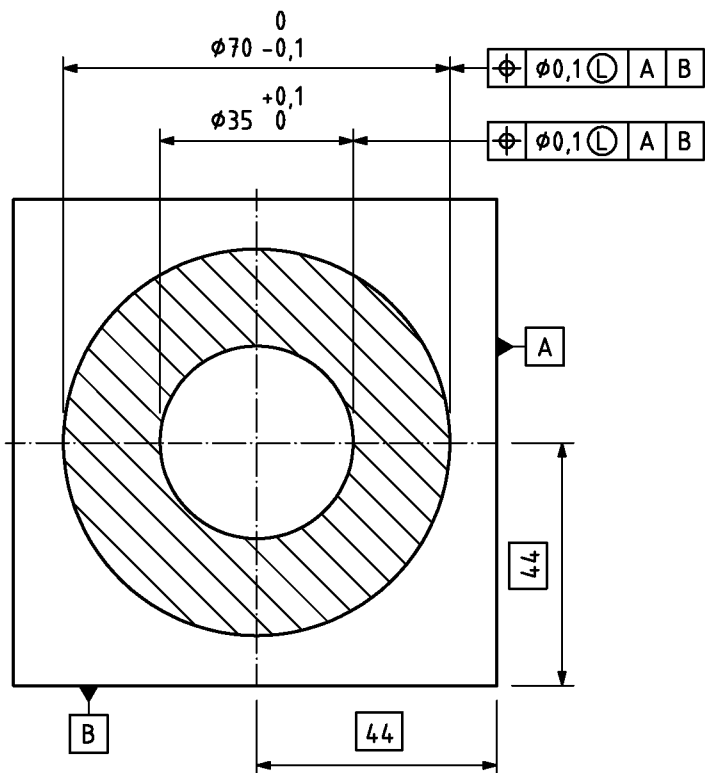
- a) The extracted feature of the toleranced feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 35,1 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- b) The extracted feature of the toleranced feature shall have everywhere a local diameter smaller than LMS = 35,3 mm [see Rule B 2) and 3.5] and larger than MMS 35,2 mm [see Rule A 2) and 3.3].
- c) The location of the MMVC is coaxial to the axis of the MMVC of the datum feature (see Rule D and 3.7 NOTE 2).
- d) The extracted feature of the datum feature shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 69,8 mm (see Rule G, 3.6, 3.7 and 3.7 NOTE 1).
- e) The extracted feature of the datum feature shall have everywhere a local diameter smaller than LMS = 70,1 mm [see Rule B 2) and 3.5] and larger than MMS = 70 mm [see Rule A 2) and 3.3].

**b) Example of MMR for an internal cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement and a form tolerance — as the datum and also with MMR**

**Figure A.7 — Examples of MMR for a cylindrical feature based on size and location (coaxiality) requirements with the axis of a cylindrical feature — with a size requirement and a form tolerance — as the datum and also with MMR**

Dimensions in millimetres

Drawing indication



Interpretation

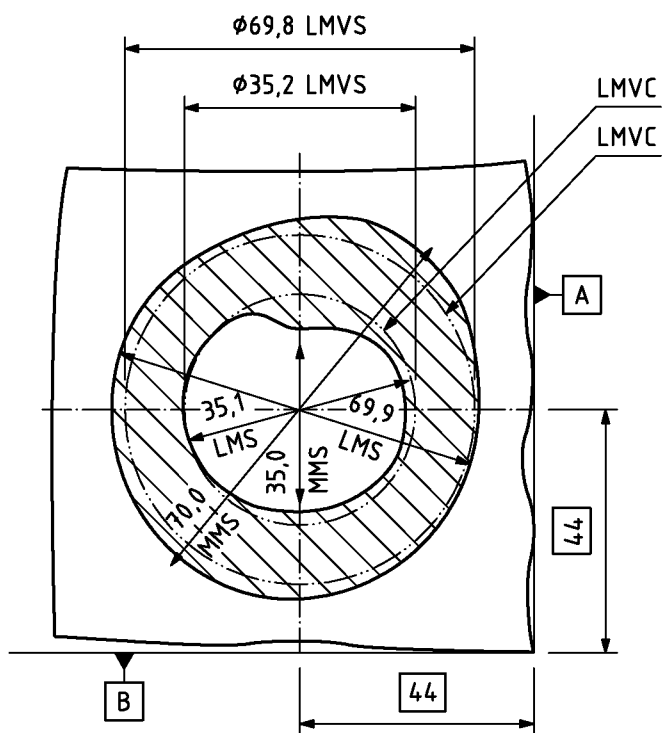


Figure A.8 (continued)

The intended function of the part illustrated in Figure A.8 is the ability to resist internal pressure and prevent breakout.

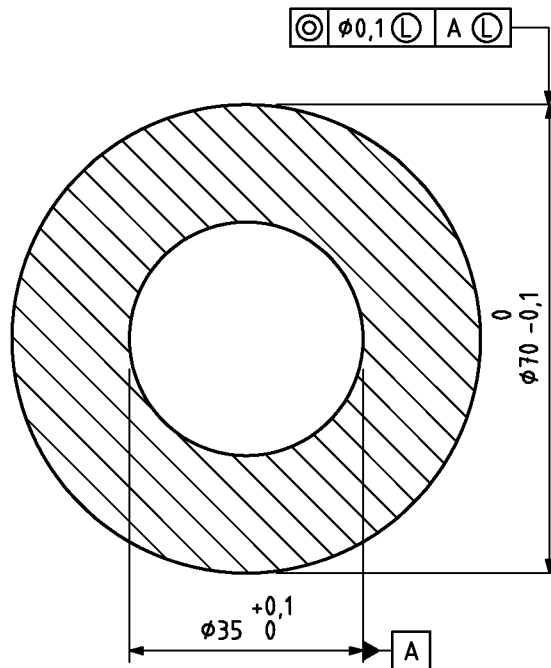
The interpretation is based on the following rules and definitions given in this International Standard.

- a) The least material virtual condition, LMVC, of the external feature shall be fully contained in the material. The diameter LMVS = 69,8 mm (see Rule J, 3.6 and 3.7).
- b) The extracted feature of the external feature shall have everywhere a local size smaller than MMS = 70,0 mm (see Rule I 2) and 3.2) and larger than LMS = 69,9 mm [see Rule H 1) and 3.5].
- c) The least material virtual condition, LMVC of the internal feature shall be fully contained in the material. The diameter LMVS = 35,2 mm (see Rule J, 3.6 and 3.7).
- d) The extracted feature of the internal feature shall have everywhere a local size larger than MMS = 35,0 mm (see Rule I 2 and 3.2) and smaller than LMS = 35,1 mm [see Rule H 2) and 3.5].
- e) The least material virtual condition, LMVC, of both the external and the internal feature shall be in a theoretically exact orientation and the location relative to the datum system at a position 44, 44 mm (see Rule K and 3.8 NOTE 2).

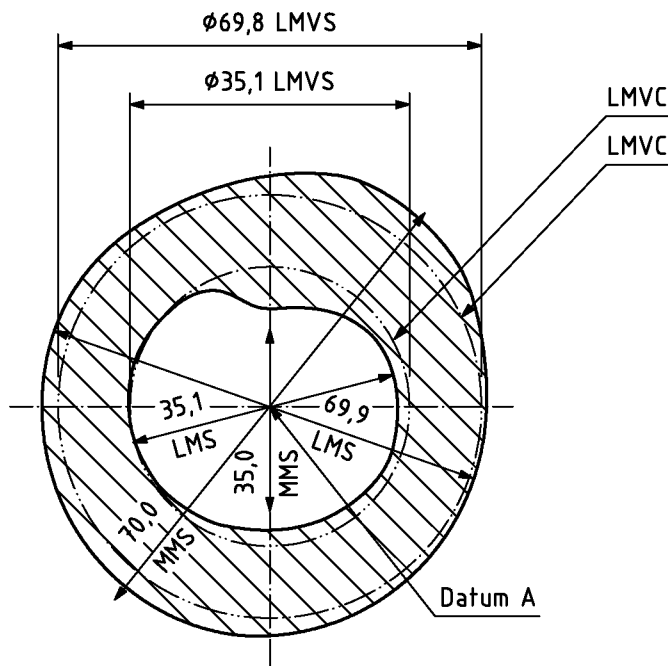
**Figure A.8 — Example of LMR for two concentric cylindrical features (internal and external) both controlled by size and location (position) to the same datum system A and B**

Dimensions in millimetres

Drawing indication



Interpretation

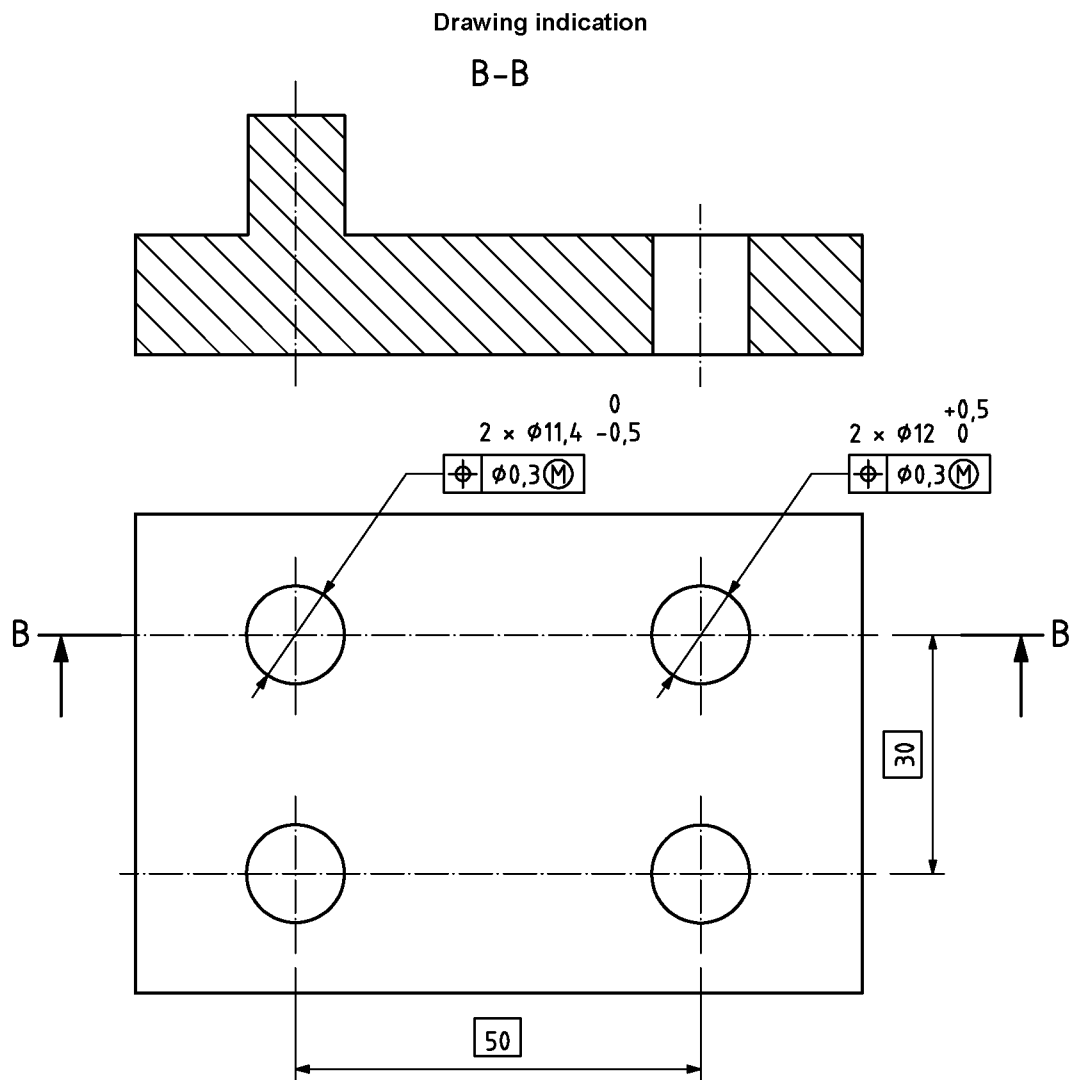


The intended function of the part illustrated in Figure A.9 is the ability to resist internal pressure and prevent breakout.

The interpretation is based on the following rules and definitions given in this International Standard

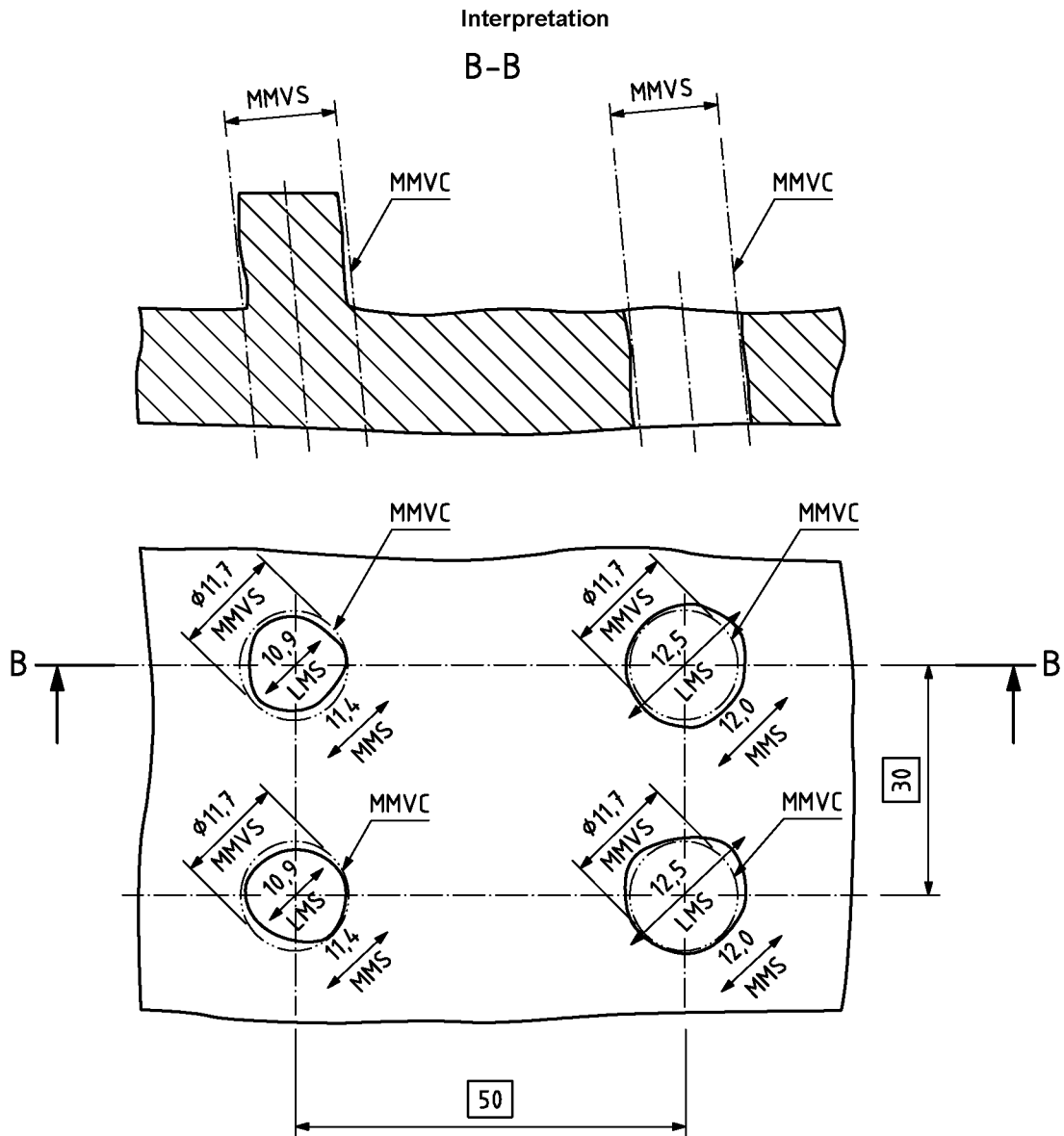
- The least material virtual condition, LMVC, of the external feature shall be fully contained in the material. The diameter LMVS = 69,8 mm (see Rule J, 3.6 and 3.7).
- The extracted feature of the external feature shall have everywhere a local size smaller than MMS = 70,0 mm [see Rule I 2) and 3.2] and larger than LMS = 69,9 mm [see Rule H 1) and 3.5].
- The least material virtual condition, LMVC, of the internal feature shall be fully contained in the material. The diameter LMVS = 35,1 mm (see Rule J, 3.6 and 3.7).
- The extracted feature of the internal feature shall have everywhere a local size larger than MMS = 35,0 mm (see Rule I 2) and 3.2) and smaller than LMS = 35,1 mm [see Rule H 2) and 3.5].
- The least material virtual condition, LMVC, of the external feature shall be in a theoretically exact location relative to the axis of the least material virtual condition, LMVC, of the internal feature (see Rule K and 3.8 NOTE 2).

**Figure A.9 — Example of LMR for an external cylindrical feature controlled by size and location (coaxiality) relative to the internal cylindrical feature used as a datum controlled by size and LMR**



The intended function of the part illustrated in Figure A.10 may be to form a clearance fit with a similar part. It is not a functional requirement that the flat surfaces of the two parts shall be in contact.

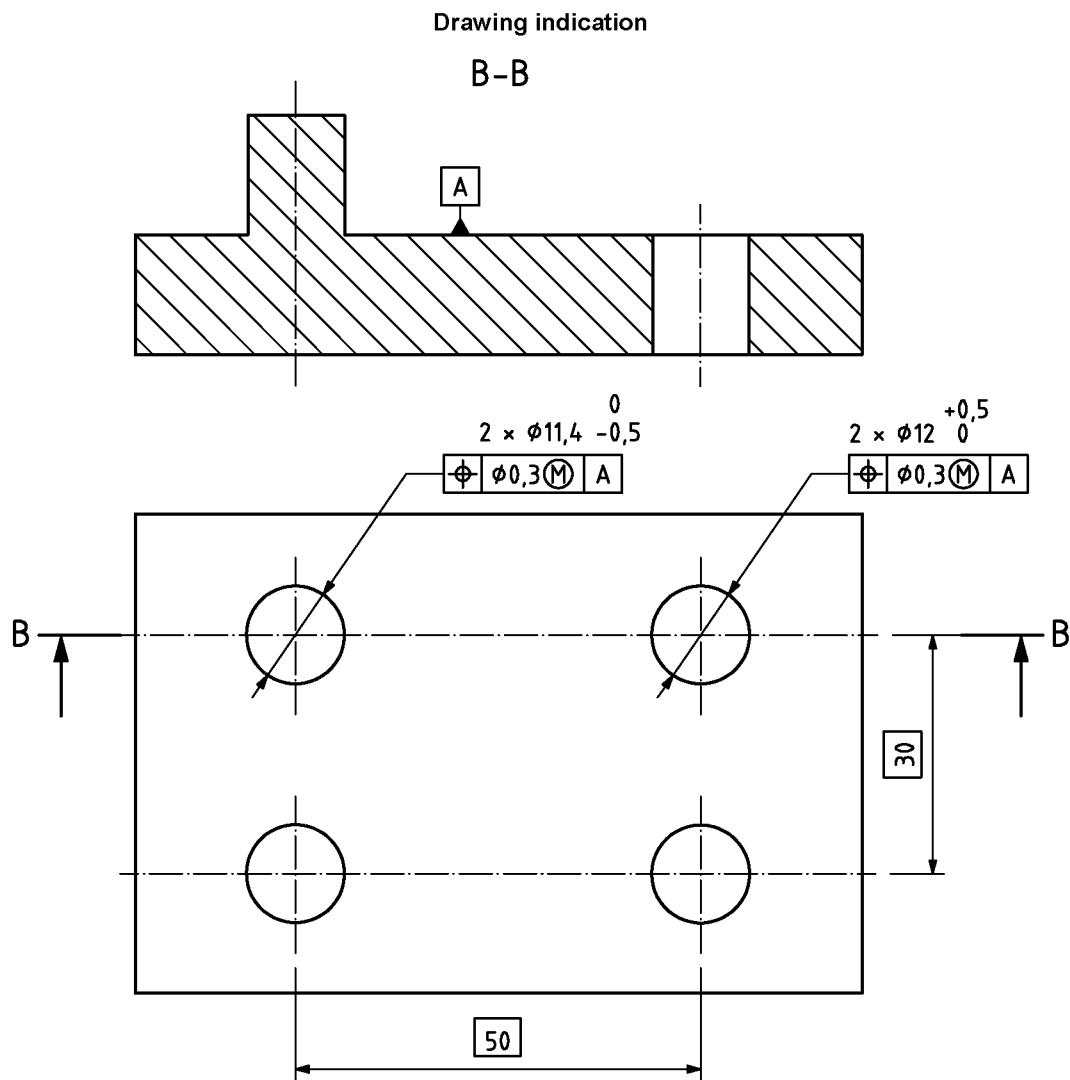
Figure A.10 (continued)



The interpretation is based on the following rules and definitions given in this International Standard.

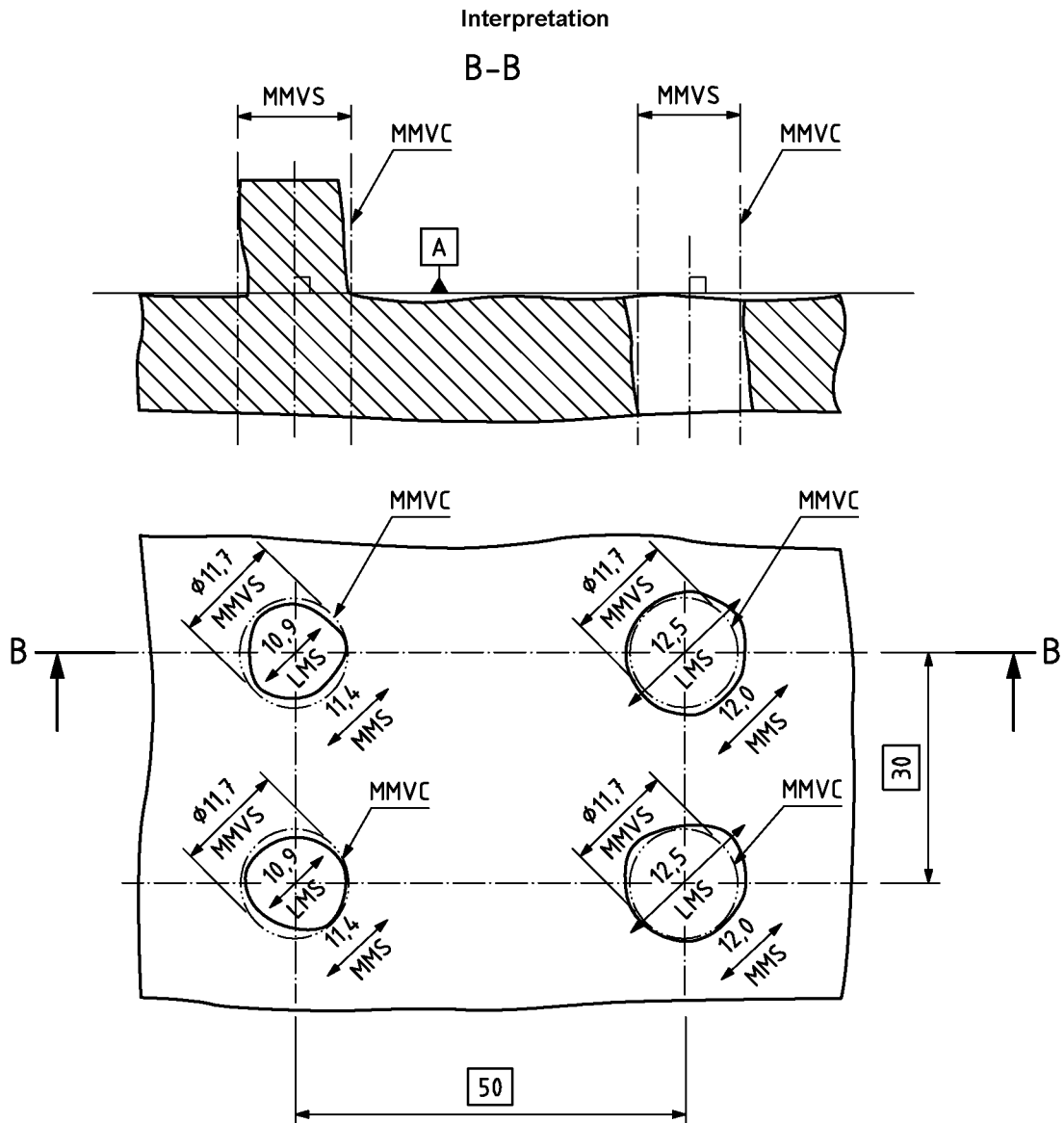
- The extracted feature of the tolerated pins shall not violate the maximum material virtual condition, MMVC, which has the diameter  $MMVS = 11,7$  mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the tolerated pins shall have everywhere a local diameter equal or larger than  $LMS = 10,9$  mm [see Rule B 1) and 3.5] and equal or smaller than  $MMS = 11,4$  mm [see Rule A 1) and 3.3].
- The extracted feature of the tolerated holes shall not violate the maximum material virtual condition, MMVC, which has the diameter  $MMVS = 11,7$  mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the tolerated holes shall have everywhere a local diameter equal or smaller than  $LMS = 12,5$  mm [see Rule B 2) and 3.5] and equal or larger than  $MMS = 12,0$  mm [see Rule A 2) and 3.3].
- The location of the four MMVCs is theoretically correct – in a pattern of  $30 \times 50$  mm relative to each other and theoretically correct parallel to each other. There is no orientation or location requirement to the rest of the part (see Rule D and 3.7 NOTE 2).

**Figure A.10 — Example of MMR used for a pattern of holes and pins located to each other by theoretical exact dimensions and position tolerances, without using a datum**



The intended function of the part illustrated in Figure A.11 may be to form a clearance fit with a similar part. It is a functional requirement that the flat surfaces of the two parts shall be in full contact when assembled.

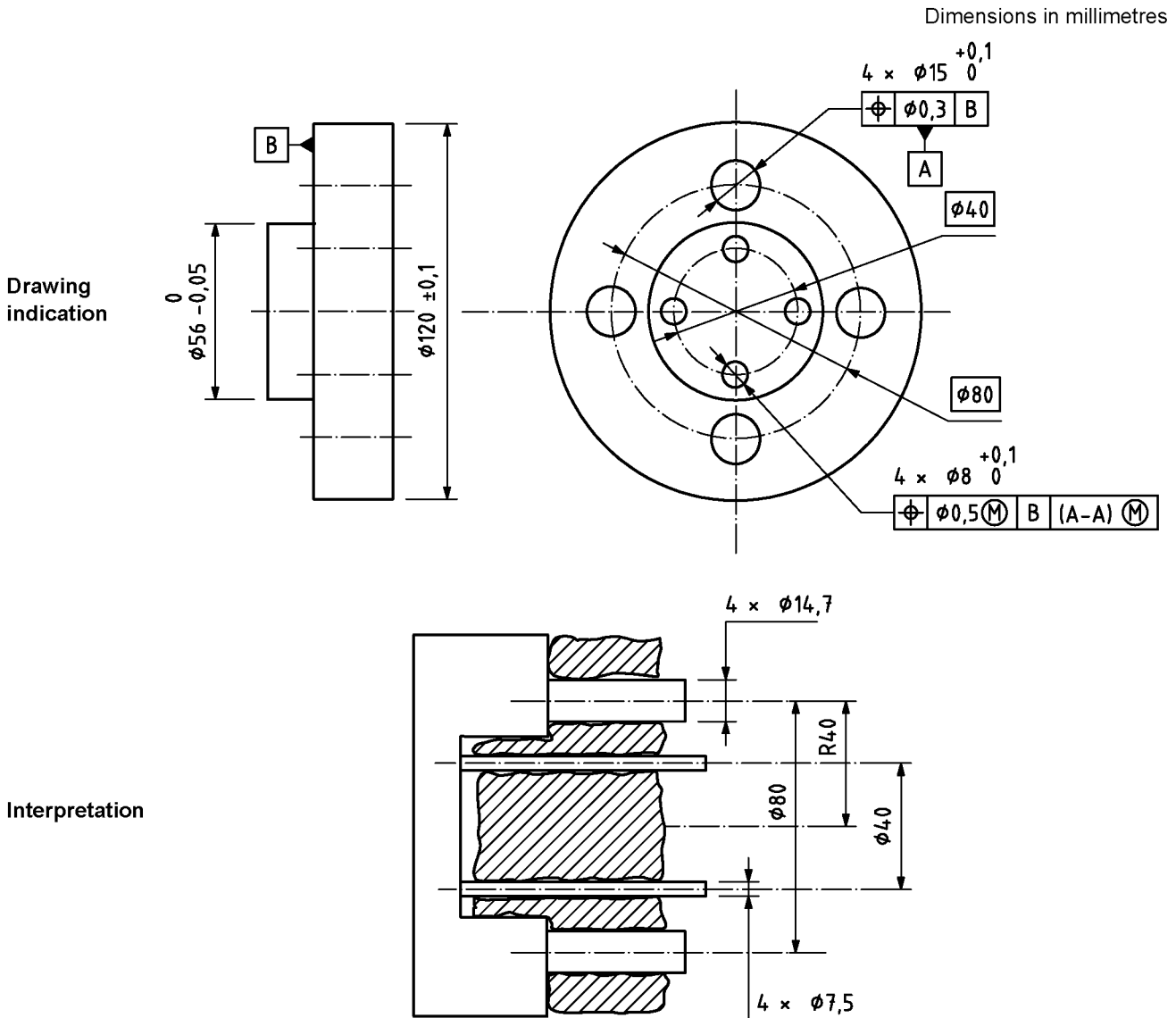
Figure A.11 (continued)



The interpretation is based on the following rules and definitions given in this International Standard.

- The extracted feature of the tolerated pins shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 11,7 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the tolerated pins shall have everywhere a local diameter equal or larger than LMS = 10,9 mm [see B 1) and 3.5] and equal or smaller than MMS = 11,4 mm [see Rule A 1) and 3.3].
- The extracted feature of the tolerated holes shall not violate the maximum material virtual condition, MMVC, which has the diameter MMVS = 11,7 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the tolerated holes shall have everywhere a local diameter equal or smaller than LMS = 12,5 mm [see Rule B 2) and 3.5] and equal or larger than MMS = 12,0 mm [see Rule A 2) and 3.3].
- The location of the four MMVCs is theoretically correct – in a pattern of 30 × 50 mm relative to each other and theoretically correct perpendicular to the datum (feature) A (see Rule D and 3.7 NOTE 2).

**Figure A.11 — Example of MMR used for a pattern of holes and pins located to each other by theoretical exact dimensions and position tolerances with a datum**



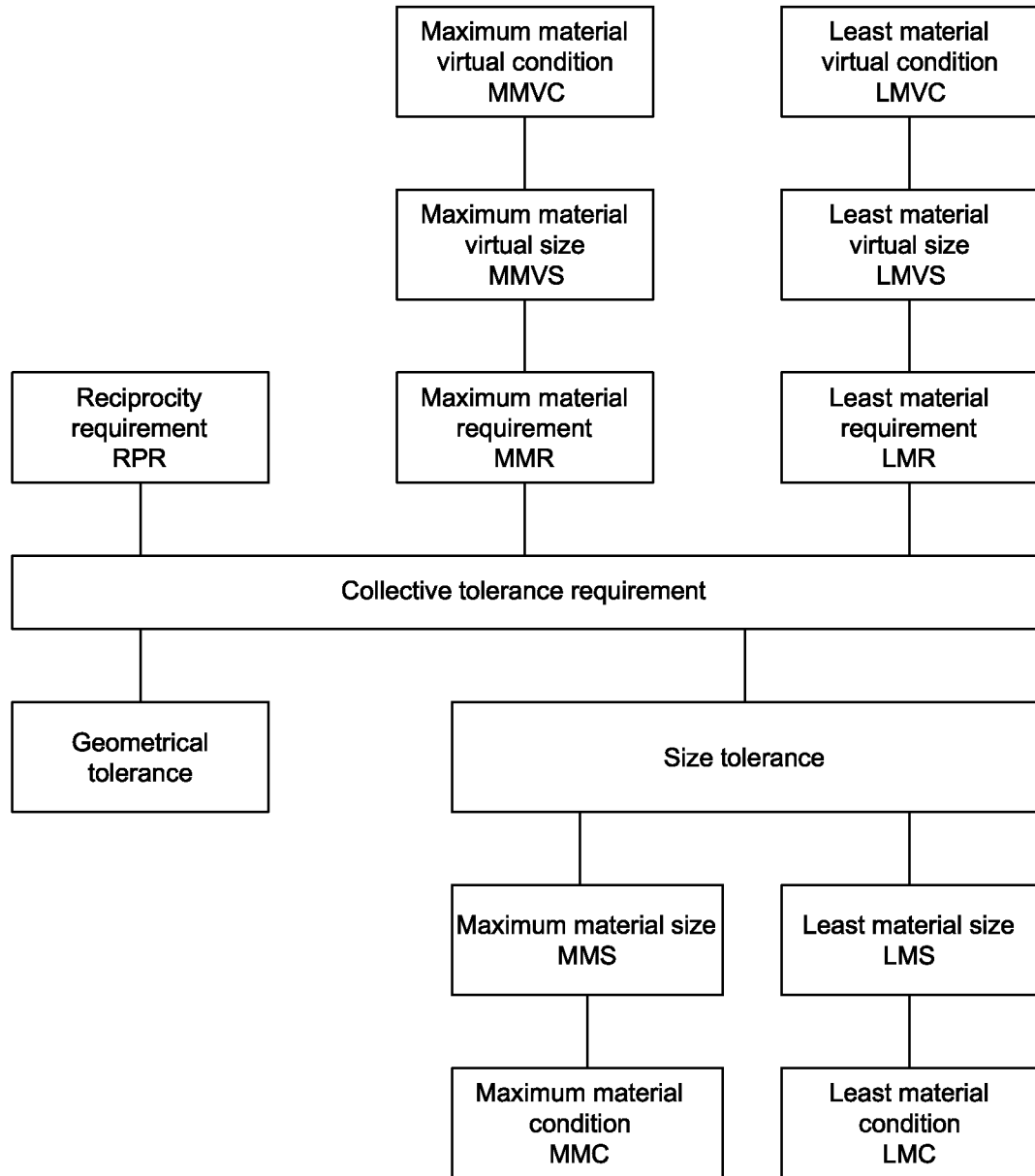
The interpretation is based on the following rules and definitions given in this International Standard.

- The extracted features of the tolerated features shall not violate the maximum material virtual conditions, MMVCs, which have the diameters MMVS = 7,5 mm (see Rule C, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted features of the tolerated features shall have everywhere a local diameter smaller than LMS = 8,1 mm [see Rule B 2) and 3.5] and larger than MMS = 8 mm [see Rule A 2) and 3.3].
- The locations of the MMVCs are positioned (and orientated) to the situation features of the collection of associated features (constraint of fixed size equal to MMS) to the datum features (see Rule D and 3.7 NOTE 2).
- The extracted features of the datum features shall not violate the MMVCs, which are four cylinders with diameter MMVS = MMS = 14,7 mm (see Rule F, 3.6, 3.7 and 3.7 NOTE 1).
- The extracted feature of the datum feature shall have everywhere a local diameter smaller than LMS = 15,1 mm [see Rule B 2) and 3.5] and larger than MMS=15 mm.

**Figure A.12 — Example of use of maximum material requirement applied on common datum**

**Annex B**  
(informative)

**Concept diagram**



**Figure B.1 — Concept diagram for terms and concepts related to maximum material requirement and least material requirement**

## Annex C (informative)

### Relation to the GPS matrix model

#### C.1 General

For full details about the GPS matrix model, see ISO/TR 14638.

#### C.2 Position in the GPS matrix model

This International Standard is a general GPS standard, which influences the chain links 1, 2 and 3 of the chain of standards on size, form of a line and surface independent of a datum, orientation, location and datums in the general GPS matrix, as graphically illustrated in Figure C.1.

		Global GPS standards						
		General GPS standards						
Fundamental GPS standards	Chain link number	1	2	3	4	5	6	
	Size	X	X	X				
	Distance							
	Radius							
	Angle							
	Form of line independent of datum	X	X	X				
	Form of line dependent of datum							
	Form of surface independent of datum	X	X	X				
	Form of surface dependent of datum							
	Orientation	X	X	X				
	Location	X	X	X				
	Circular run-out							
	Total run-out							
	Datums	X	X	X				
	Roughness profile							
	Waviness profile							
	Primary profile							
	Surface imperfections							
Edges								

Figure C.1 — Position in the GPS matrix model

#### C.3 Related International Standards

The related International Standards are those of the chains of standards indicated in Figure C.1.

## Bibliography

- [1] ISO 5458:1998, *Geometrical product specifications (GPS) — Geometrical tolerancing — Positional tolerancing*
- [2] ISO/TR 5460:1985, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Verification principles and methods — Guidelines*
- [3] ISO 7083:1983, *Technical drawings — Symbols for geometrical tolerancing — Proportions and dimensions*
- [4] ISO/TR 14638:1995, *Geometrical product specifications (GPS) — Masterplan*