TECHNICAL HANDBOOK

FUNCTIONAL DIMENSIONING

ISO-GPS Tolerancing

Cetiso

Information

Cetiso

Cotation fonctionnelle Et Tolérancement ISO

Professional training organization
Training activities,
Technical advice and support.

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Website and contact: https://cetiso.fr

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enventive

Geometric Dimensioning & Tolerancing

This handbook is intended to complement the following training sessions:

- **CFiso1**: **« Understanding an ISO definition drawing in the industry ».**
  This training session is intended to help establish a process of understanding and relevant critical analysis of industrial drawing in ISO-GPS language.
- **CFiso2**: **« Apply functional dimensioning and ISO-GPS tolerancing in industry ».**
  This training session is intended to help establish a relevant tolerancing and critical analysis for industrial drawings.
- **CFiso3**: **« Apply ISO-GPS tolerancing to your products».**
  This training session allows you to apply a structured industrial tolerancing approach to your parts.

This handbook is a useful tool for mechanical engineering industry.
It was created to be made freely available to all technicians.

We ensure its development and distribution free of charge.

For this handbook to be used in the best conditions, it is preferable to have followed the Cetiso training courses.

It is not exhaustive.
It is not intended to replace technical drawing standards and must be supplemented by referring the ISO-GPS standards.

"Intersection planes, Orientation planes, Direction features and Collection planes" are not included.

The viewing planes defined in the definition drawing will refer to the main datum system.

Lexicon

English - French lexicon and applicable standards used

English	French
Standard	Norme
Functional dimensioning	Cotation fonctionnelle
Tolerance stack-up	Chaîne de cotes
Dimension	Dimension
Size	Taille
Envelope	Enveloppe
Theoretically exact dimension (TED)	Dimension théorique exacte
Geometrical tolerance	Tolérance géométrique
Form	Forme
Straightness	Rectitude
Roundness	Circularité
Line profile	Profil d'une ligne
Flatness	Planéité
Cylindricity	Cylindricité
Surface profile	Profil d'une surface
Orientation	Orientation
Perpendicularity	Perpendicularité
Parallelism	Parallélisme
Angularity	Inclinaison
Location	Position
Position	Localisation
Concentricity	Concentricité
Coaxiality	Coaxialité
Symmetry	Symétrie
Circular run-out	Battement circulaire
Total run-out	Battement total
Datum feature	Elément de référence
Datum	Référence spécifiée
Common datum	Référence commune
Datum system	Système de références
Datum target	Référence partielle
Common zone	Zone commune
Combined zone	Zone combinée
Tolerance zone	Zone de tolérance
Common tolerance	Tolérance commune
United Feature	Elément unifié
Maximum material	Maximum de matière
Least material	Minimum de matière
Non-rigid parts	Pièces non rigides
Free state	Etat libre

Application standards referred to

The **invocation principle** involves that, by default, all ISO-GPS standards are mentioned on a definition drawing.

Important: the publication dates of the standards are not indicated.

Internal specifications are recommended, with a revision index indicating the issue date of the standards used in the company.
The specification reference with revision index must be indicated on the drawing.

List of application and general sector-specific tolerances standards updated on cetiso.fr

NF EN ISO 8015: August 2011
Fundamentals — Concepts, principles and rules

NF EN ISO 1101: April 2017
Geometrical tolerancing — Tolerances of form, orientation, location and run-out
(this handbook does not cover viewing planes and filters).

NF EN ISO 5459: November 2011
Geometrical tolerancing — Datums and datum systems

NF EN ISO 14405-1: December 2016
Dimensional tolerancing — Part 1: Linear sizes

NF EN ISO 14405-2: January 2019
Dimensional tolerancing — Part 2: Dimensions other than linear or angular sizes

NF EN ISO 14405-3: March 2017
Dimensional tolerancing — Part 3: Angular sizes

NF EN ISO 5458: June 2018
Geometrical tolerancing — Pattern and combined geometrical specification

NF EN ISO 10579: November 2013
Dimensioning and tolerancing — Non-rigid parts

NF EN ISO 3040: July 2016
Dimensioning and tolerancing — Cones

NF EN ISO 1660: April 2017
Geometrical tolerancing — Profile tolerancing

NF EN ISO 2692: March 2015 (new version: June 2021)
Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)

Glossary

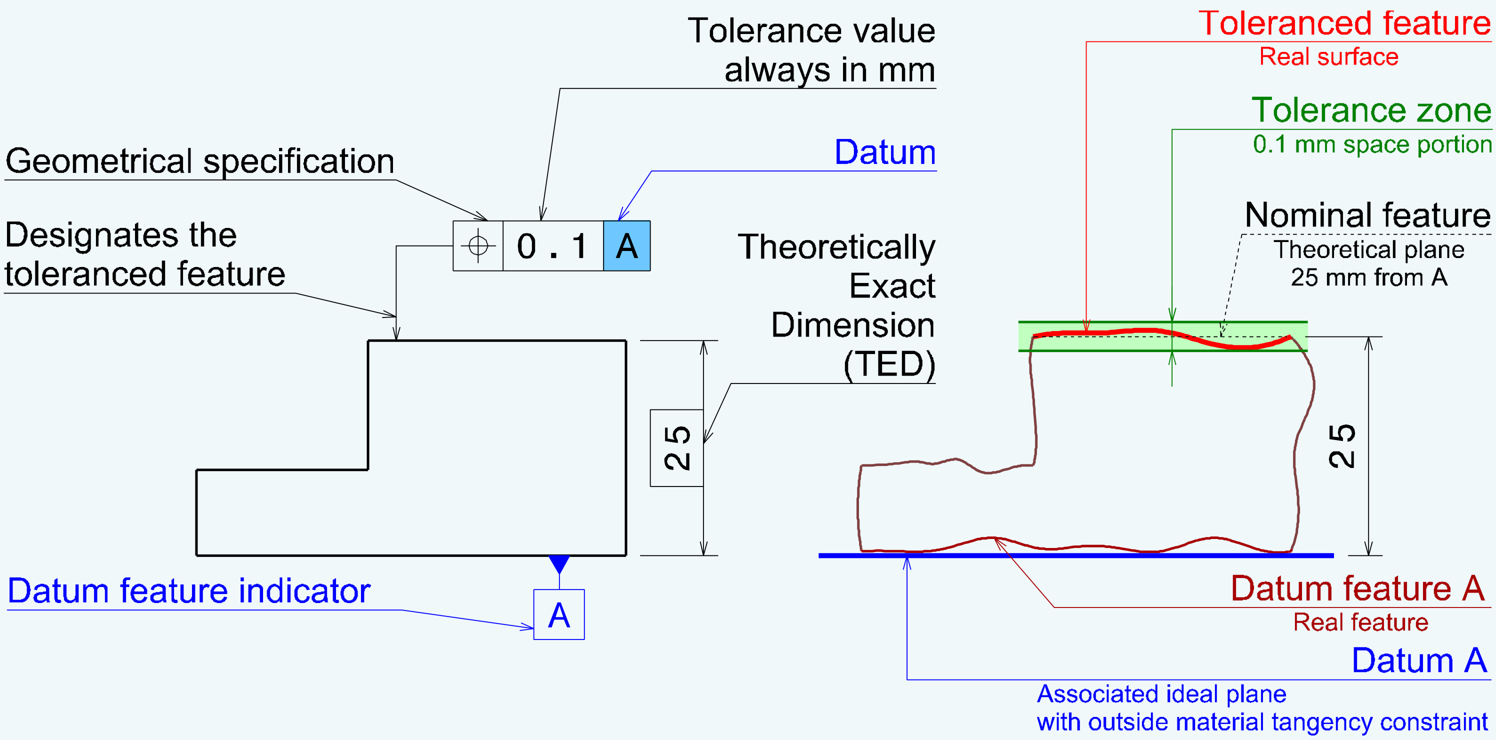
ISO 1101

- **Theoretically Exact Dimension (TED):** Linear or angular dimension defining the theoretically exact geometry, extents, locations and orientations of features. TED can be defined by referring to the 3D model (complex forms).
Implicit TED: 0 mm, 0°, 90°, 180°, 270° and the angular distance between equally spaced features on a complete circle.
- **Toleranced Feature (TF):** Real feature for which a specification is defined.
- **Geometric specification:** Applies to a single complete feature, unless explicitly indicated otherwise, e.g., using a modifier.
- **Tolerance Zone (TZ):** A portion of ideal geometric space which must contain a toleranced feature and for which borders depend on the specification.

ISO 5459

- **Datum feature:** A real feature used for establishing a datum.
- **Associated feature:** An ideal feature which is fitted to the datum feature with an association criterion simulating contact between the real surface of the workpiece and other components.
- **Datum (DT):** Point, straight line, plane (one or more situation features) of one or more associated features, selected to define the location or orientation of a tolerance zone.

- **Single datum** [| | A] **:**
Datum established from one datum feature taken from a single surface or from one feature of size.
- **Common datum** [| | A-B] **:**
Datum established from two or more datum features considered simultaneously.
- **Datum target** (A1) (A2) (A3) **:**
Portion of a datum feature which can nominally be a point, a line segment or an area.
- **Datum system** [| | A | B | C] **:**
A datum system comprises an ordered list of two or three single or common datums.
- **Primary datum** [| | A | B | C] **:**
This datum is not influenced by constraints from other datums.
- **Secondary datum** [| | A | B | C] **:**
This datum is influenced by an orientation constraint from the primary datum.
- **Tertiary datum** [| | A | B | C] **:**
This datum is influenced by an orientation constraint from the primary datum and the secondary datum.



ISO 2692

- **Maximum material condition** Ⓜ: The condition of the extracted feature considered, for which the dimensional entity is at the size limit at all locations, such that the feature has maximum material (dimension at which the part is the heaviest).

- **Maximum material virtual condition:** Condition of the associated ideal form feature with virtual dimensions for maximum material, caused by the combined effects of a dimensional entity and geometrical tolerance (form, orientation or location). The virtual condition is exactly located or oriented relative to the datum system.

- **Least material condition** Ⓛ**:** The condition of the extracted feature considered, for which the dimensional entity is at the size limit at all locations, such that the feature has least material (dimension at which the part is the lightest).

ISO 10579

- **Non-rigid part:** Part which deforms to an extent that the free state is beyond the dimensional and/or geometrical tolerances from the drawing.

- **Free state** Ⓕ**:** Condition of a part subjected only to the force of gravity.

Independency principle:

By default,
every specification shall be fulfilled independent of other specifications…

except when a standard or a specific instruction defines a link between requirements as part of the specification under consideration:
Ⓔ, CZ, CT, UF, …

The local dimension and the geometrical specification are independent.

Feature principle:

Unless indicated otherwise, the toleranced feature only includes the single complete feature mentioned.

Rigid workpiece principle:

By default, **a part is toleranced in its free state, without any deformation due to external stresses.**

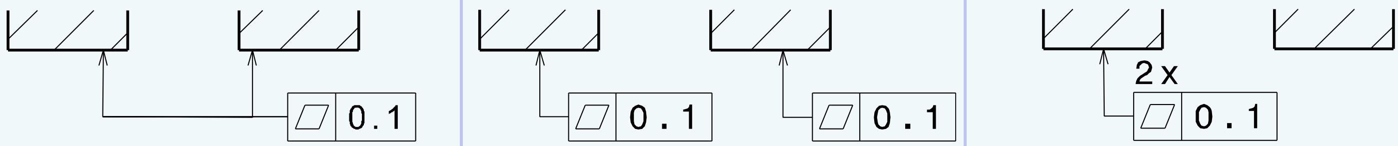
Functional control principle:

The specification of a workpiece is complete when **all intended functions** of the workpiece are described and controlled with GPS specifications.

Reference condition principle:

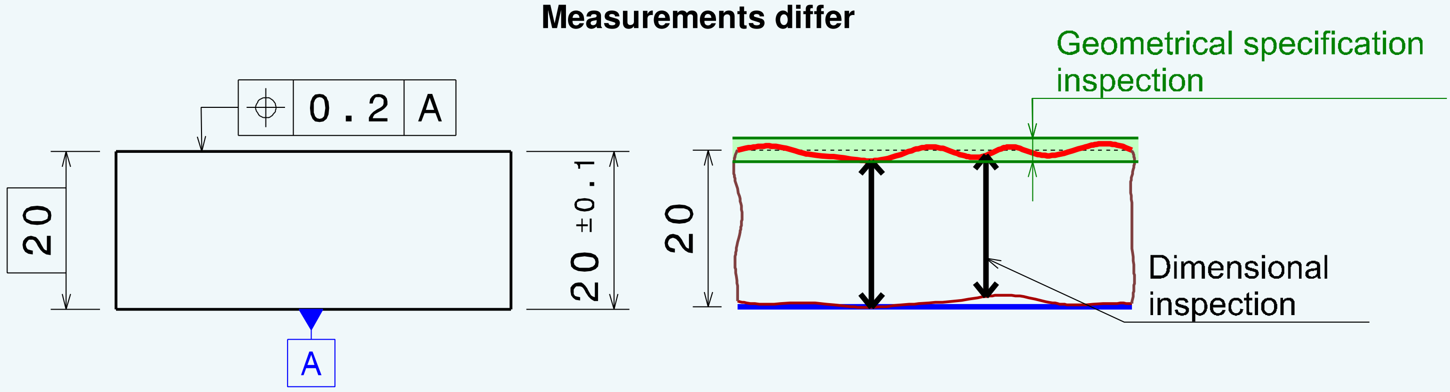
By default, the normal reference temperature is defined at **20 °C** when measuring a part (standard ISO 1).

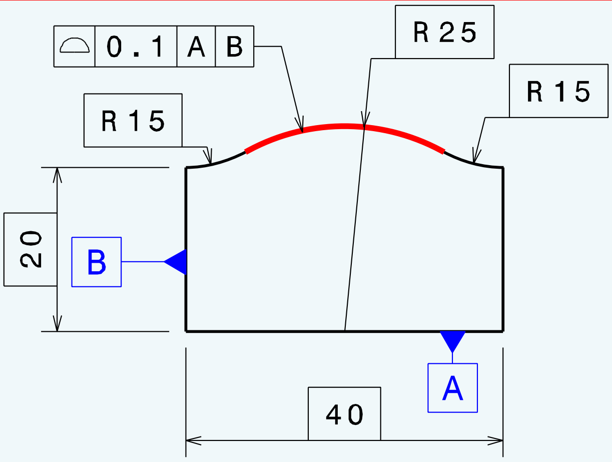
These three entries are equivalent:

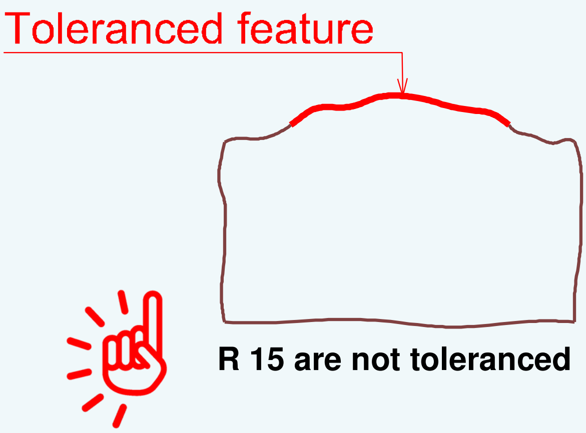


The measurement is performed according to the independency principle

Measurements differ







Tolerancing could be applied in a constrained state to represent part operating conditions. For this purpose, Standard ISO 10579-NR and constraining conditions must be indicated on the drawing.

Generic and recurrent functions exist for mechanical design:

- -Assembly or mounting options (to do first)
- -Appearance, (e.g., the consistency of a gap)
- -Leak tightness
- -Operation (maneuvering, etc.)
- -Resistance (to forces, ambient conditions)
- -Comfort / Ergonomics
- -Regulations / Safety
- -…

Original idea by Gérald ECAROT (MATAF method)

Note: Modifying this reference temperature may imply a risk as measuring devices are calibrated to 20°C.

Dimensional Tolerances

LP

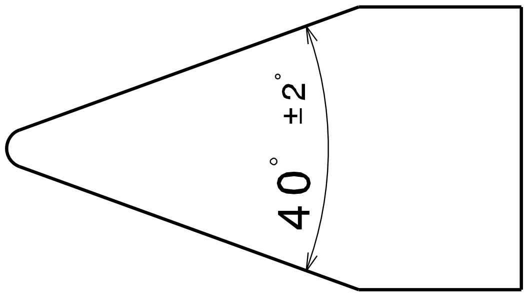
Linear size

Linear size: limits only the real local dimensions of a feature, but not form imperfections (measurement between two points).
Dimensional tolerance can only apply to features with the following nominal geometry:

- A cylinder, a sphere, tube thickness, etc.
- Two parallel planes facing each other in opposite directions

LC

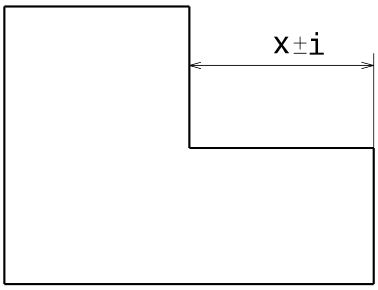
Angular size



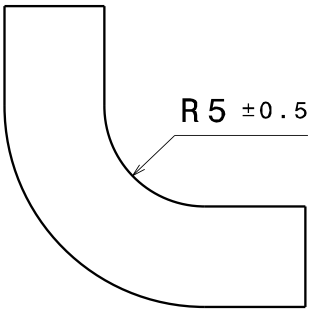
Angular size: exclusively limits the general orientation of lines or linear features of surface, but not form imperfections (measurement between two straight lines).

Ambiguous dimensions

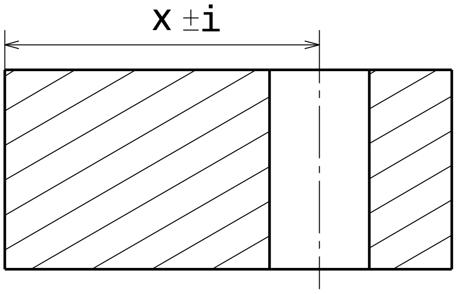
Unauthorized entries



Ambiguous:
No facing points

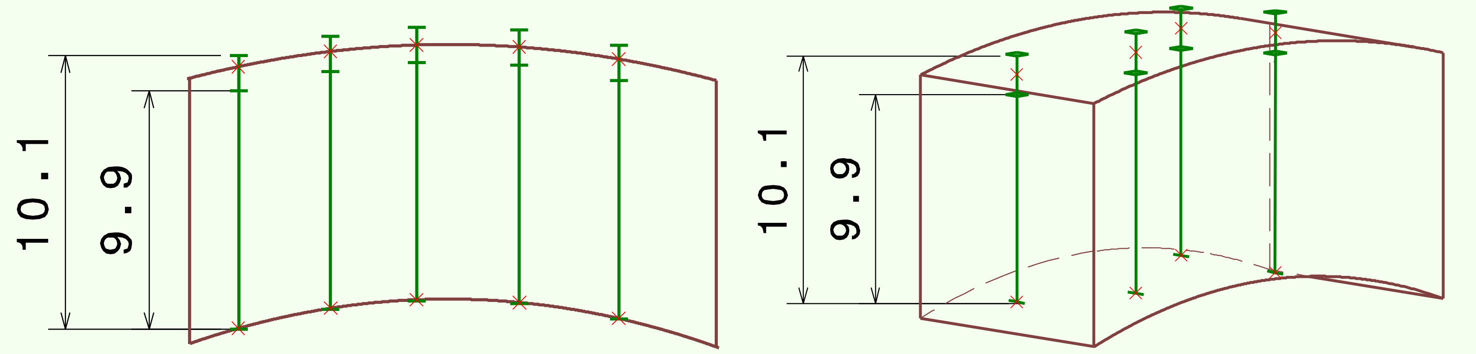


Ambiguous:
No facing points

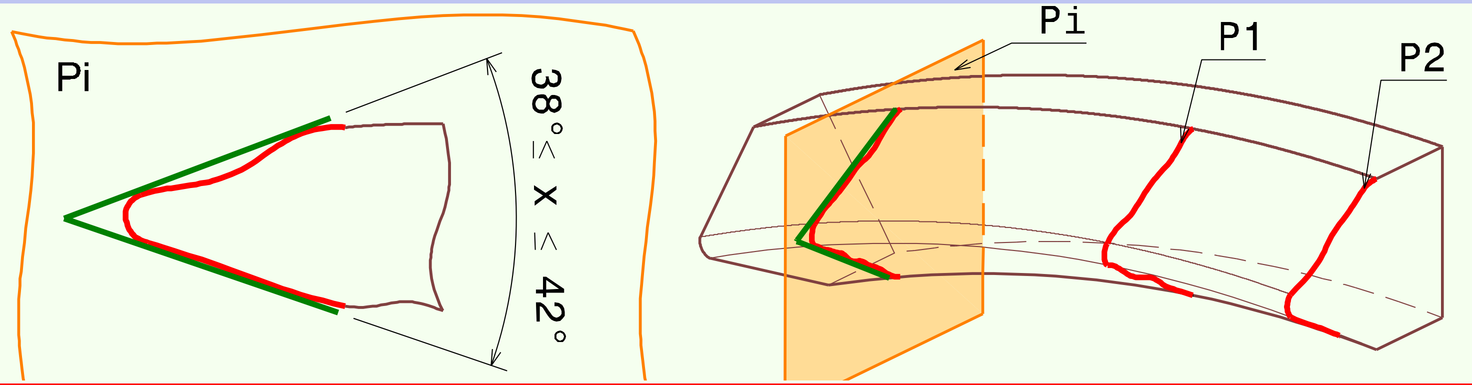


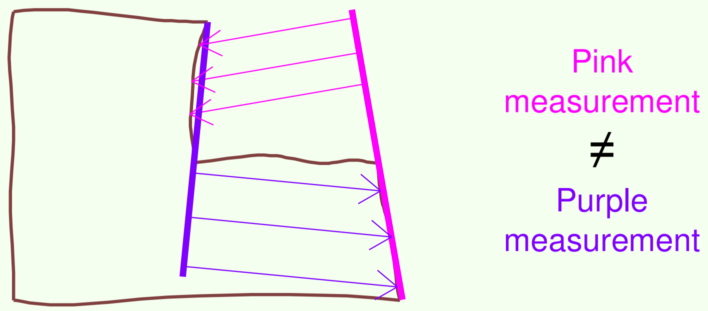
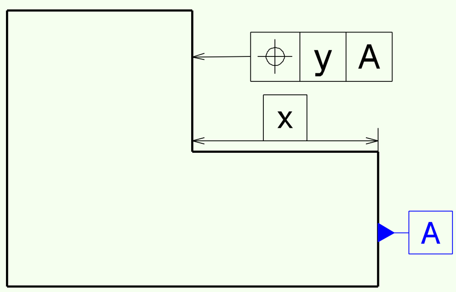
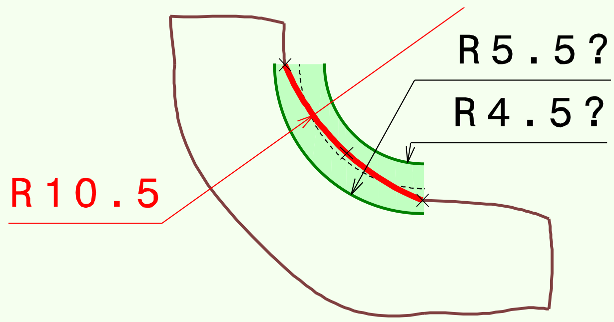
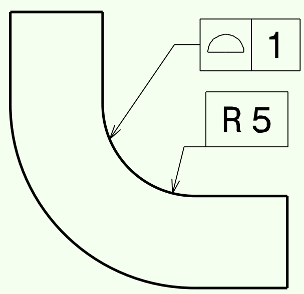
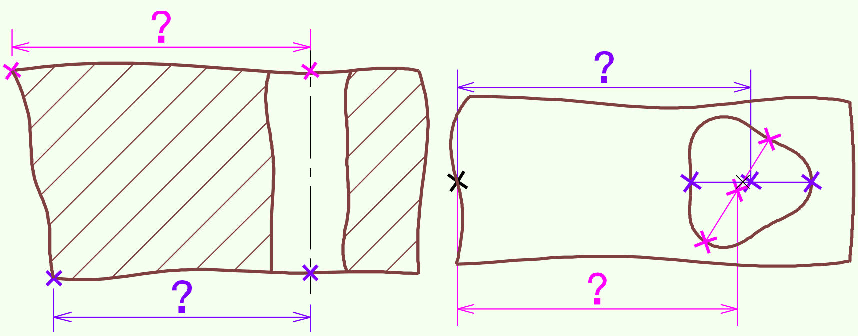
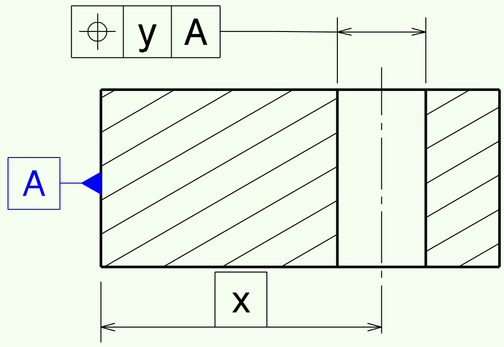
Ambiguous:
No facing points

In general, local dimensional tolerancing alone is not



The direction of the measurement is determined
by an association based on the least square criterion



Reason for the lack of clarity:	Clarification proposal:
	
	
	

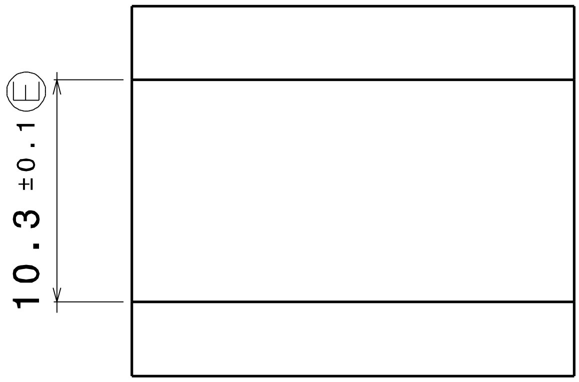
sufficient to state functional requirements.

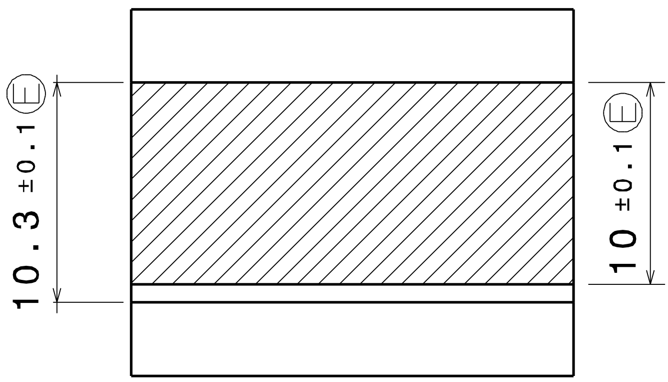
Dimensional Tolerances

Ⓔ Envelope requirements

Example of a spacer

Example of a groove





To ensure that mounting is possible, the **envelope requirement** Ⓔ can be added to the linear size.
This implies that the ideal form envelope for the dimension with maximum material for the feature will not be exceeded.

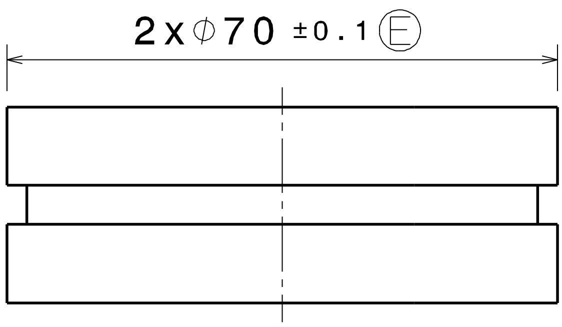
Note: Dimension at max material:
- Max. for a solid form
- Min. for a hollow form

➔ i.e., heaviest part

The envelope requirement can only apply to:
- A cylinder, a sphere
- Two parallel planes facing each other in opposite directions

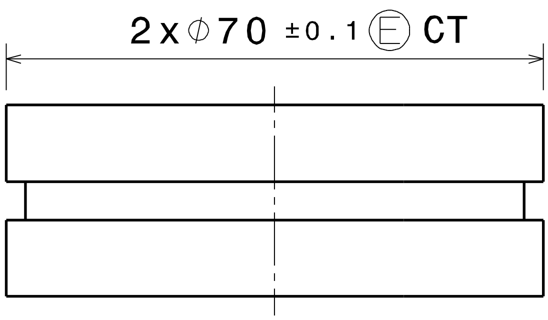
Only use this approach if a part fits inside another part

CT Common tolerance

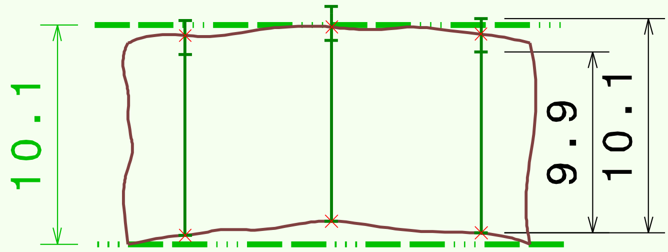


Common error

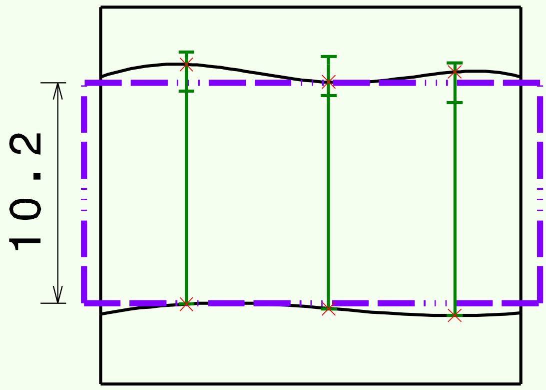
Without the CT modifier, the independency principle applies.



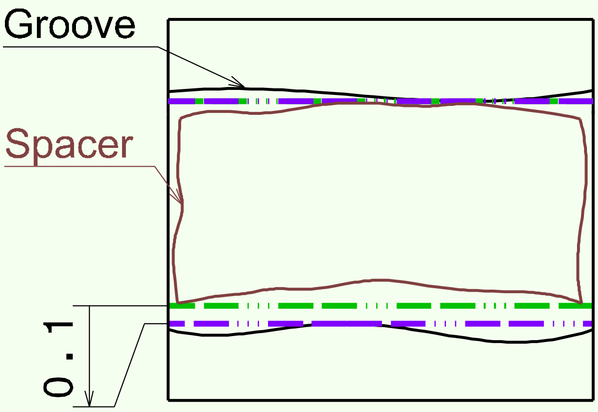
Dimensional entity
Common Tolerance CT:
several separate dimensional entities considered as a unique dimensional entity to which a common tolerance is applied.



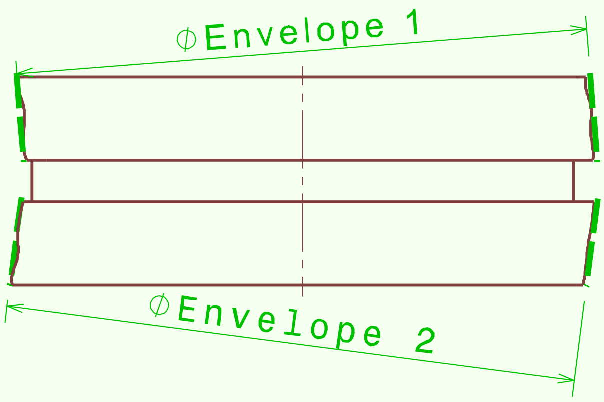
Dimension of the spacer envelope = 10.1.

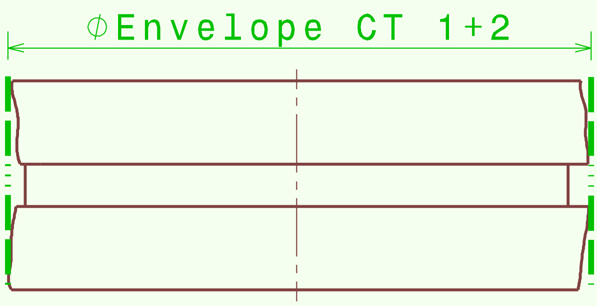


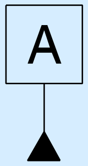
Dimension of the spacer envelope = 10.1.



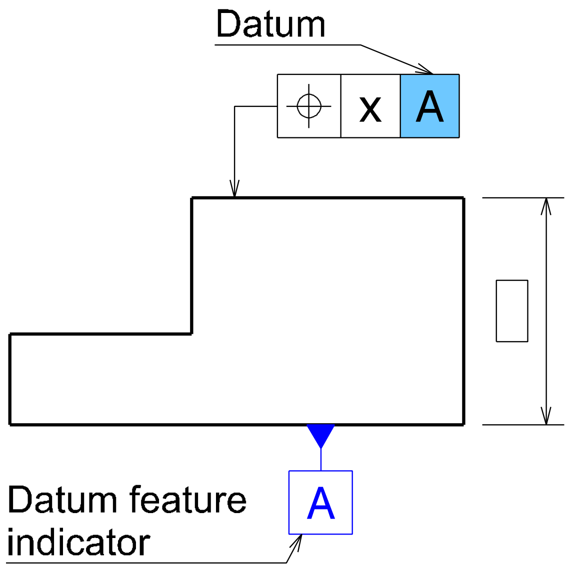
Results: a min gap of 0.1 is ensured to assemble the spacer in the groove.

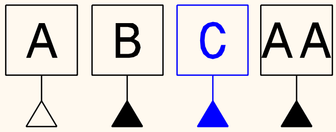






Datums

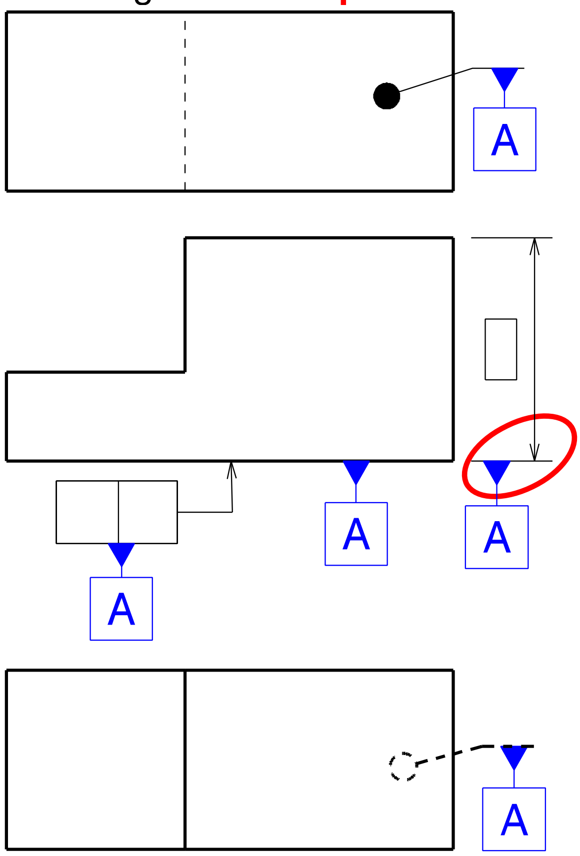




Datum feature:
A real feature used to determine the location of a datum

Datum:
Point, straight line, plane (one or more situation features) of one or more features associated, selected to define the location or orientation of a tolerance zone

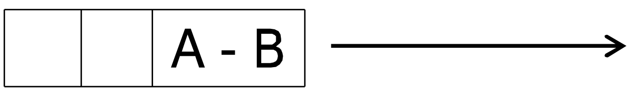
Designation of **a plane**



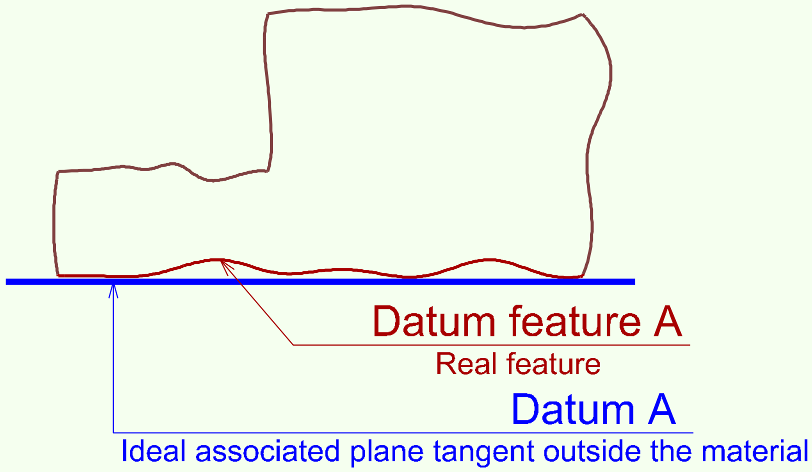
The identifying triangle is separate from the dimension line

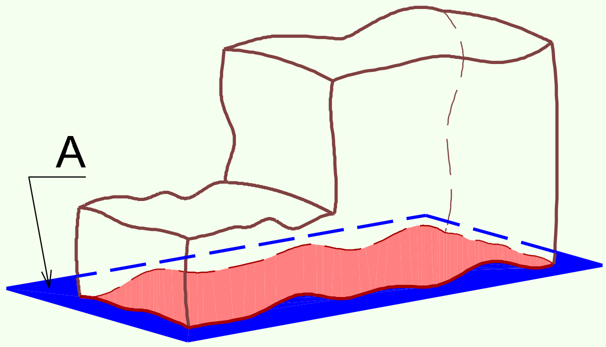
Several existing

Single datum



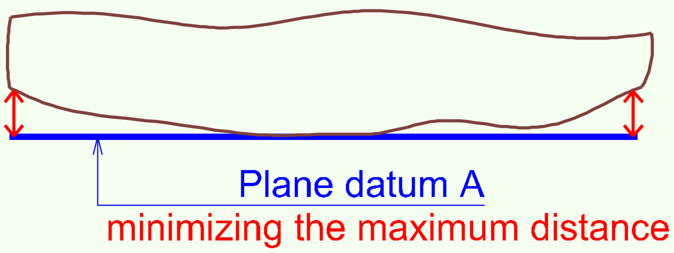
Common datum

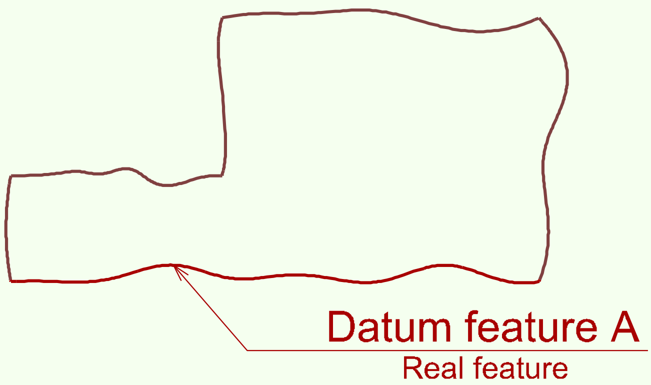


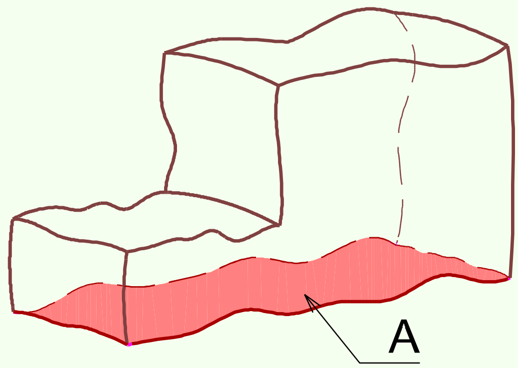


The association criterion used for datum by default is based on the principle of simulating the contact between the surface with an ideal form and the actual surface.

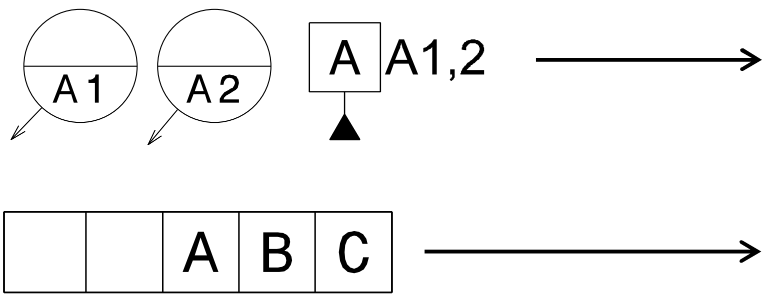
The associated feature is externally tangent to the material. If the result of this process is not unique, the associated feature to be taken into consideration corresponds to that which reduces the maximum distance between the associated feature and the real feature as much as possible:







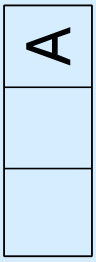
kind of datums:



Datum targets

Datum system

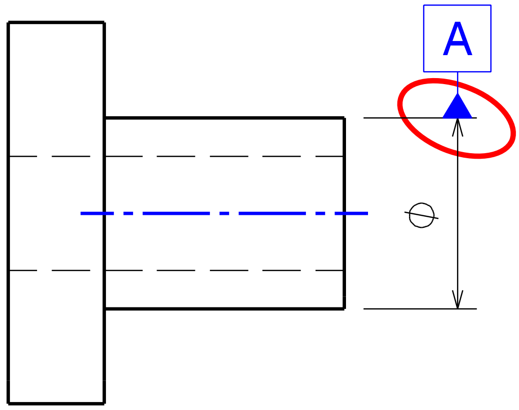
Datums



Single datum

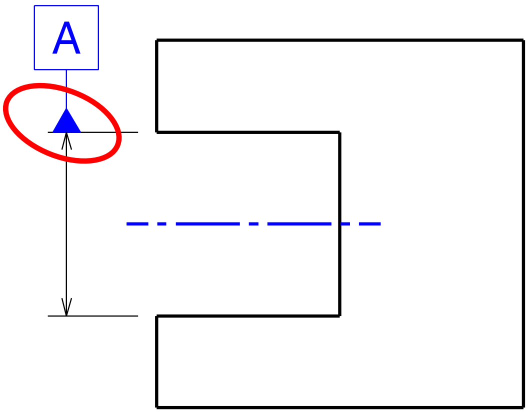
Single datum:
Datum defined using a datum feature for a surface considered alone or a dimensional entity.

Designation of the **axis of a cylinder**



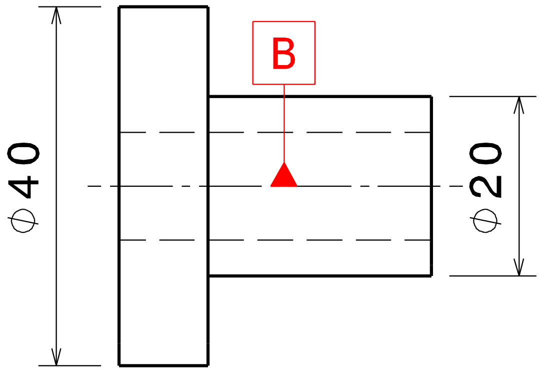
The datum feature indicator must be placed as **an extension** of a dimension line

Designation of a **median plane**



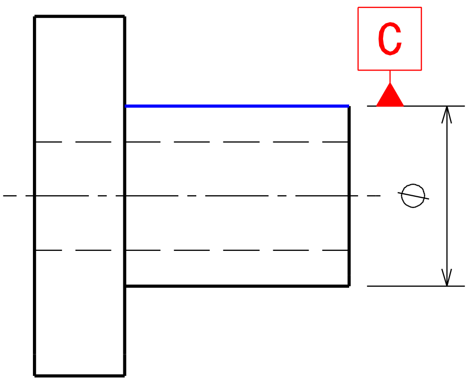
The datum feature indicator must be placed as **an extension** of a dimension line

Frequent errors



Forbidden entries:

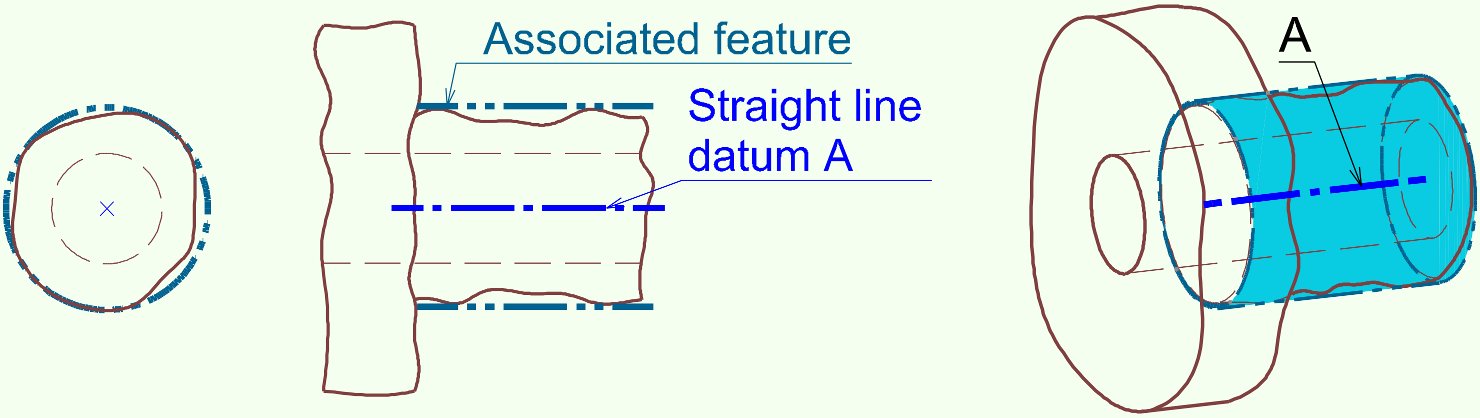
Ø20 axis?
Ø40 axis?
Common axis for both?
Axis of the inner cylinder?



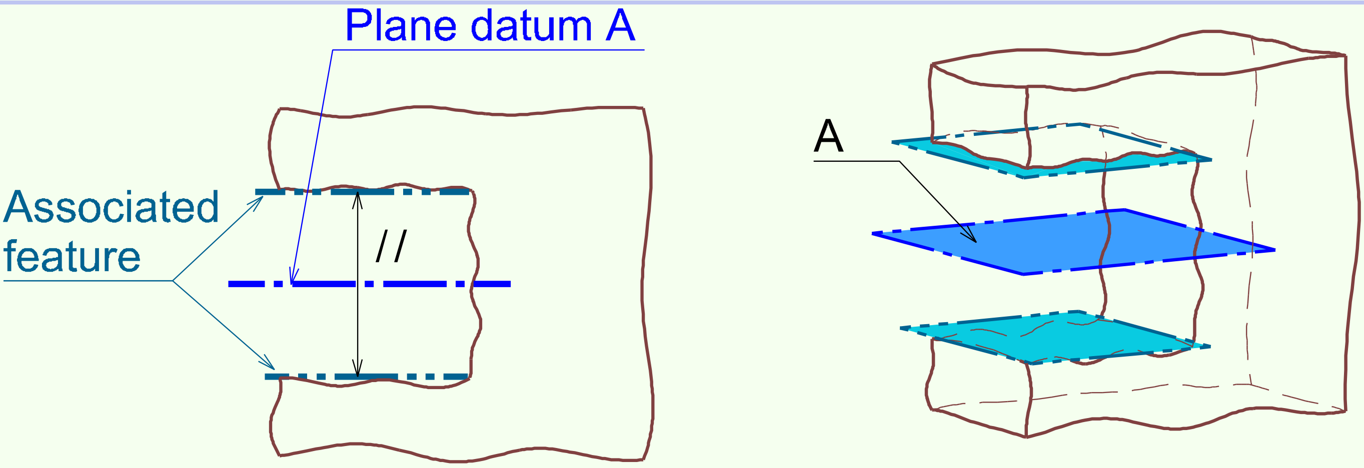
Common error:

In this case datum C does not indicate the cylinder axis, but could designate the **generatrix** of the cylinder

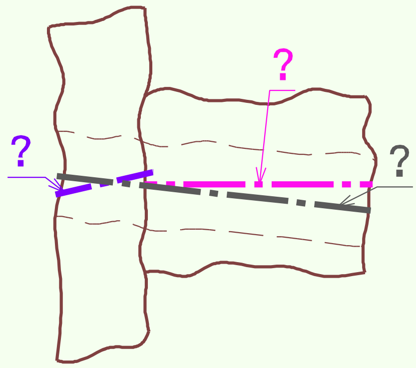
One single box and letter in the datum section

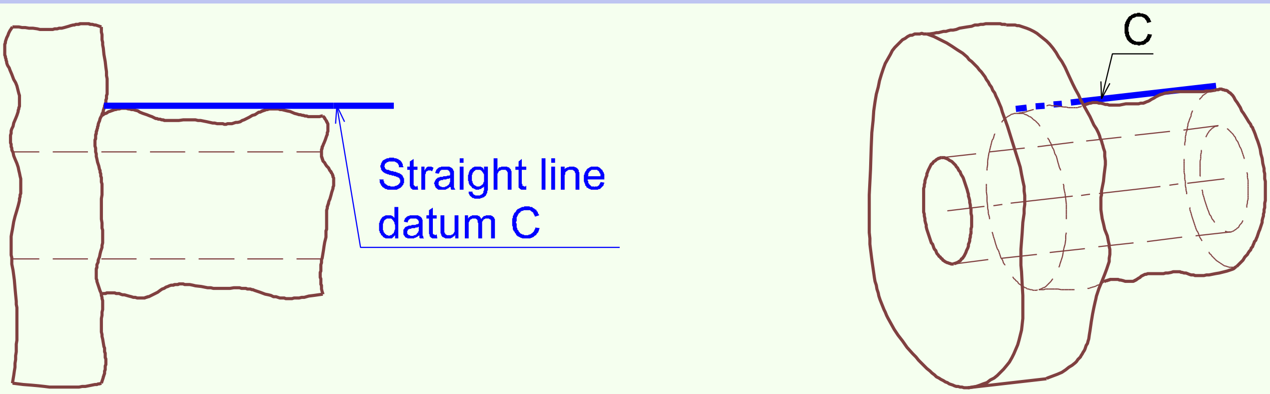


Associated feature = the smallest circumscribed cylinder



Associated features = 2 inscribed parallel planes at maximum distance

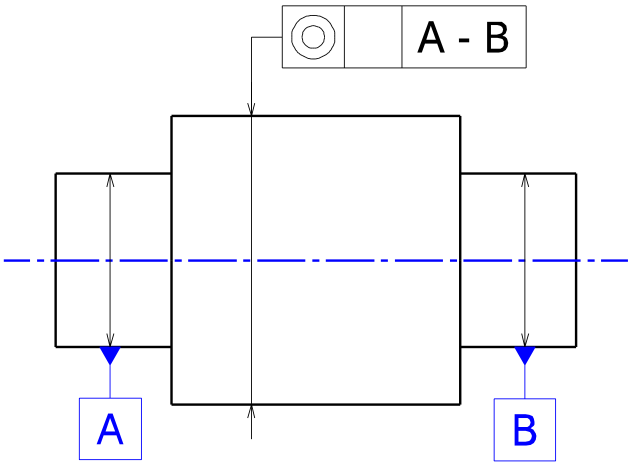




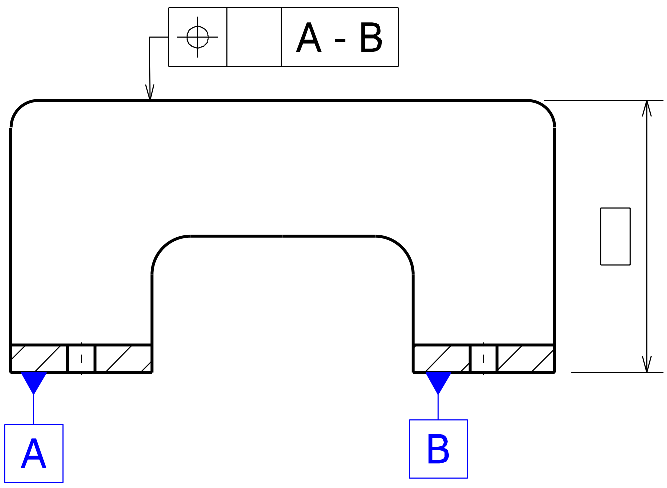
A - B

Common datum

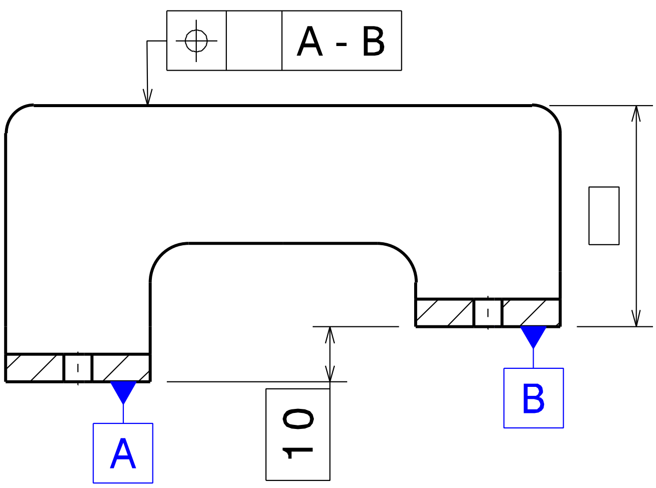
Common datum:
The common datum is established based on at least two datum features considered simultaneously



A common datum based on **two** theoretically coaxial **cylinder axes**.



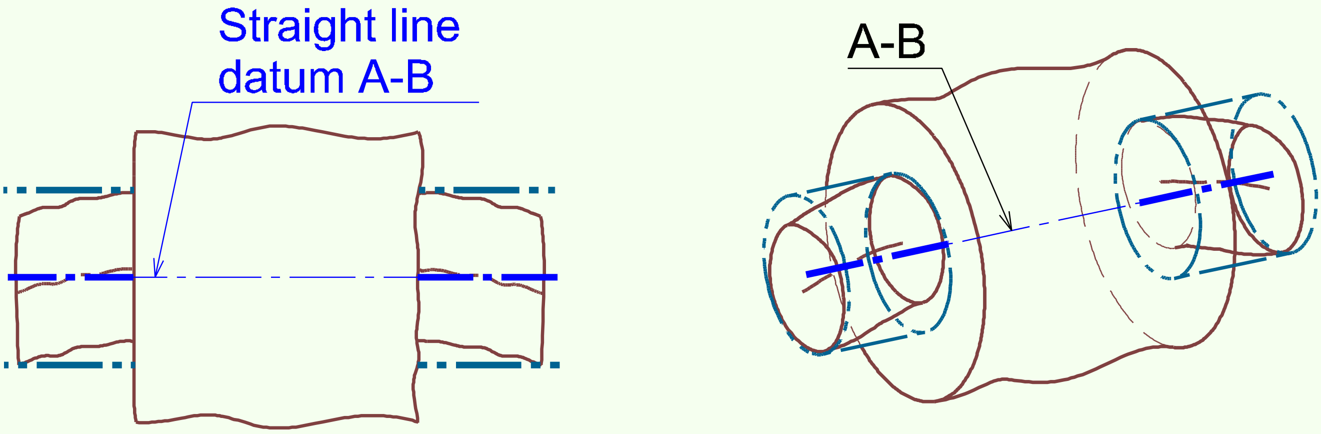
A common datum based on **two coplanar planes.**



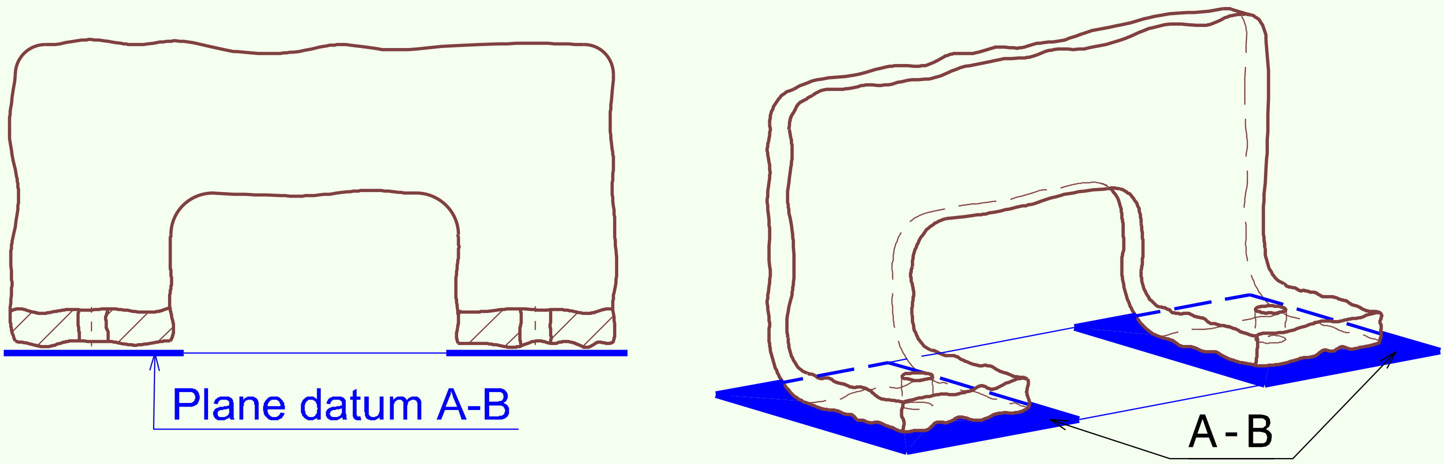
A common datum based on **two offset planes.**

At least two letters separated by a dash in the datum section.

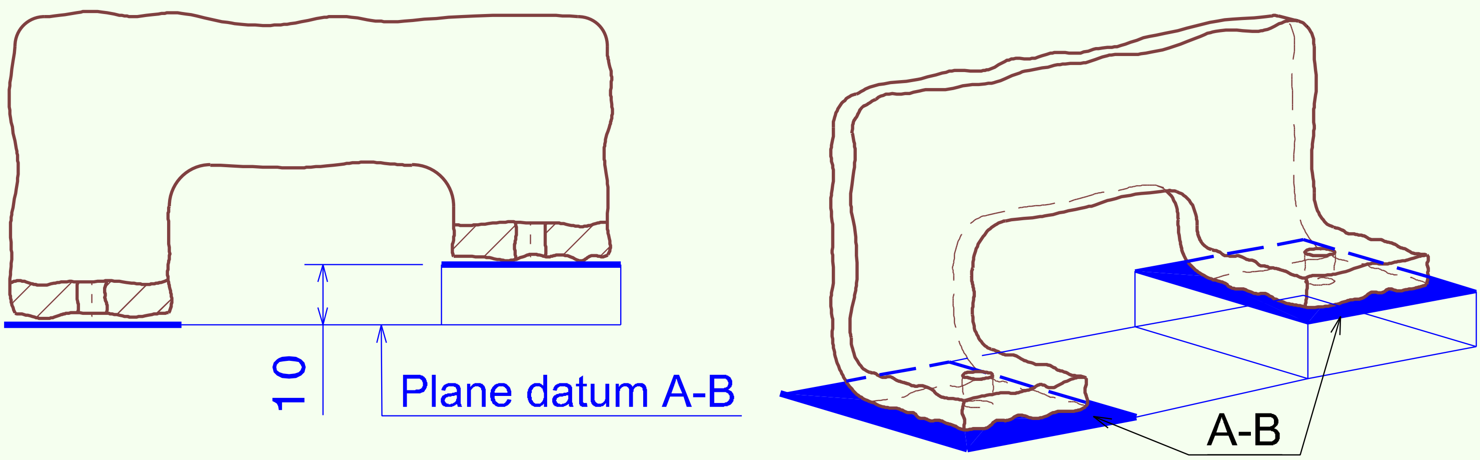
- More than two letters may be used, and the order has no effect on the meaning,
- The association is simultaneously set,
- Theoretically exact location and orientation (linked by TED unless implicit).



2 exactly coaxial circumscribed cylinders matching the actual cylindrical surfaces.
The features are simultaneously associated



2 exactly aligned planes tangent to the outside of the material.
The features are simultaneously associated

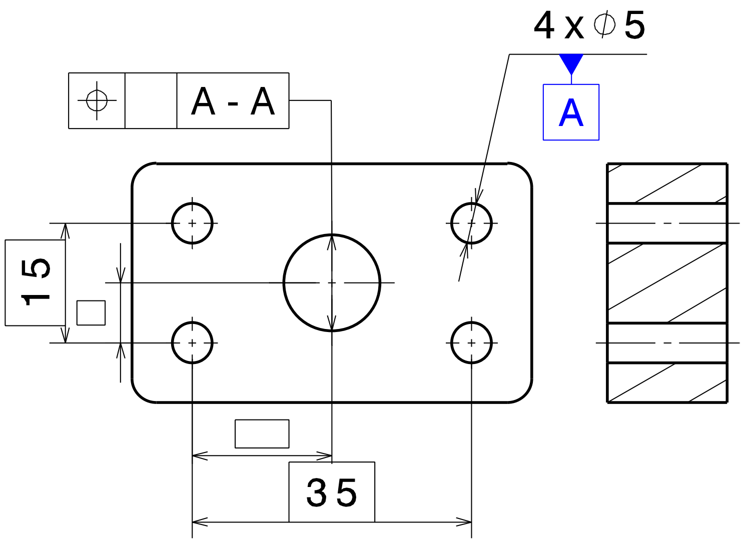


2 planes exactly offset by 10 mm tangent to the outside of the material.
The features are simultaneously associated

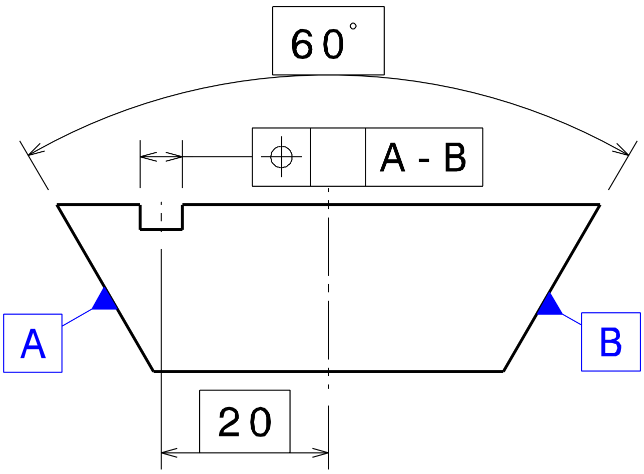
Datums

Common datum

A - A

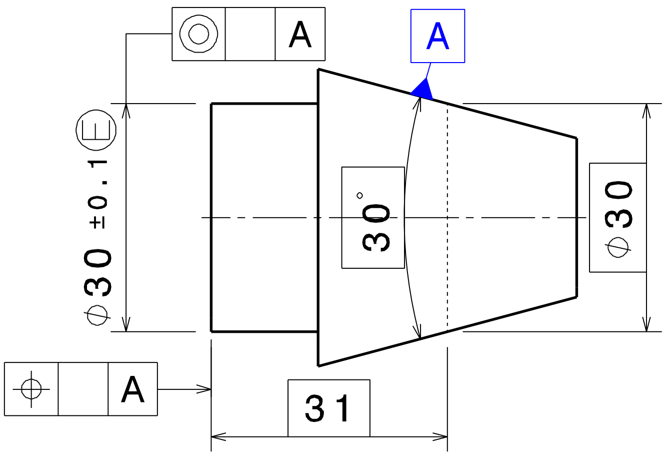


A common datum based on **non-coaxial cylinder axes**.



A common datum based on **two oriented planes at 60°**.

Datum Cone

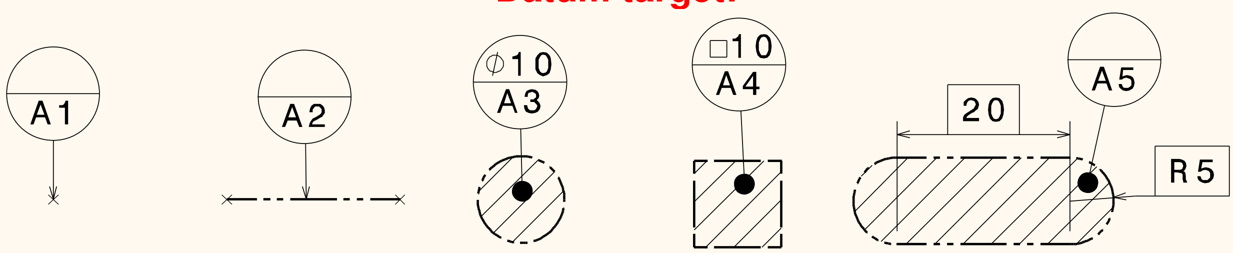


A datum based on a cone

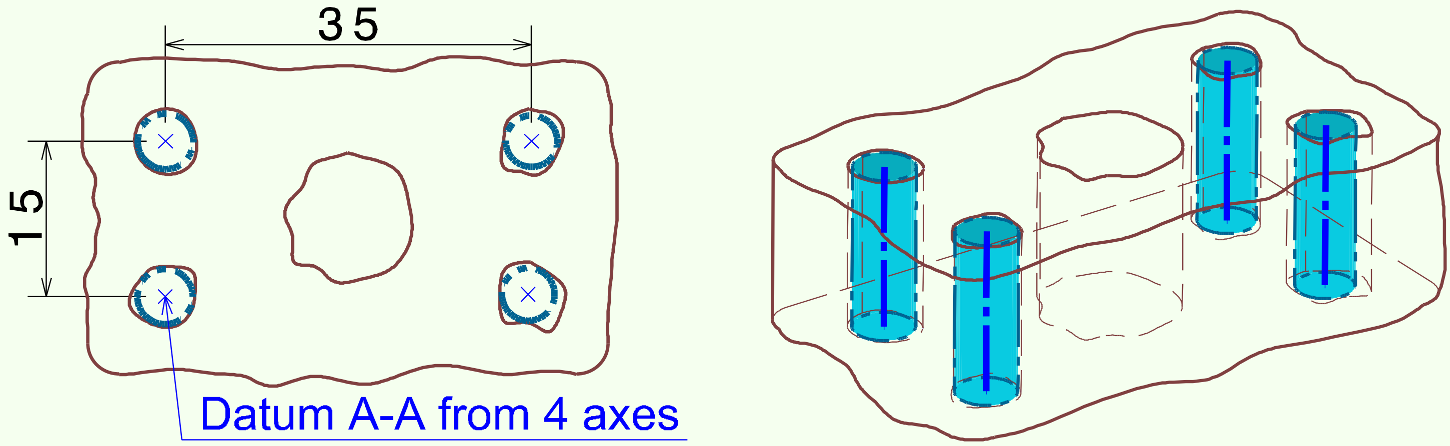
Datum target

A1

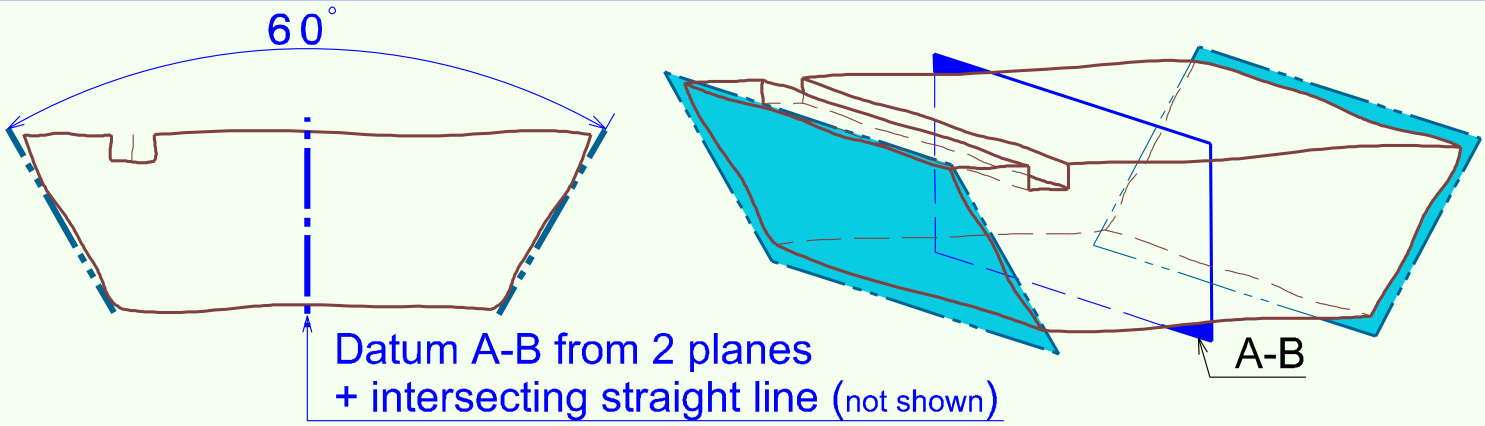
Datum target:



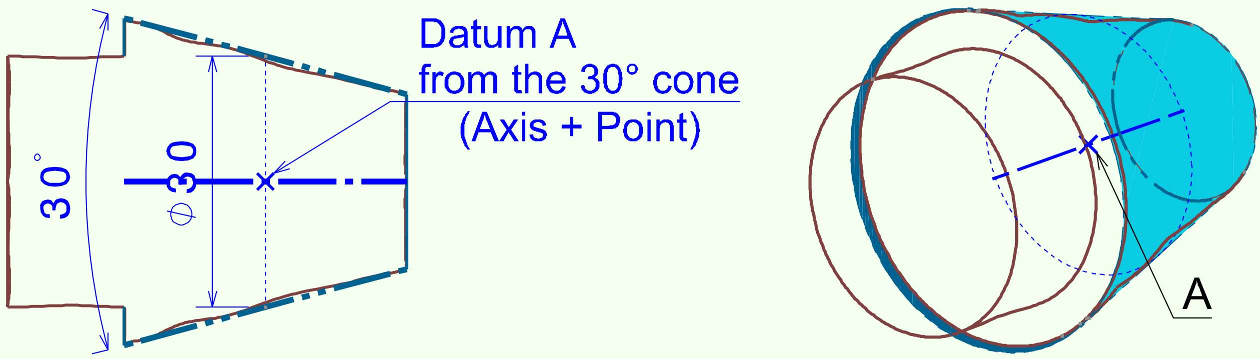
Portion of a datum feature which can nominally be a point, a line segment or an area.



The axes of the four largest possible cylinders in theoretically exact locations.
The features are simultaneously associated.



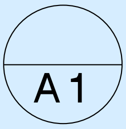
2 planes exactly oriented at 60° tangent to the outside of the material.
The features are simultaneously associated

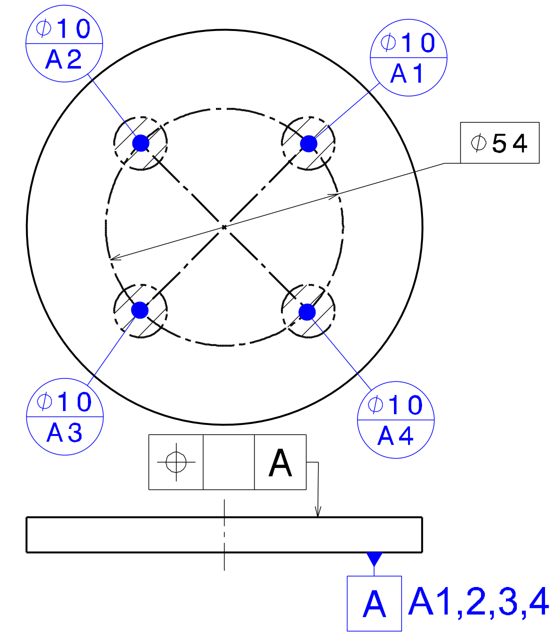


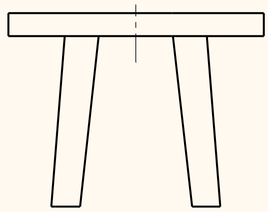
Associated feature = 30° cone angle, minimizing the maximum deviation.
The datum is the axis and the point of the gauge plane (apex of the cone if not defined)

Use when one or more portions of a single datum surface is used rather than the entire surface.
Datum targets are in theoretically exact locations.
They should be used to simulate real functional contacts between parts

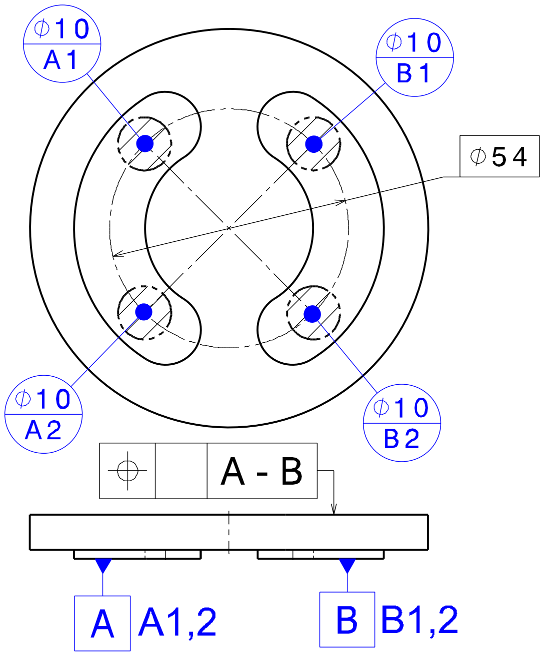
Datum target

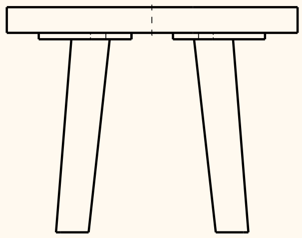






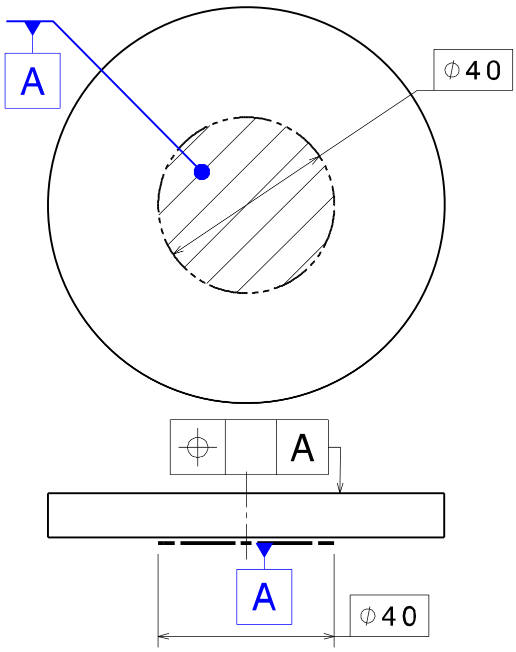
If a single datum is established using datum targets in one **single surface**, the single datum feature identifier for the surface must be repeated near the datum feature indicator, followed by the list of numbers (separated by commas) identifying the datum targets.

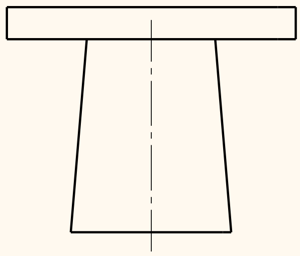




If the datum is established using datum targets in **several surfaces**, then a **different** datum feature identifier **must be** used for each surface.

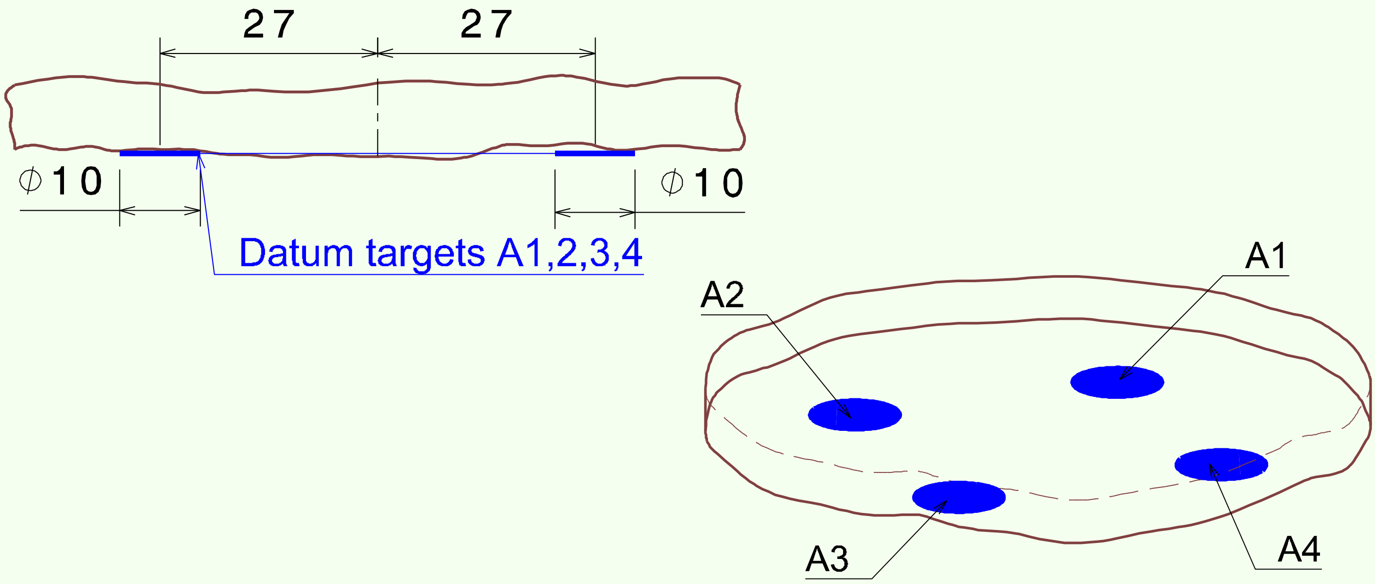
Note: A different letter must be used for each surface.



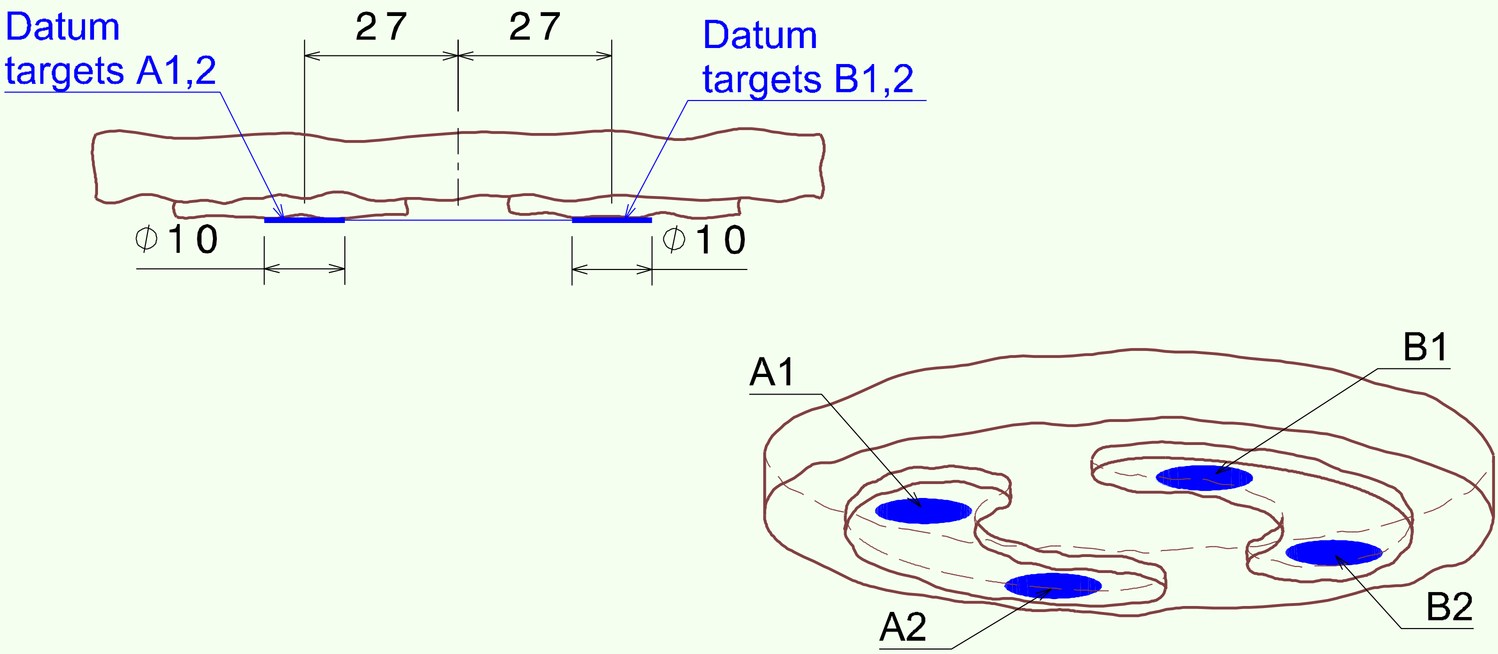


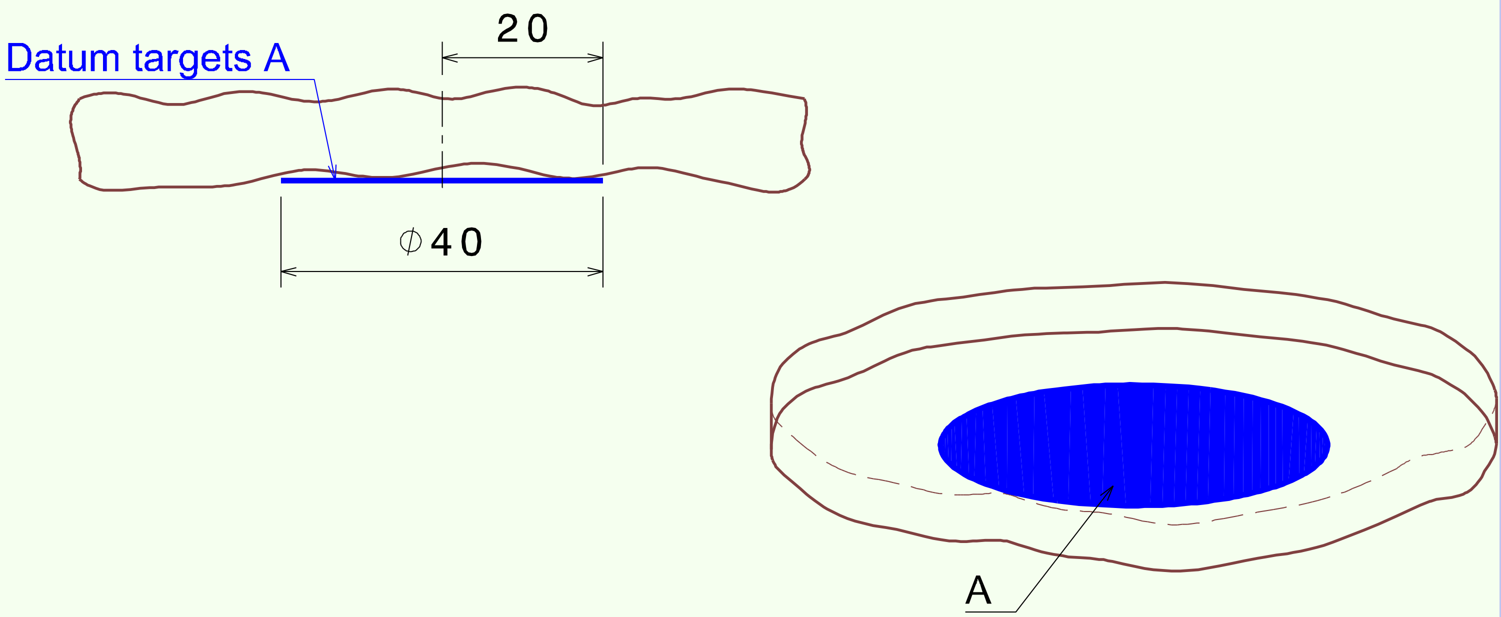
If **one single datum target** exists, the indication may be **simplified** by placing the datum feature directly in the zone (two possible entries).

(ISO 5459)



Datum targets are in theoretically exact locations

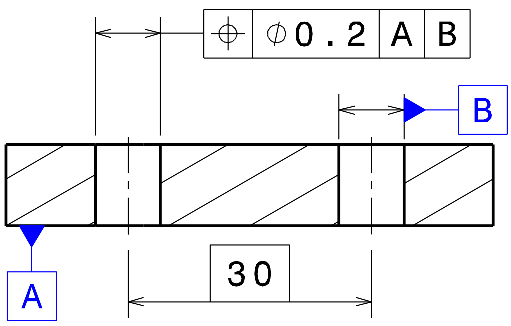


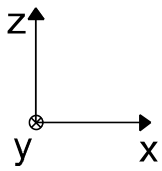


A B C

Datum system

Datum system:
A datum system comprises an ordered list of two or three single or common datums.
A datum system represents the ideal functional interfaces for the parts.

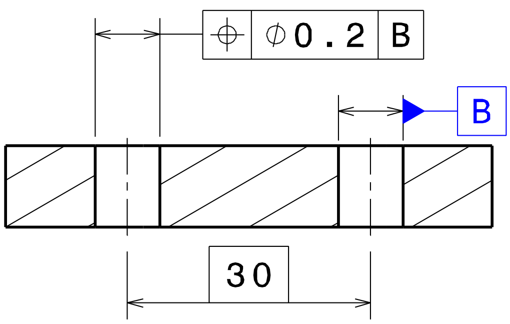


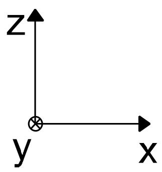


	Tx	Ty	Tz	Rx	Ry	Rz
A			X	X	X	
B	X	X				

The datum system is:

A: primary datum
B: secondary datum

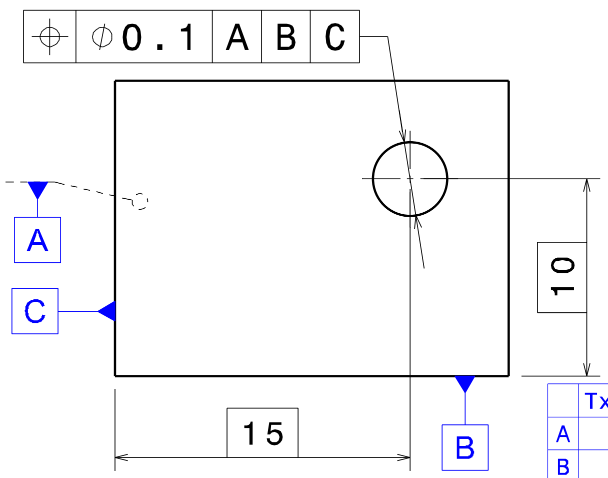


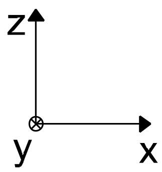


	Tx	Ty	Tz	Rx	Ry	Rz
B	X	X		X	X	

Common error

If the primary datum A is not indicated

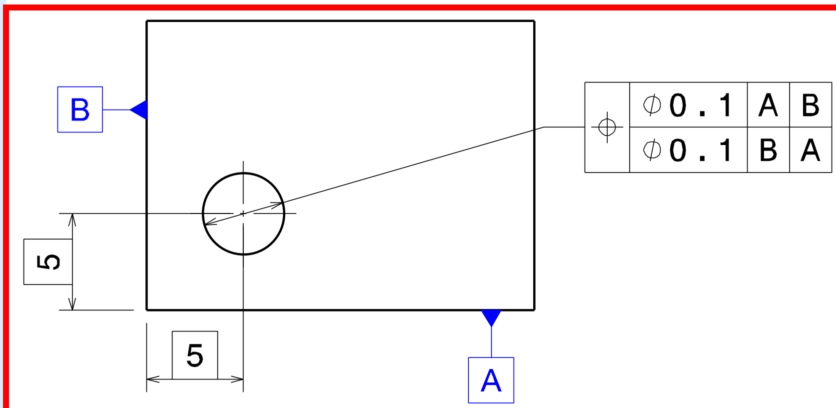




	Tx	Ty	Tz	Rx	Ry	Rz
A		X		X		X
B			X		X	
C	X					

The datum system is:

A: primary datum
B: secondary datum
C: tertiary datum



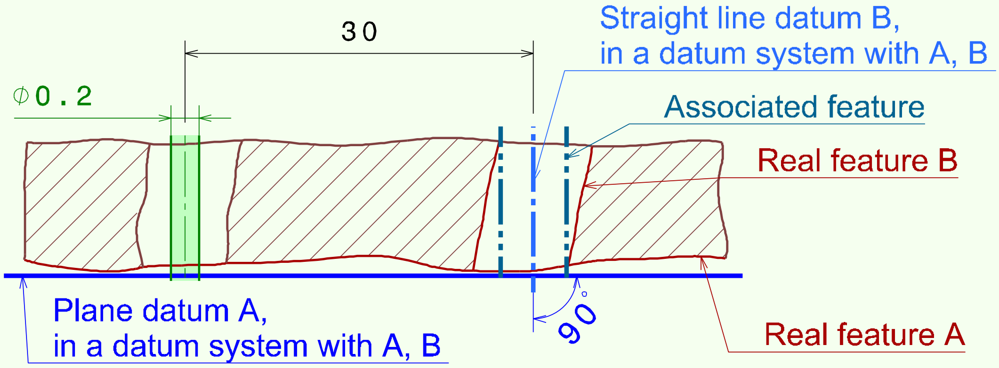
Common error

Changing the order of the datum system will modify measurements

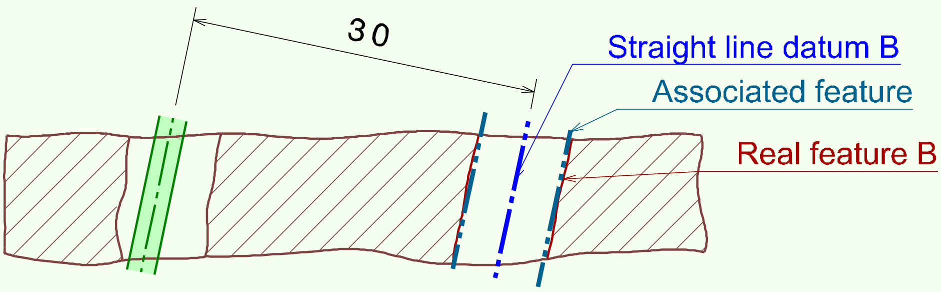
		A	B	C

At least 2 or 3 datums (2 - 3 boxes)
Implicit rules in a datum system:

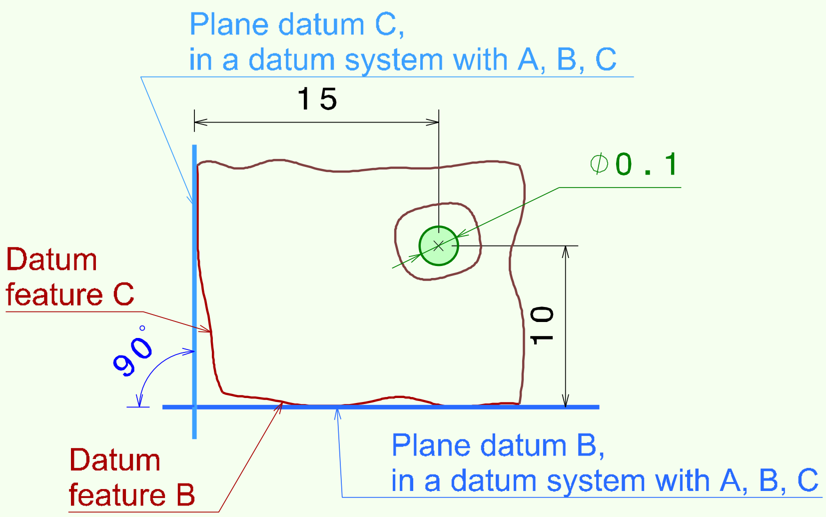
B, the secondary datum is theoretically exactly oriented relative to A.
C, the tertiary datum is theoretically exactly oriented relative to A and B.

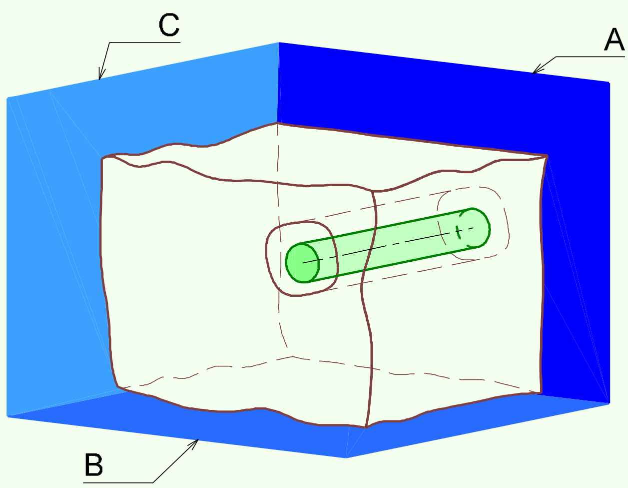


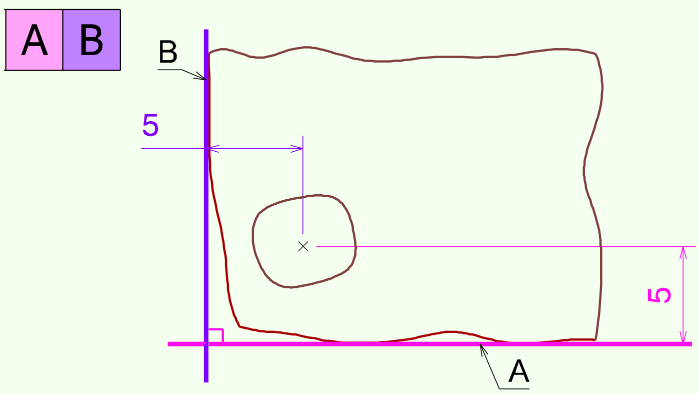
Associated feature: inscribed cylinder with maximum Ø with an axis **perpendicular** to plane datum A

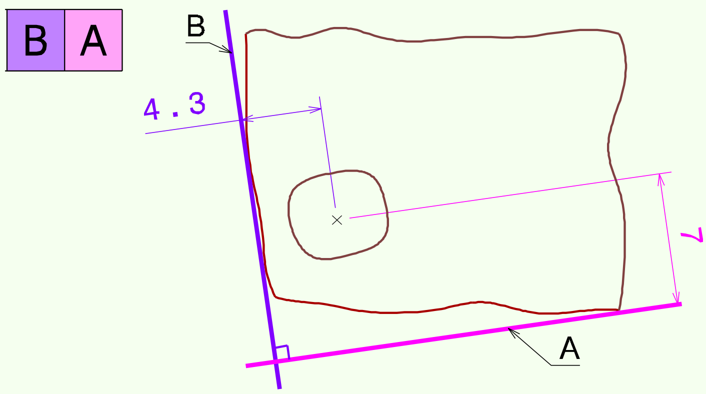


Associated feature: inscribed cylinder with maximum Ø









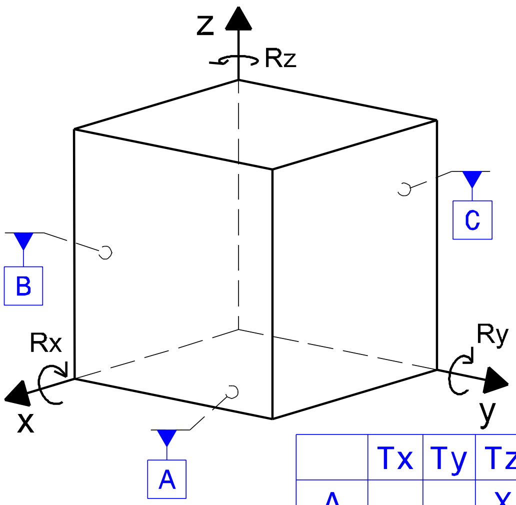
Main datum system

The **main datum system** represents the ideal environment which gives the **final location** of the part in space during **operation**.

The environment may be:

- The ideal interface in contact with the part,
- A means of assembly.

This system will provide a reference or origin for tolerancing features, guide the production process, set up the part during metrology procedures and define the location and/or orientation of a tolerance zone.



	Tx	Ty	Tz	Rx	Ry	Rz
A			X	X	X	
B		X				X
C	X					

Datum system | A | B | C |:

Datum A blocks: translation along Tz, and rotations Rx and Ry = 3 theoretical contact points

Datum B blocks: translation along Ty, and rotation Rz = 2 theoretical contact points

Datum C blocks: translation along Tx. = 1 theoretical contact point

A model coordinate system:

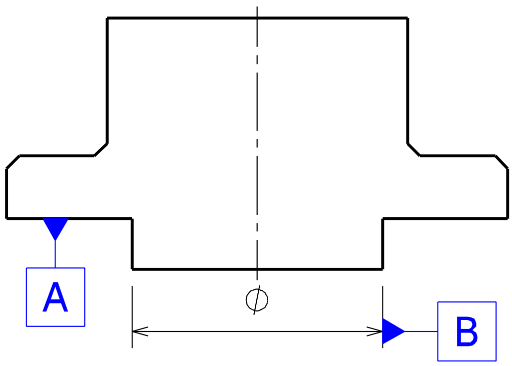
The orientation of the model coordinate system must be common to the same project team and specific to the industry.

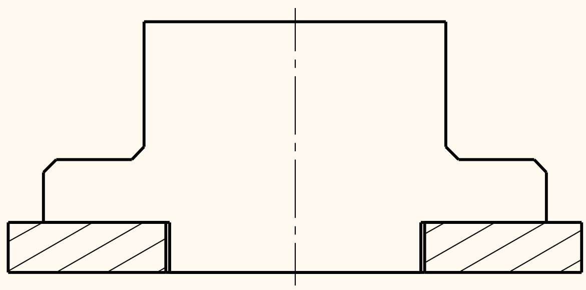
Ideally, axis Z is oriented upwards (opposite to gravity).

Forces:

The order of the datums in the main datum system can depend on the forces applied to the part **once assembled**. It is necessary to know the assembly method to determine the order.

| A | B | or | B | A | ?





If the part is tightened onto a planar type datum, the latter is frequently the primary datum

Isostatism:

A solid has 6 degrees of freedom:

- 3 translations along Tx, Ty, Tz
- 3 rotations along Rx, Ry, Rz.

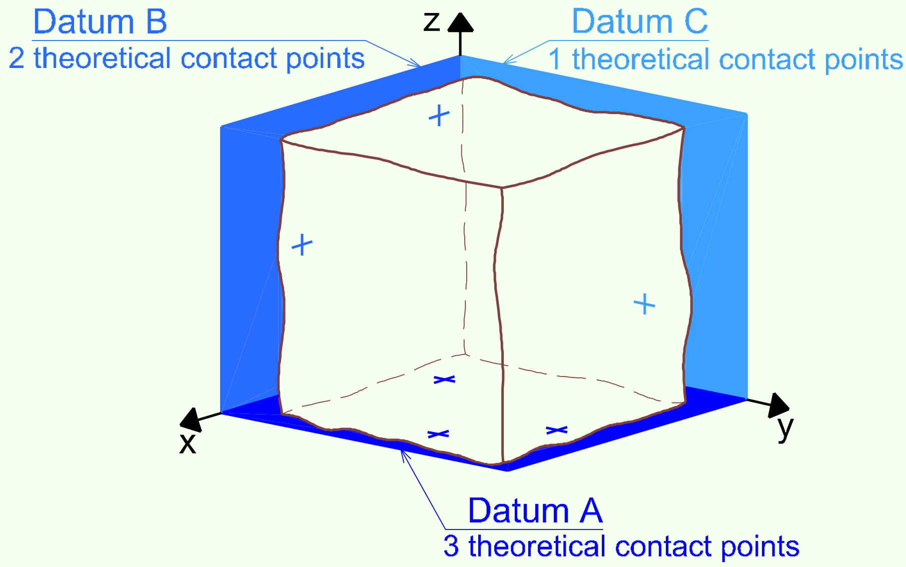
The datums in the main datum system are provided by the surfaces in contact with the functional interface and/or a means of assembly.

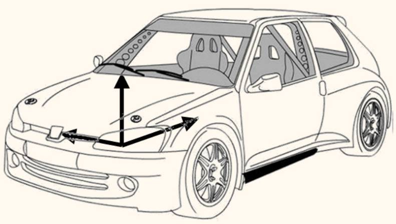
If a drawing specifies the system

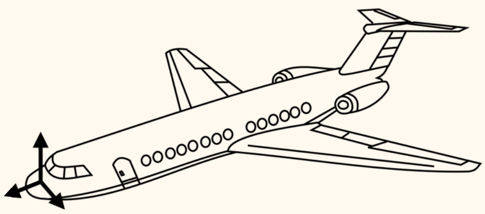
| A | B | C | or | D-E | F | G | , |

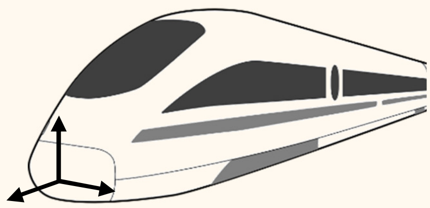
Generally, **only** the following types of specifications should appear:

A	B	C	D-E	F	G
A	B		D-E	F	
A			D-E		



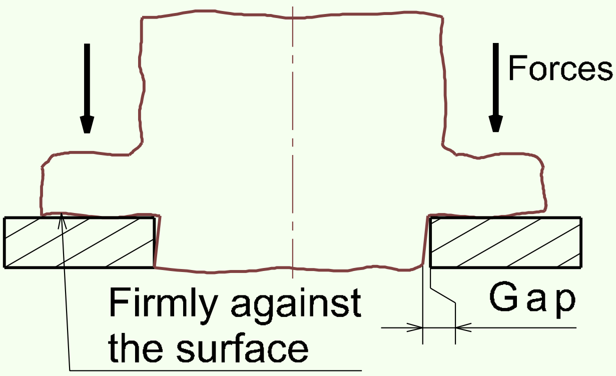




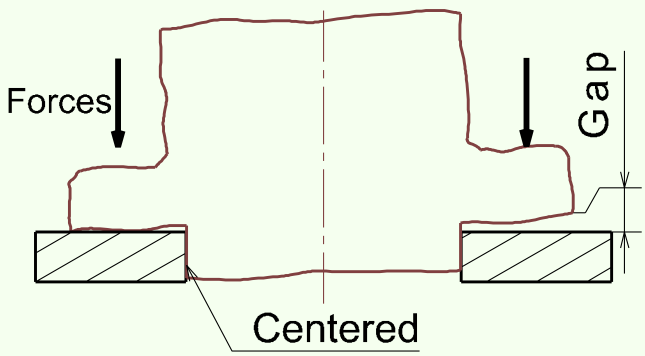


The **order of the letters** in the datum system is defined by the features which locate the part **after assembly**, not by features used during the assembly process**.**

Correct isostatism | A | B |



Incorrect isostatism | B | A |



Tolerance Zone:

A portion of ideal geometric space which must contain a real feature and for which borders depend on the tolerancing characteristic:

- **Form,**
- **Orientation**,
- **Location,**
- **Run-out**

A geometrical tolerance is indicated on a drawing by:

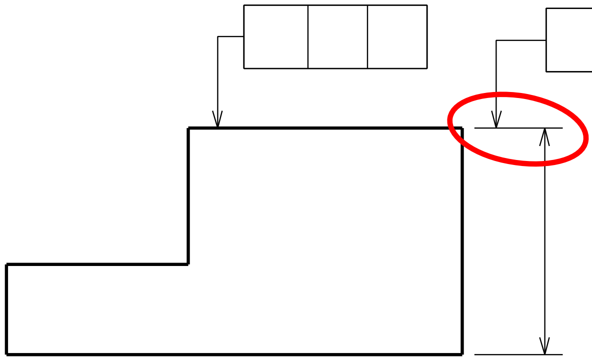
- An arrow indicating the toleranced feature
- A tolerance frame indicating the tolerancing characteristics.

Note: Tolerance value is stated in mm (never in degrees).

By default, the width of the **tolerance zone** is symmetrical and normal to the specified geometry (e.g., a location of 0.1 is equivalent to ±0.05).

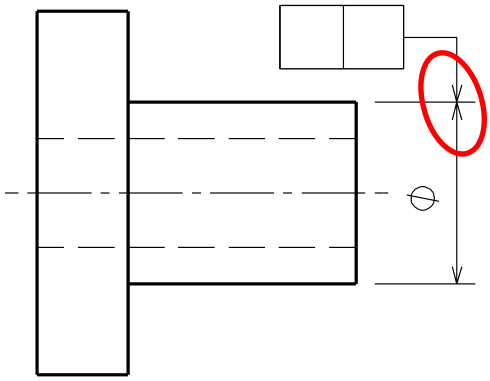
If the tolerance value is **not preceded by the Ø sign**, the direction of the width of the tolerance zone can be obtained by the orientation of the leader line (arrow) indicated by a TED (or use an orientation plane indicator).

Designation of a **flat surface**



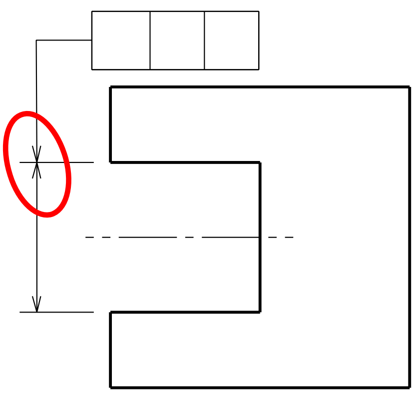
The leader line is separated from the dimension line.

Designation of the **real axis of a cylinder**



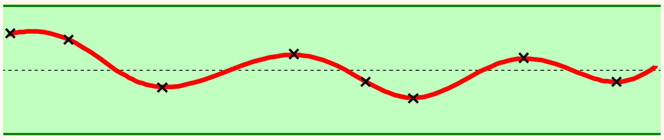
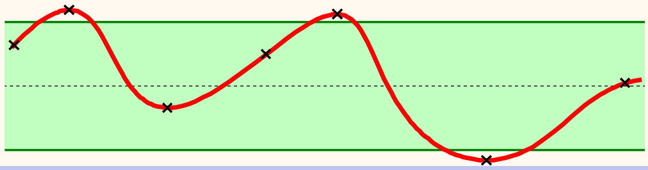
The leader line is aligned with the dimension line.

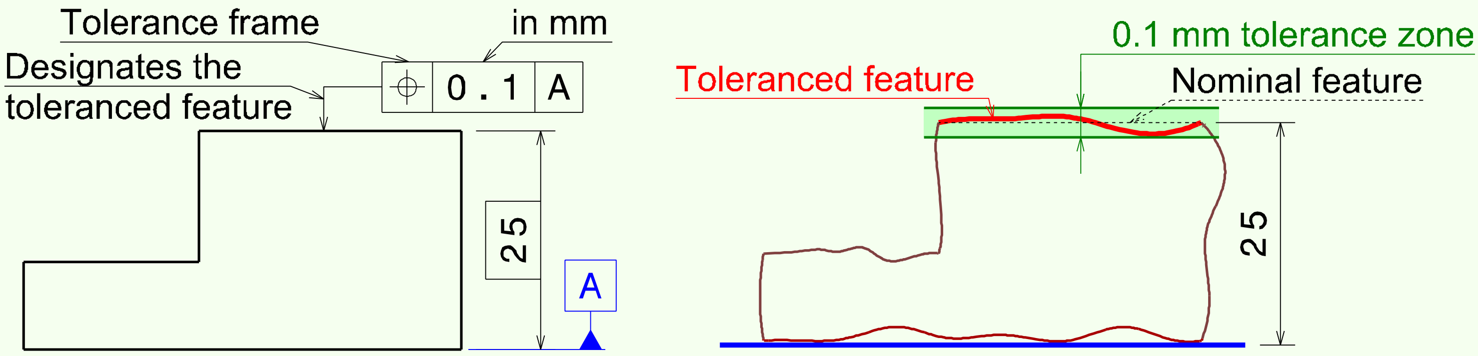
Designation of the **extracted median surface**

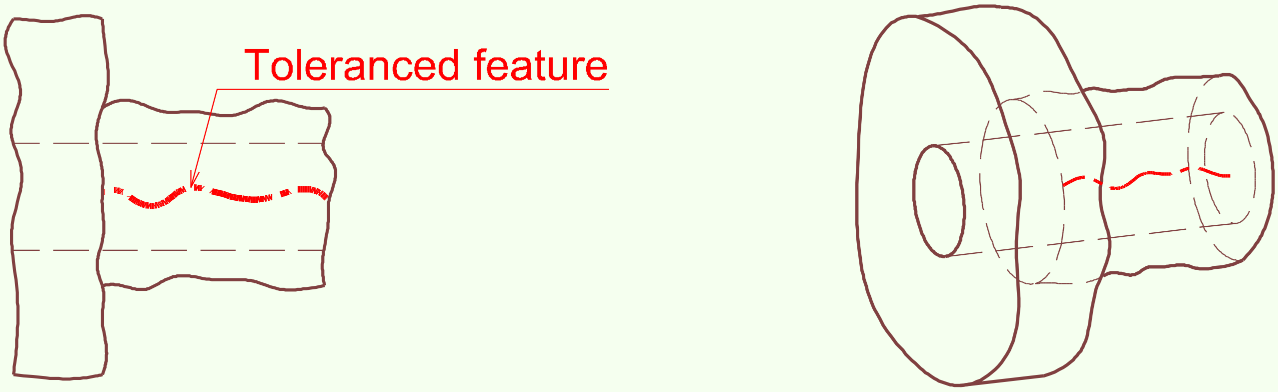


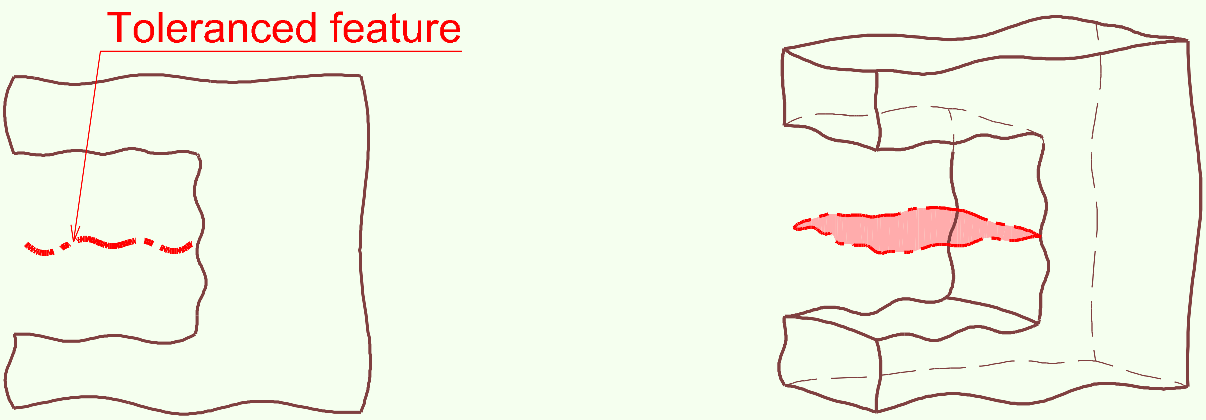
The leader line is aligned with the dimension line.

The **toleranced feature** comply with the specification
if all points are within the tolerance zone.

The toleranced feature is **conform**	The toleranced feature is **non-conform**
	



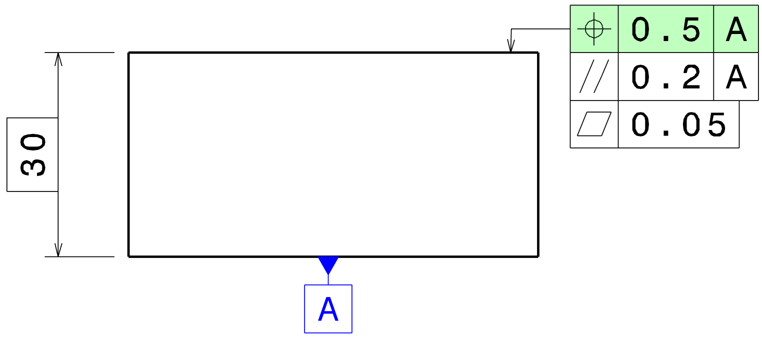




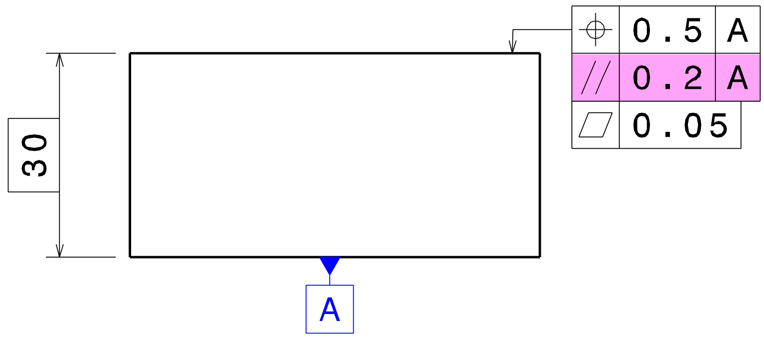
Inclusion of geometrical tolerances

Inclusion logic for geometrical tolerances

The location includes the orientation, which includes the form.

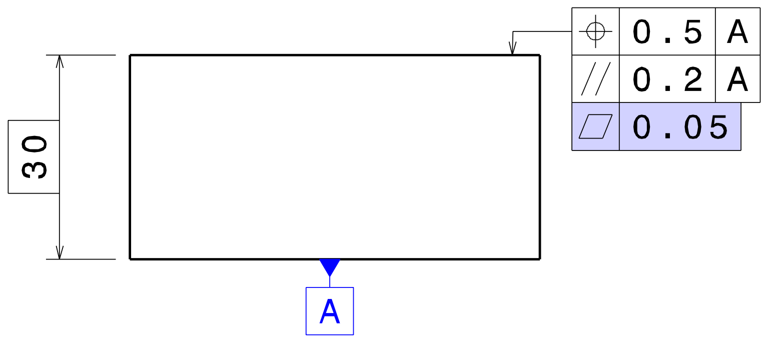


The **location tolerance zone** is defined by the 30 mm TED relative to datum A.

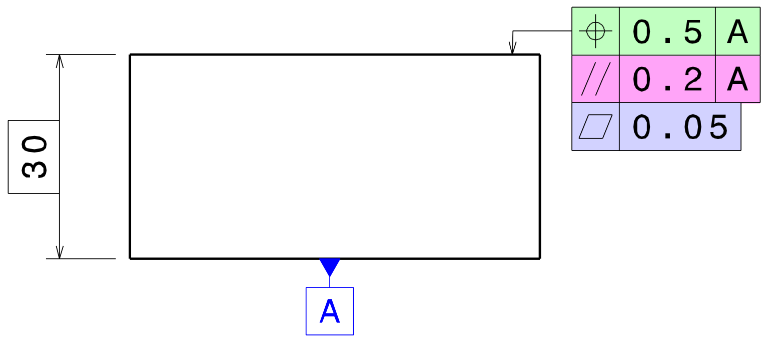


The **orientation tolerance zone** is parallel to datum A.

This zone is not fixed relative to A

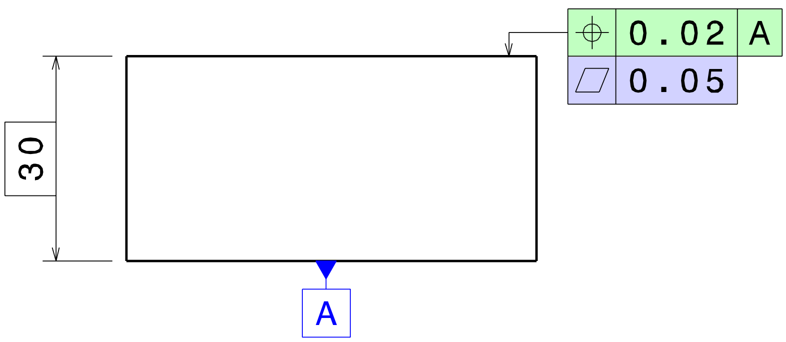


Form tolerance zone, which adapts to the surface.



The **location TZ** includes the **parallelism TZ**, which includes the **form TZ.**

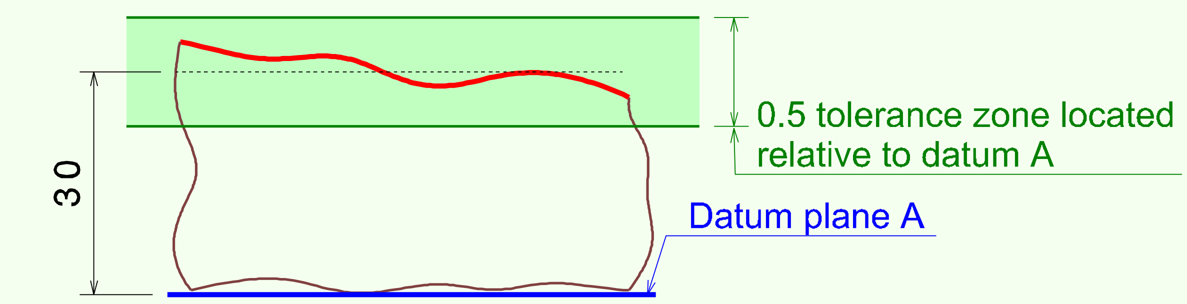
Note: for the same datum A

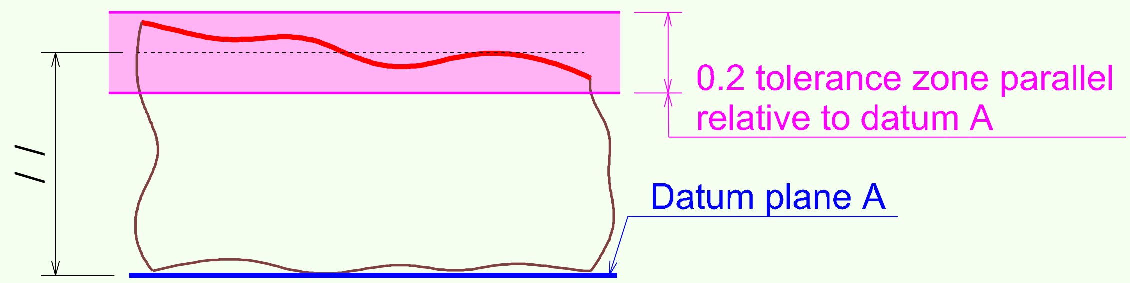


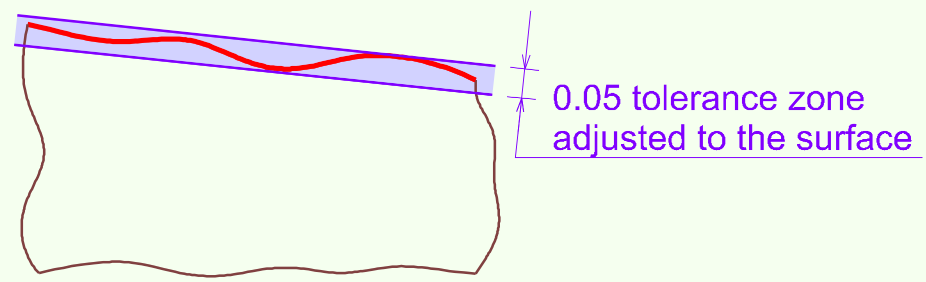
Common error

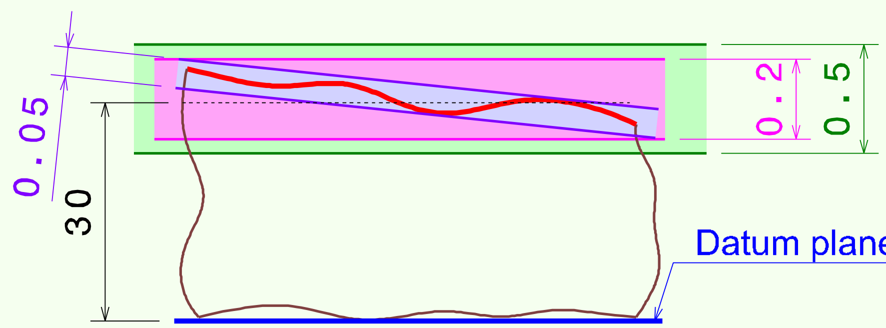
Form tolerance may not exceed location tolerance.

Note: The inclusion applies if the same datum system is used for location and orientation.









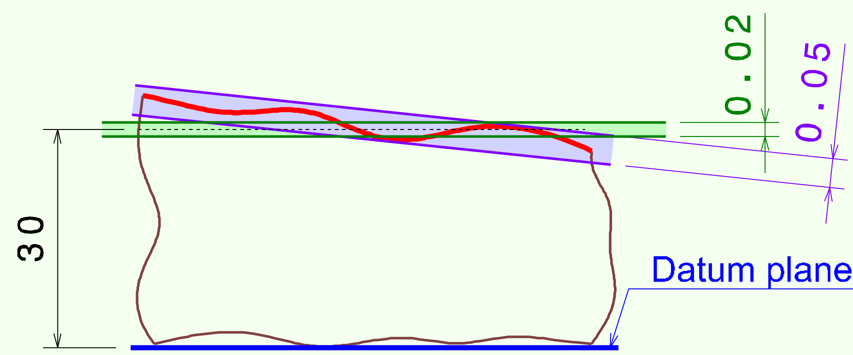


Table of geometrical symbols

Type	General case		Particular case	
Form tolerances	**Line profile** (Any)	⌒	**Straightness**	⏤
			Roundness	○
	Surface profile (Any)	⌓	**Flatness**	▱
			Cylindricity	⌭
Orientation tolerances	**Angularity**	∠	**Parallelism**	∥
	Line profile Surface profile (with datum)	⌒ ⌓	**Perpendicularity**	⊥
Location tolerances	**Position** Point, straight line, planar surface	⌖	**Concentricity / Coaxiality**	◎
	Line profile Surface profile (with datum))	⌒ ⌓	**Symmetry**	⌯
Run-out tolerances	**Circular** (single)	↗	**Radial** **Axial** **Any**	
	Total (double)	⌰		

Use case

Used to:
-**Limit deformation** when assembling on a primary datum, leak tightness, etc.

- Linear forms: when a **linear contact** exists as the primary datum
- Surface forms: when a **surface-type contact** exists as the primary datum

Note: If the primary datum is a **common datum**, the form imperfections must be limited by a **Combined Zone** (common zone) specification.

-**Limit overall dimensions,** e.g.:

- A long cylinder whose form imperfections **will not** fit within the dimensional IT + Ⓔ. Overall dimensions = Max. dimension + Cylindricity
- Two coaxial cylindrical surfaces for the primary datum toleranced for dimensions + Ⓔ. Overall dimensions = Max. envelope dimension + Straightness in Combined Zone (CZ)

-**Reduce the uncertainty** of establishing metrological datum.

-**Limit the cumulative effect** of form imperfections.

Applied to nominally straight lines and nominally planar surfaces.
Used to:
-An assembly function as a secondary datum:
e.g., short centering ($Øhole_{min}$ - $Øshaft_{max}$ > ⊥hole + ⊥shaft), etc.

Note: If the secondary datum is a common zone, the orientation imperfections must be limited to a **Combined Zone** (common zone).

-Limit **non-linear behavior** (leverage effect) by limiting the tolerance zone for locations.

Used to:
-Position **the secondary or tertiary datums** relative to the previous ones in order to satisfy an assembly function or position a pattern of primary datum.

Note: If the secondary or tertiary datums are in a **common zone**, their location imperfections must be limited to a **Combined Zone** (common zone).

-Position the **interfaces** for other parts.

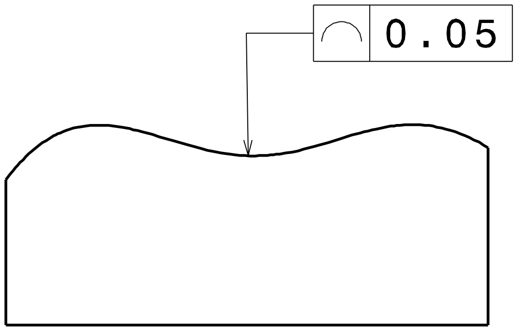
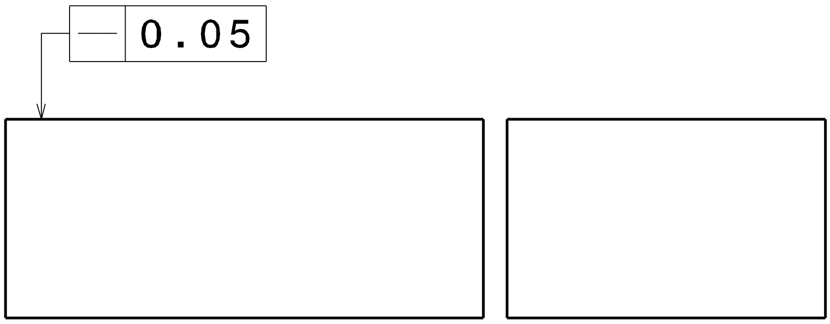
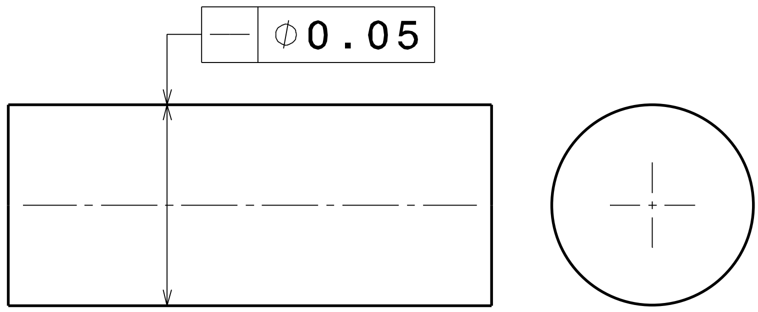
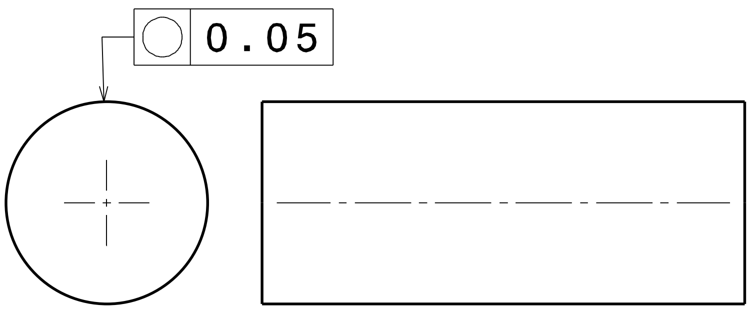
-**Limit overall dimensions**: e.g. the general geometrical specification with a surface profile relative to the main datum system.

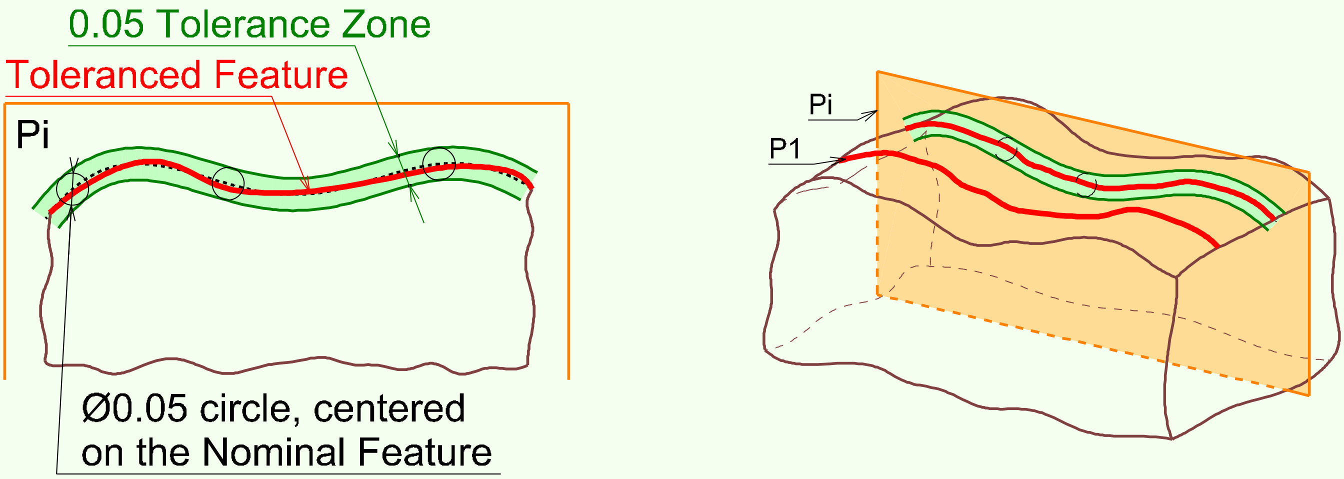
Applied when two parts **rotate relatively** to one another.

Used to:

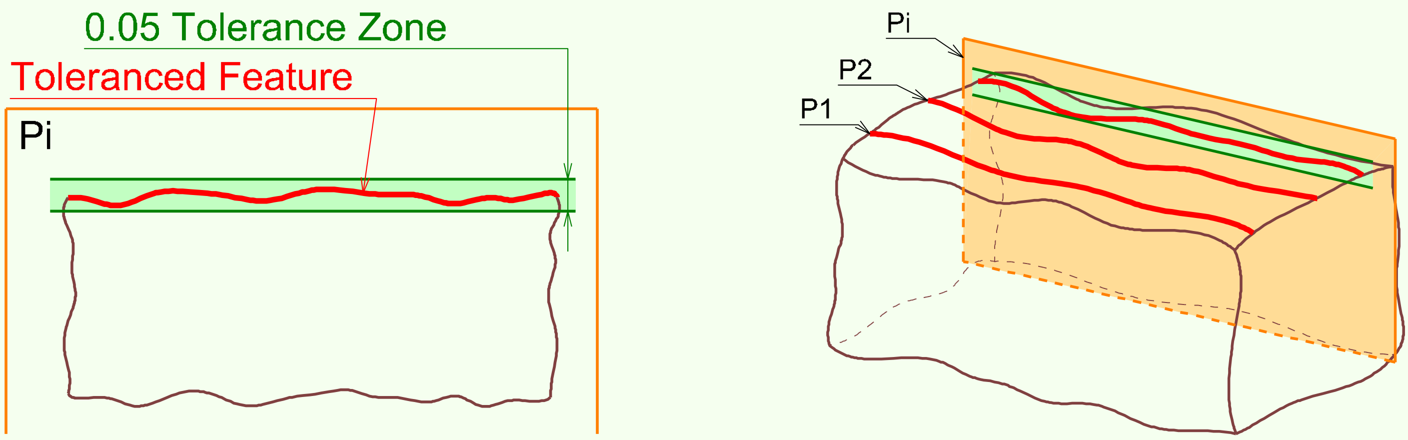
-**Limit vibrations (unbalance)**: aligning the center of gravity with the axis of rotation (static balancing) is not sufficient. One of the main axes of inertia must be aligned with the axis of rotation (dynamic balancing) to limit imbalance. These main axes of inertia are easy to identify using CAD software.

-Maintain **regular movements**.

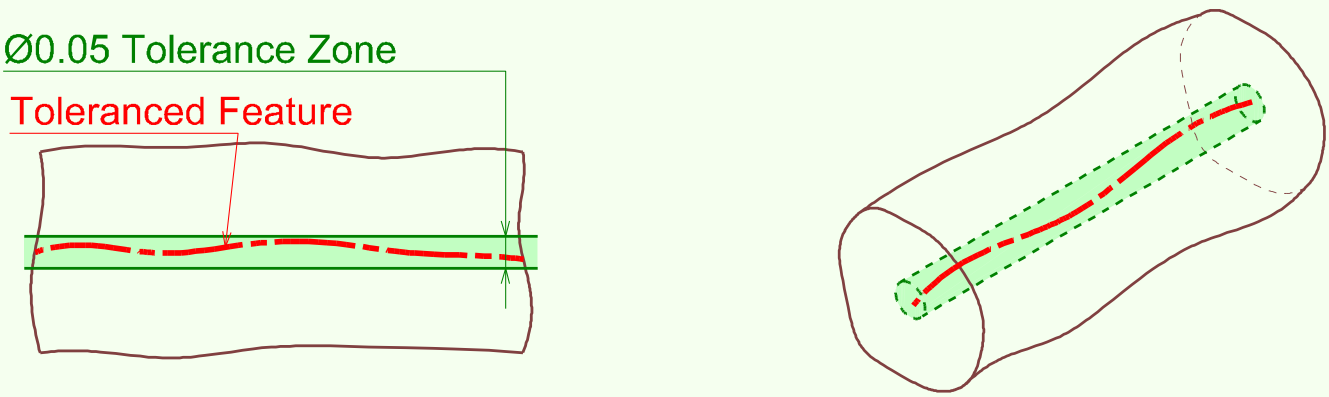
Symbol	Drawing	Definition
⌒ Line profile	 Nominal Feature: according to CAD model (mean dimensions)	TF: All lines of the real surface, parallel to the view plane. TZ: In each section Pi, a planar surface limited by two envelope lines separated by circles with a diameter of 0.05, centered on the nominal feature.
— Straightness		TF: All nominally straight lines of the real surface, parallel to the view plane. TZ: In each section Pi, a planar surface limited by two parallel straight lines at a distance of 0.05.
		TF: A nominally straight line, an axis extracted from a cylinder. TZ: A volume limited by a cylinder diameter of 0.05.
○ Circularity		TF: All nominal curves lines on cross sections of the cylinder. TZ: In each section Pi, a planar surface limited by two concentric circles at a distance of 0.05.



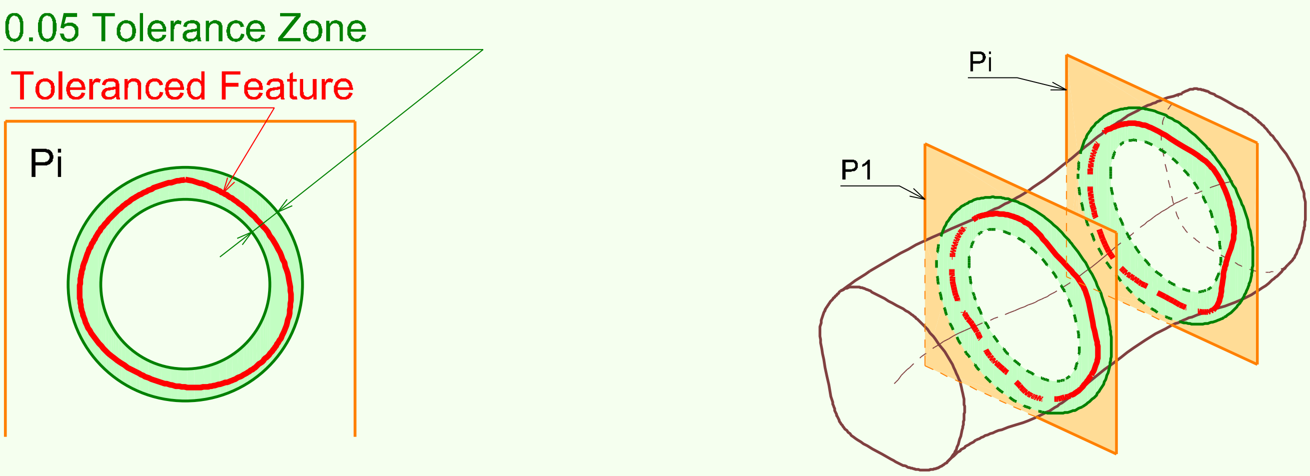
0.05 Tolerance Zone
Toleranced Feature
Pi
Ø0.05 circle, centered
on the Nominal Feature
Pi
P1



0.05 Tolerance Zone
Toleranced Feature
Pi
Pi
P2
P1



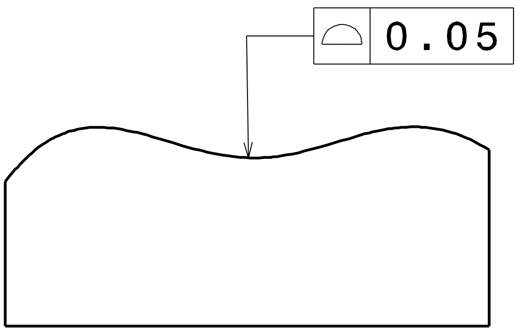
Ø0.05 Tolerance Zone
Toleranced Feature



0.05 Tolerance Zone
Toleranced Feature
Pi
Pi
P1

35 Symbol	Drawing	Definition

⌓ Surface profile

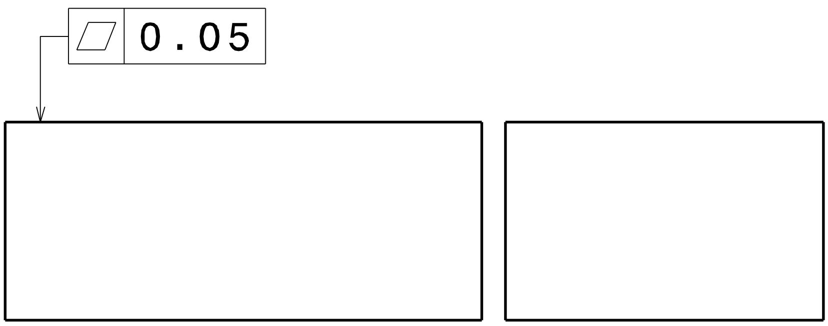


Nominal Feature: according to CAD model (mean dimensions)

TF: A surface.

TZ: A volume limited by two envelope surfaces separated by spheres with a diameter of 0.05, centered on the nominal surface.

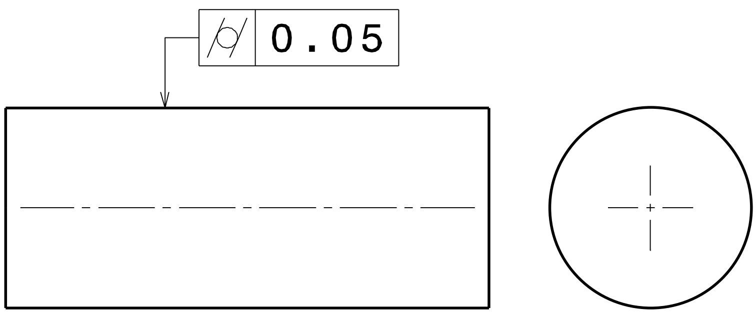
▱ Flatness



TF: A nominally planar surface.

TZ: A volume limited by two parallel planes at a distance of 0.05.

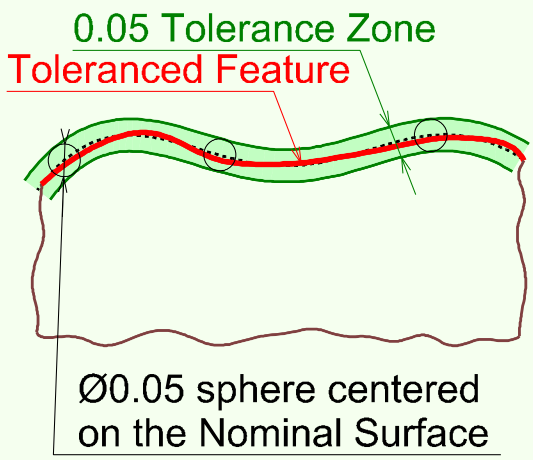
⌭ Cylindricity

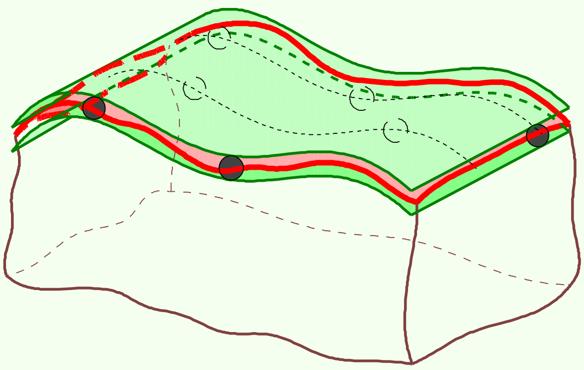


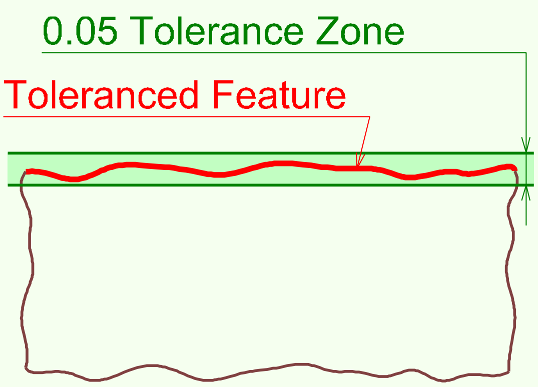
TF: A nominally cylindrical surface.

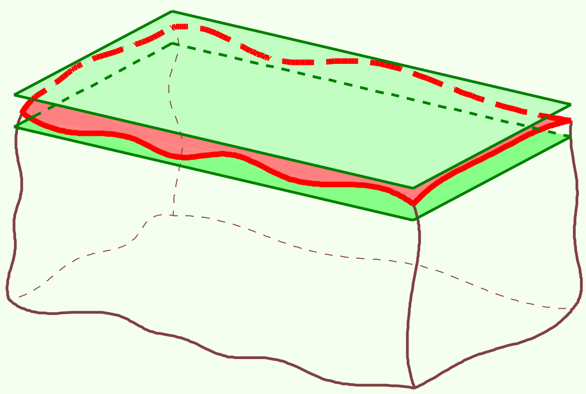
TZ: A volume limited by two coaxial cylinders at a distance of 0.05.

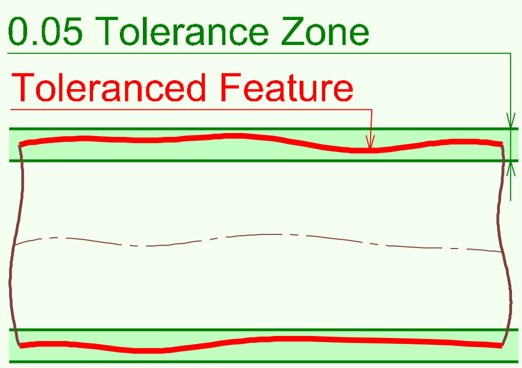
Meaning

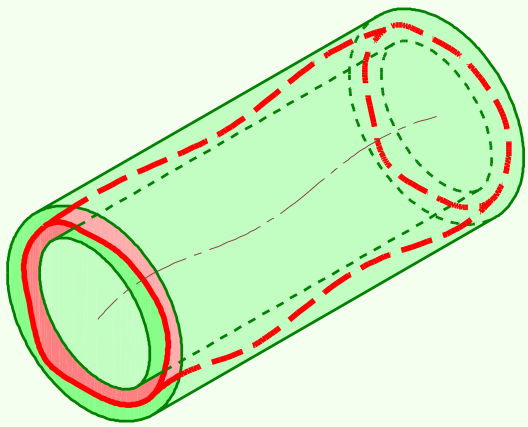

0.05 Tolerance Zone
Toleranced Feature
Ø0.05 sphere centered
on the Nominal Surface

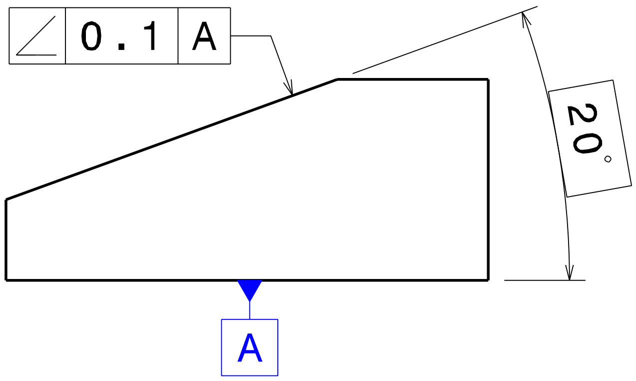
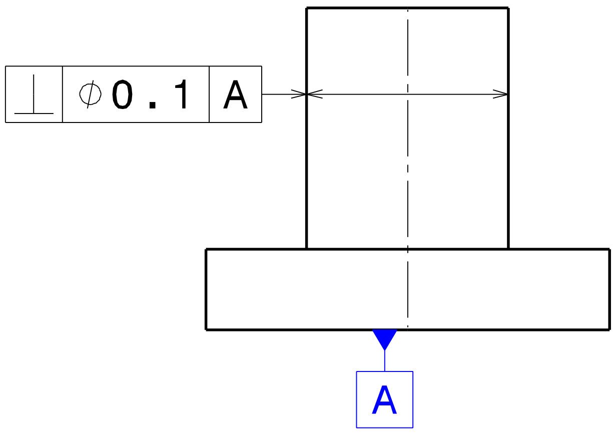
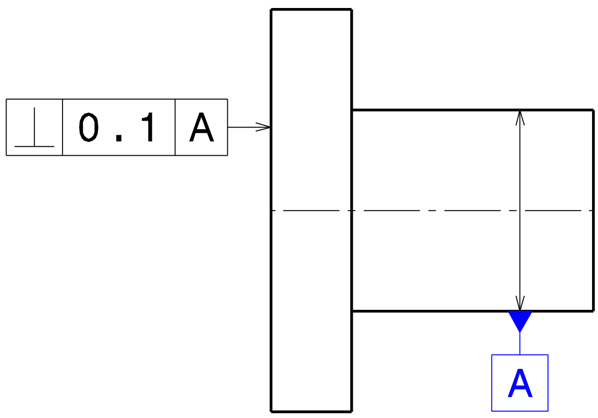



0.05 Tolerance Zone
Toleranced Feature

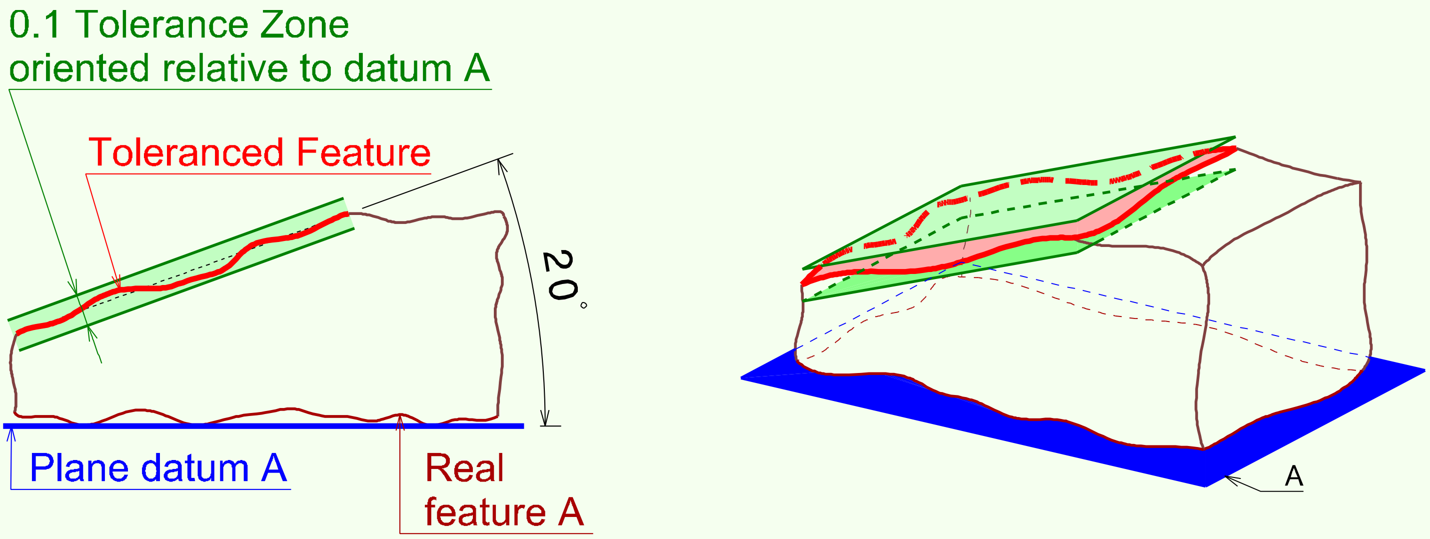


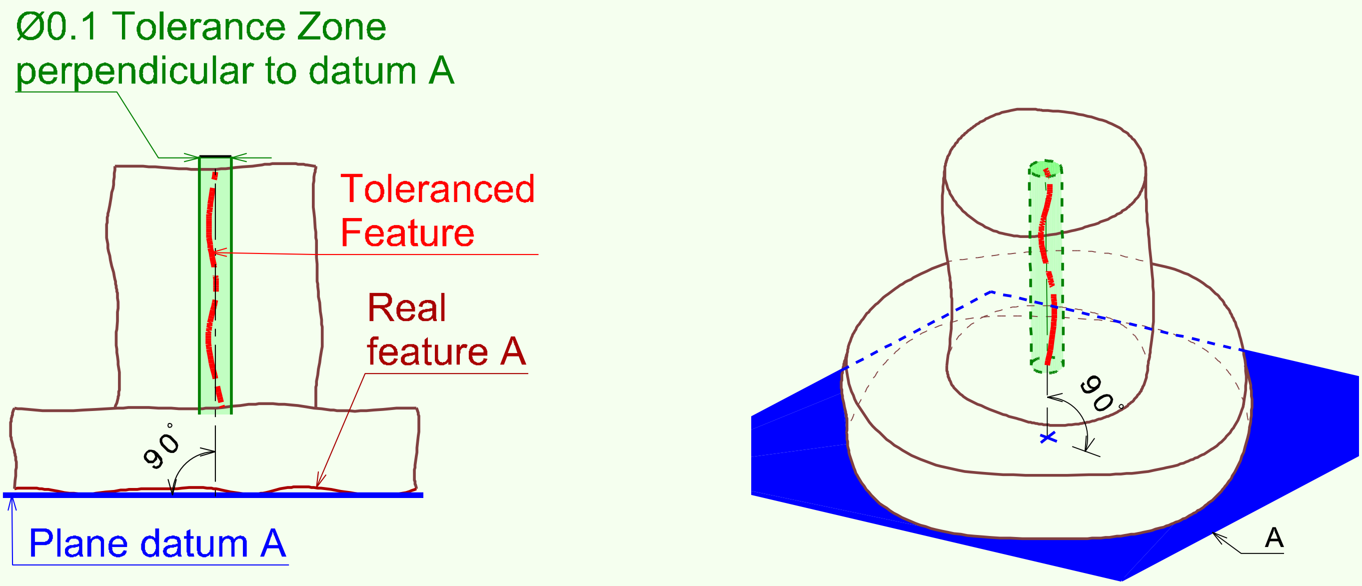

0.05 Tolerance Zone
Toleranced Feature

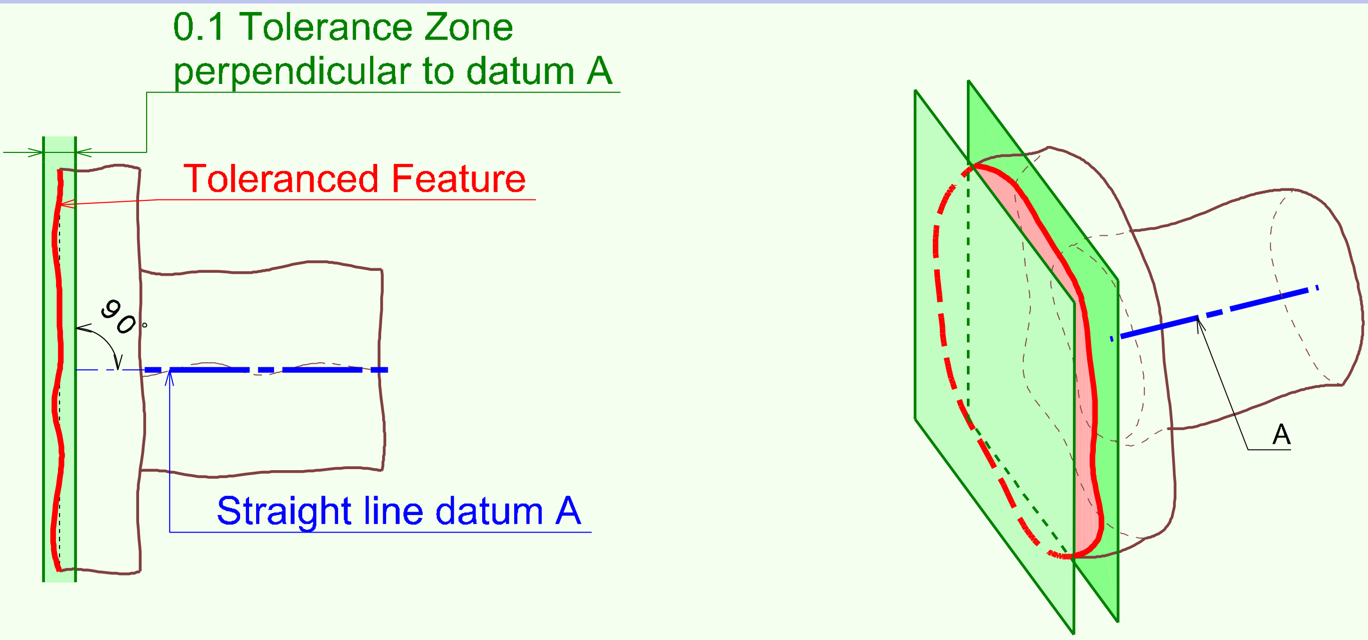


Symbol	Drawing	Definition
∠ Angularity		TF: A nominally planar surface. TZ: A volume limited by two parallel planes at a distance of 0.1 oriented relative to datum A. DT: A Primary datum.
⊥ Perpendicularity		TF: A nominally straight line, an axis extracted from a cylinder. TZ: A volume limited by a cylinder diameter of 0.1, with an axis perpendicular to datum A. DT: A Primary datum.
⊥ Perpendicularity		TF: A nominally planar surface. TZ: A volume limited by two parallel planes at a distance of 0.1, perpendicular to datum A. DT: A Primary datum.

Meaning


0.1 Tolerance Zone
oriented relative to datum A
Toleranced Feature
20°
Plane datum A
Real
feature A
A

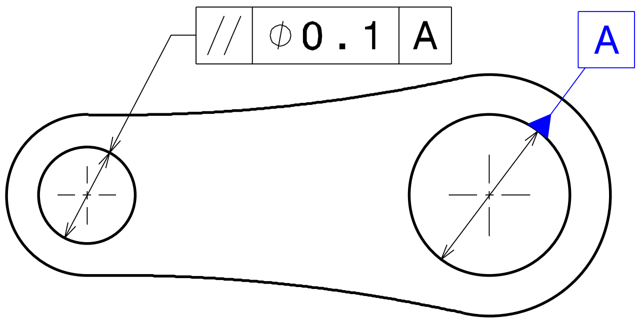

Ø0.1 Tolerance Zone
perpendicular to datum A
Toleranced
Feature
Real
feature A
90°
Plane datum A
90°
A


0.1 Tolerance Zone
perpendicular to datum A
Toleranced Feature
90°
Straight line datum A
A

Symbol	Drawing	Definition

Parallelism

Symbol: //



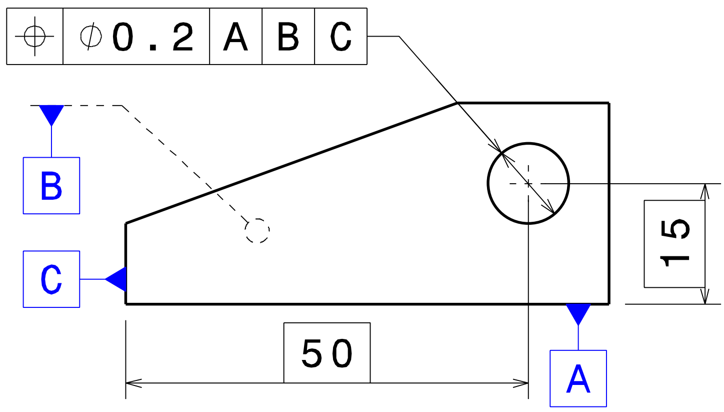
TF: A nominally straight line, an axis extracted from a hole.

TZ: A volume limited by a cylinder diameter of 0.1, with an axis parallel to datum A.

DT: A Primary datum.

Location

Symbol: ⌖



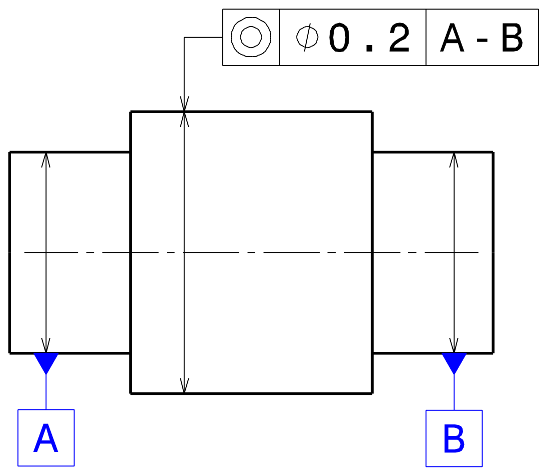
TF: A nominally straight line, an axis extracted from a hole.

TZ: A volume limited by a cylinder diameter of 0.2, located relative to the datum system A, B and C.

DT: A Primary datum.
B Secondary datum.
C Tertiary datum.

Coaxiality / Concentricity

Symbol: ◎

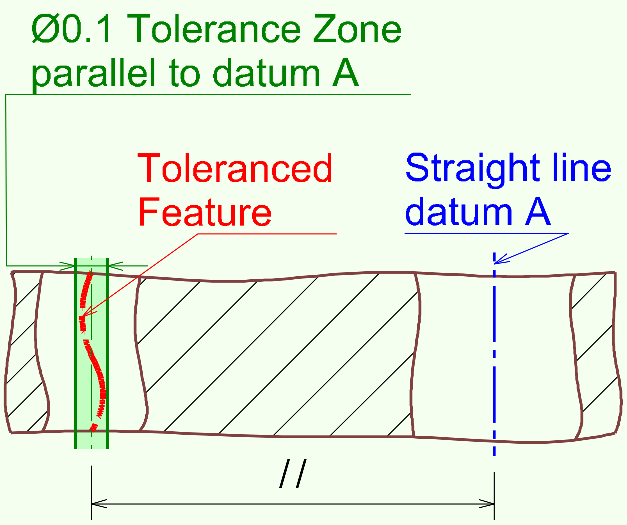


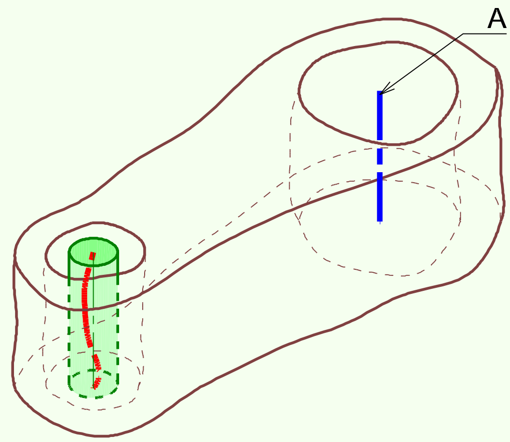
TF: A nominally straight line, an axis extracted from a cylinder.

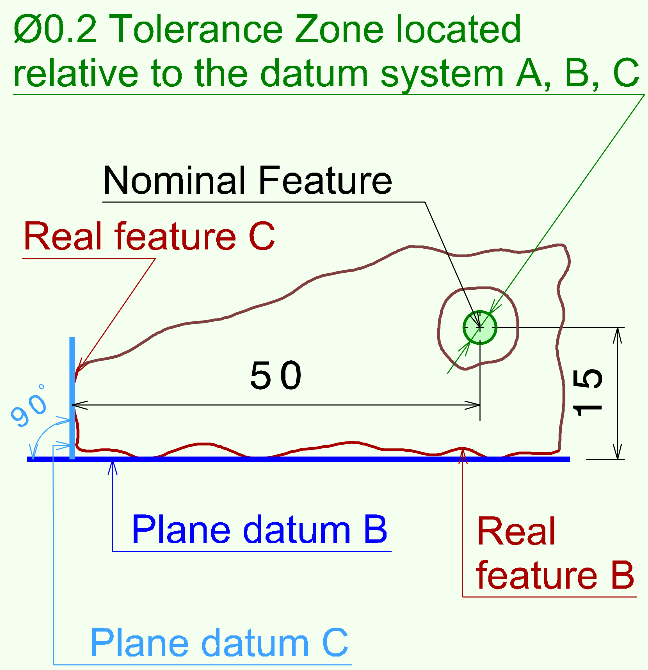
TZ: A volume limited by a cylinder diameter of 0.2, centered on datum A-B.

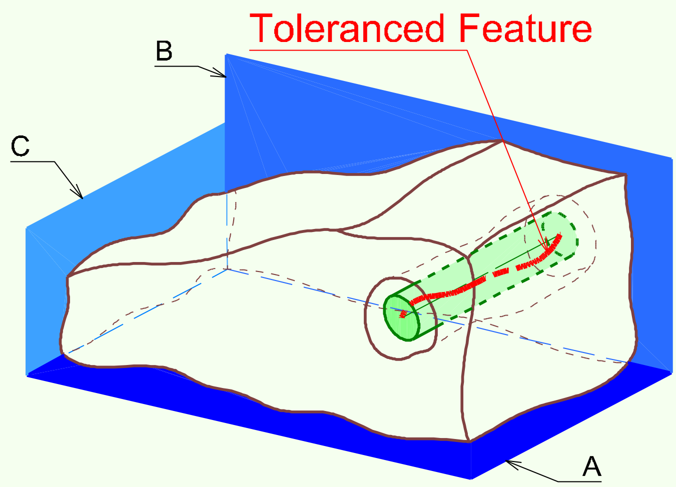
DT: A-B Common datum.

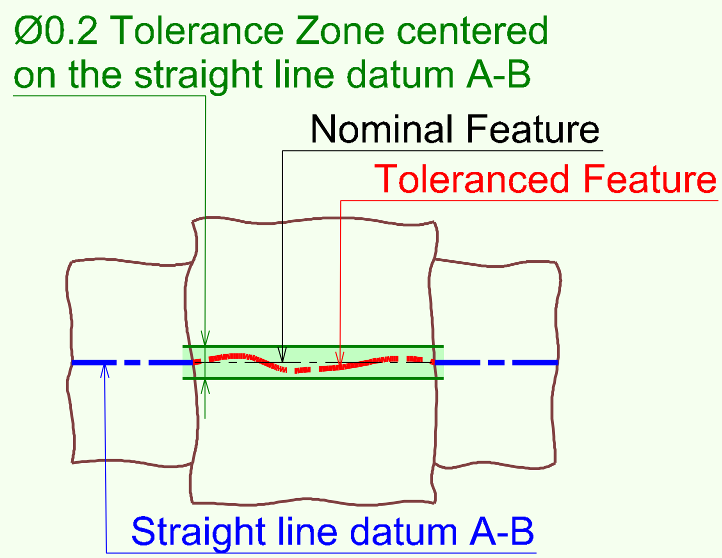
Note:
- Coaxiality to align two axes
- Concentricity to align two centers of circles.

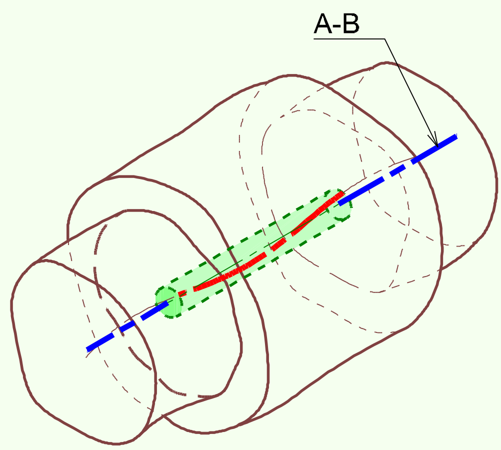

Ø0.1 Tolerance Zone
parallel to datum A
Toleranced
Feature
Straight line
datum A
//

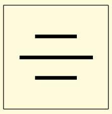
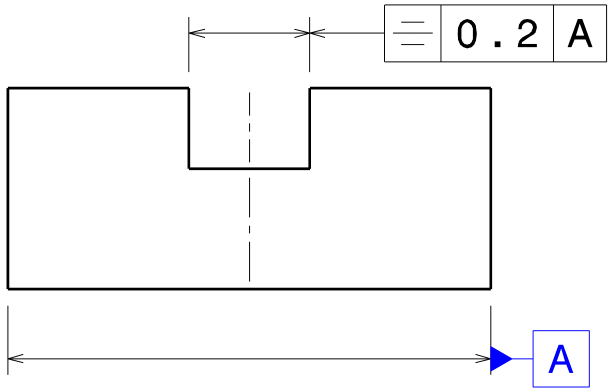
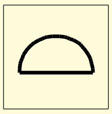
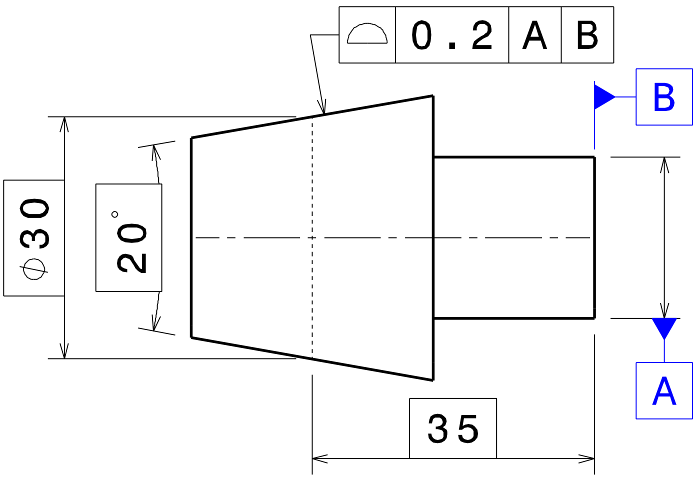
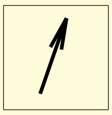
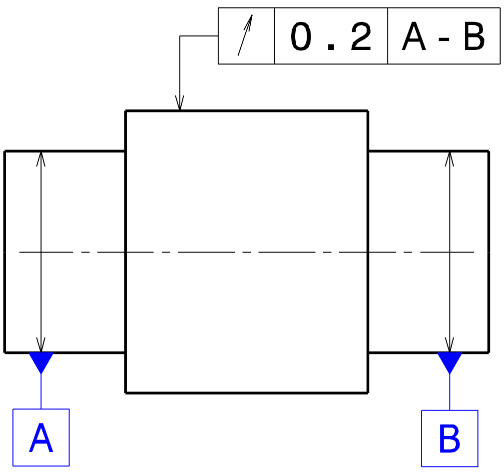

A


Ø0.2 Tolerance Zone located
relative to the datum system A, B, C
Nominal Feature
Real feature C
50
15
90°
Plane datum B
Real
feature B
Plane datum C

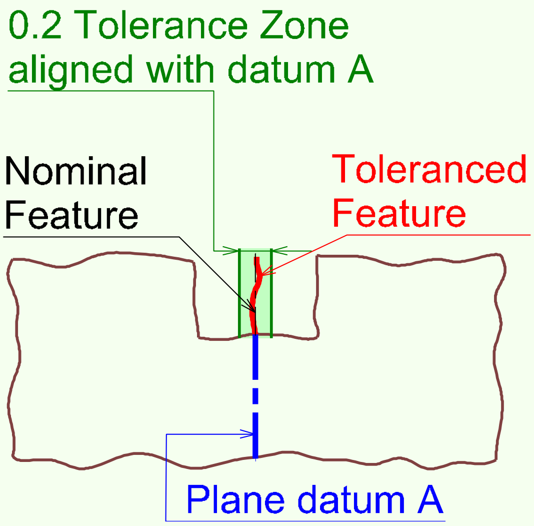

Toleranced Feature
B
C
A

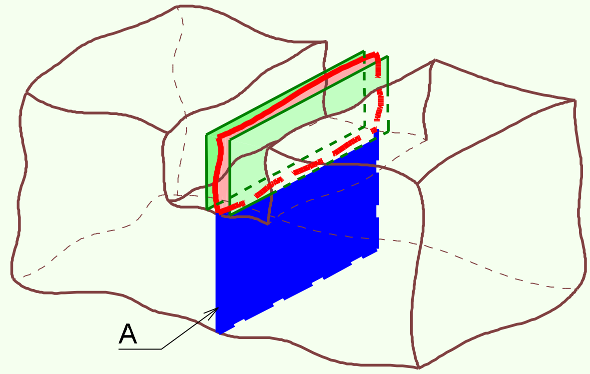

Ø0.2 Tolerance Zone centered
on the straight line datum A-B
Nominal Feature
Toleranced Feature
Straight line datum A-B

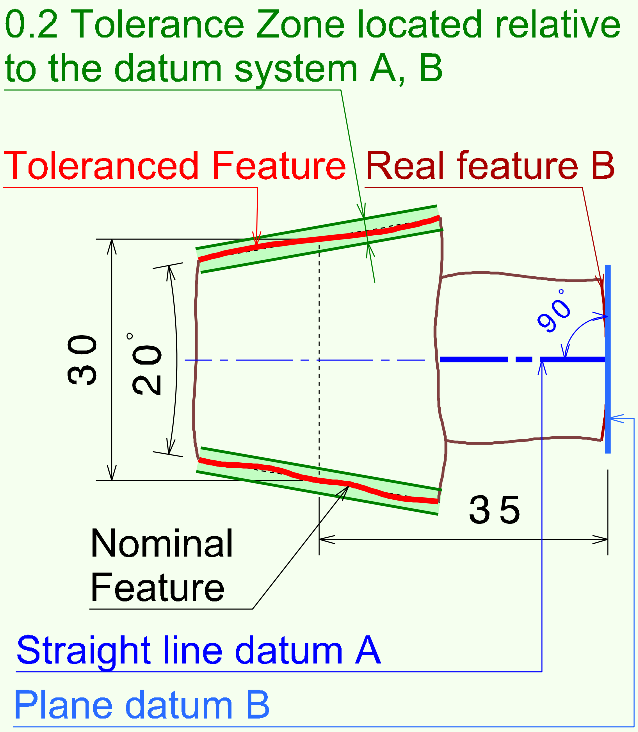

A-B

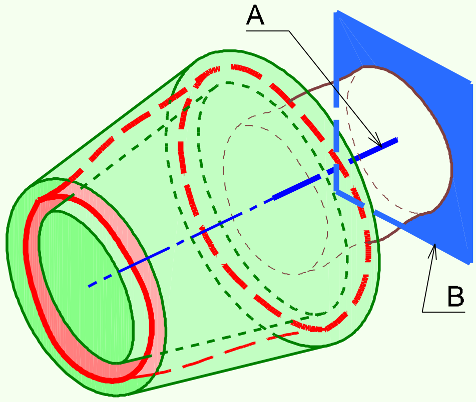
Symbol	Drawing	Definition
 Symmetry		TF: A nominally planar median surface extracted from the groove. TZ: A volume limited by two parallel planes at 0.2, located symmetrically relative to the datum A. DT: A Primary datum. **Note:** To align a planar surface, a straight line or a point between two planes relative to a plane or a straight line.
 Surface profile with datum		TF: A nominally conical surface. TZ: A volume limited by two envelope surfaces separated by spheres with a diameter of 0.2, for which the centers rolling the theoretical conical surface located relative to the datum system A and B. DT: A Primary datum. B Secondary datum.
 Circular run-out radial		TF: All nominal circular lines in planes which are perpendicular to the straight-line datum. TZ: In each section Pi, a planar surface limited by two concentric circles at a distance of 0.2, centered on datum A-B. DT: A-B Primary datum.

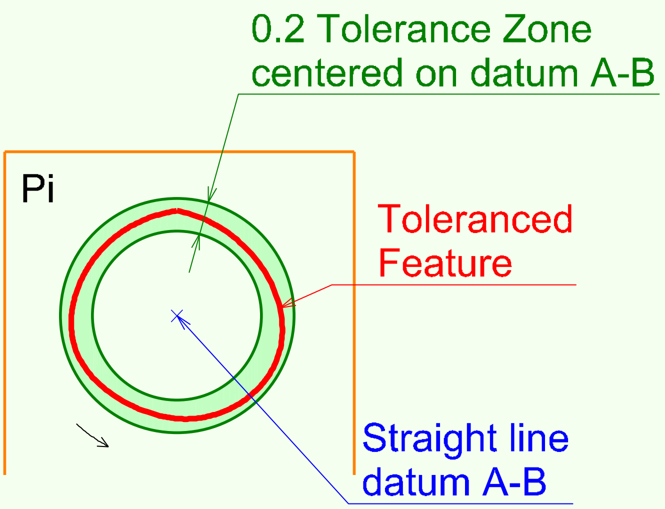
Meaning

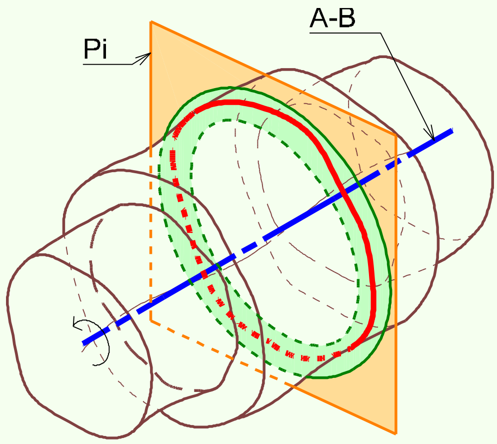

0.2 Tolerance Zone
aligned with datum A
Nominal
Feature
Toleranced
Feature
Plane datum A


A


0.2 Tolerance Zone located relative
to the datum system A, B
Toleranced Feature
Real feature B
30
20°
90°
35
Nominal
Feature
Straight line datum A
Plane datum B

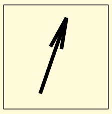

A
B

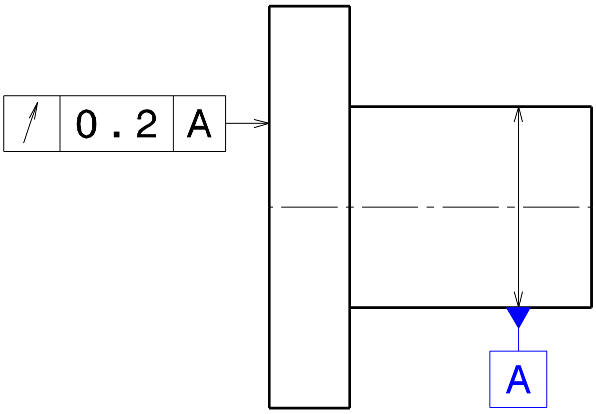

0.2 Tolerance Zone
centered on datum A-B
Pi
Toleranced
Feature
Straight line
datum A-B


Pi
A-B

43 Symbol | Drawing | Definition

Circular run-out axial



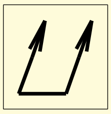


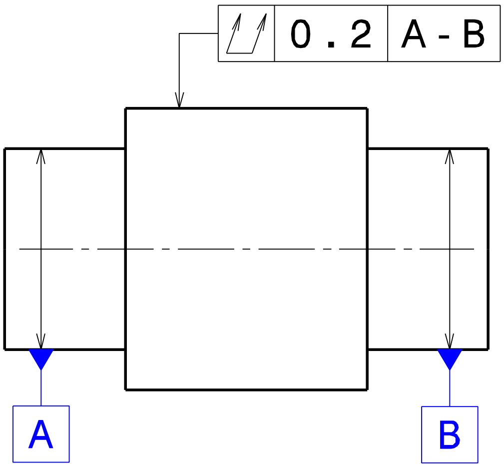
TF: All nominal intersecting circular lines on a nominally planar surface and an ideal cylinder centered on straight line datum A.

TZ: In each section Ci, a cylindrical surface limited by two circles at a distance of 0.2, centered on datum A.

DT: A Primary datum.

Total run-out radial



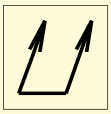


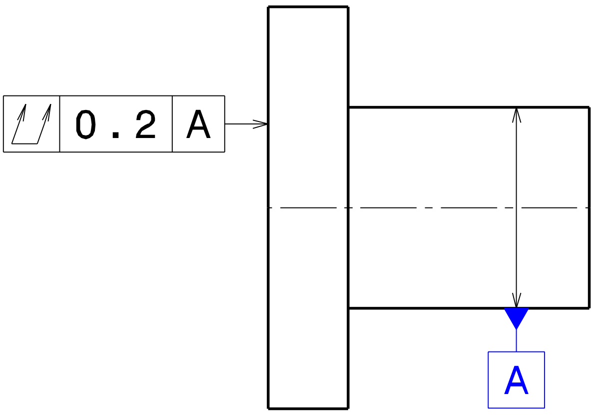
TF: A nominally cylindrical surface.

TZ: A volume limited by two coaxial cylinders at a distance of 0.2, centered on datum A-B.

DT: A-B Primary datum.

Total run-out axial



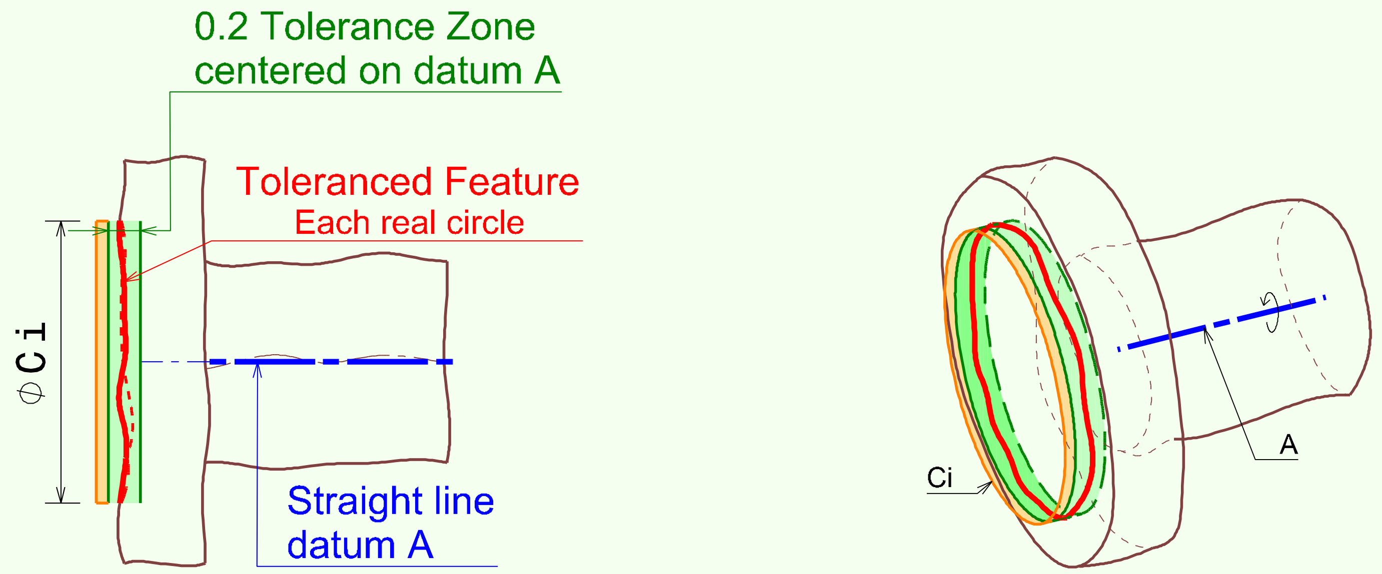


TF: A nominally planar surface.

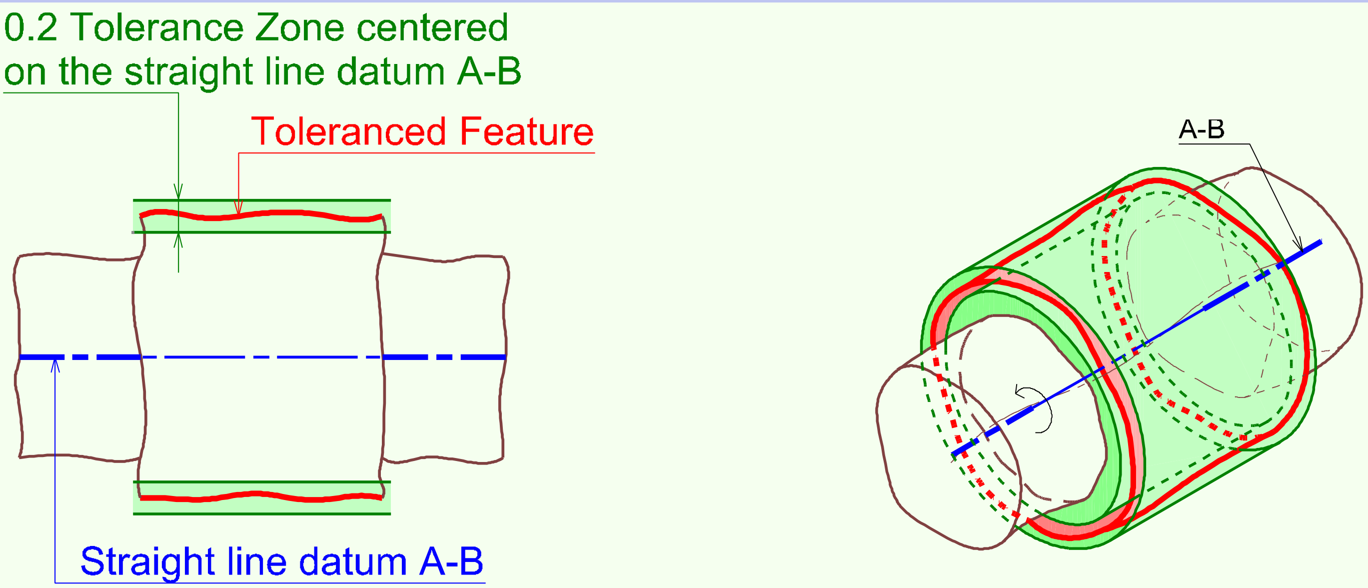
TZ: A volume limited by two parallel planes at a distance of 0.2, perpendicular to datum A.

DT: A Primary datum.

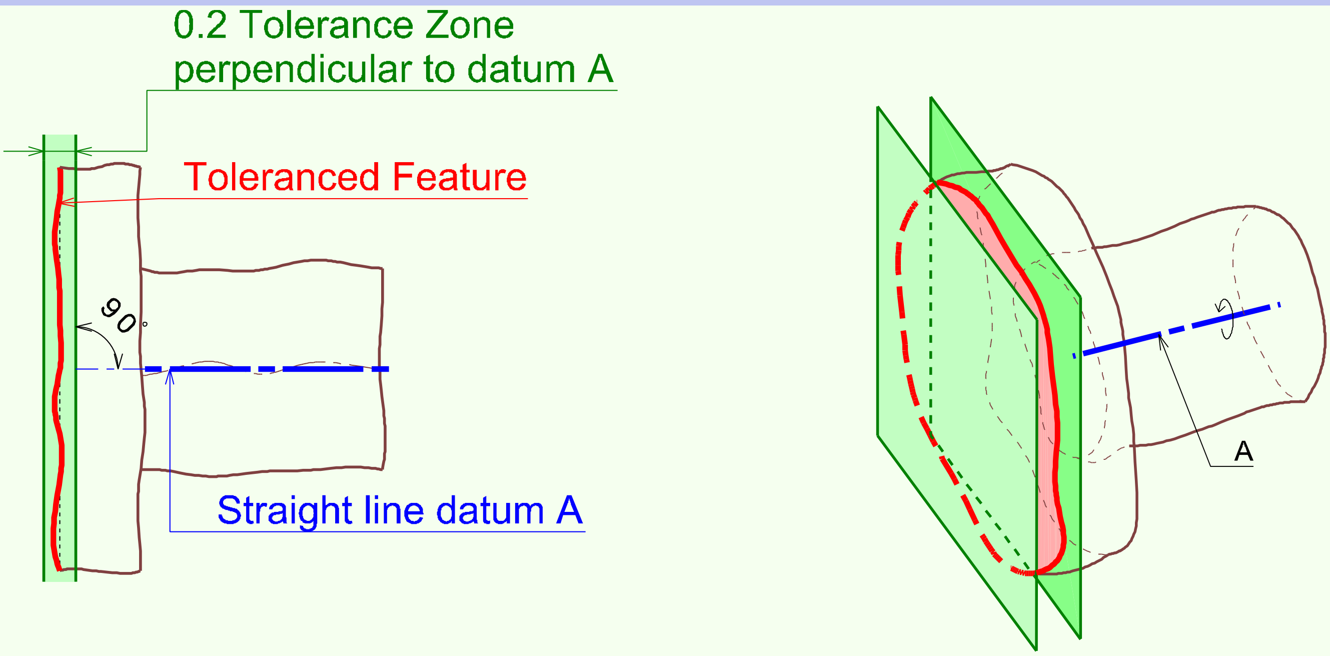
Note: This entry is equivalent to perpendicularity.



0.2 Tolerance Zone
centered on datum A
Toleranced Feature
Each real circle
φCi
Straight line
datum A
Ci
A



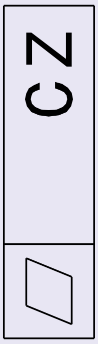
0.2 Tolerance Zone centered
on the straight line datum A-B
Toleranced Feature
Straight line datum A-B
A-B



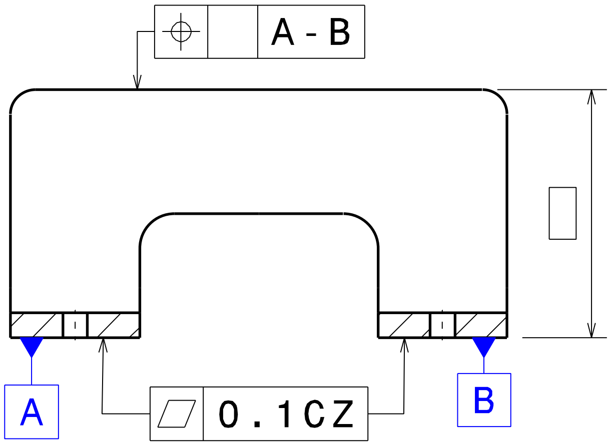
0.2 Tolerance Zone
perpendicular to datum A
Toleranced Feature
90°
Straight line datum A
A

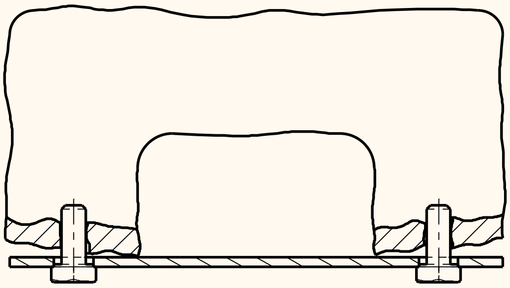
Forms in Combined Zones (Common Zone)

Flatness in Combined Zones

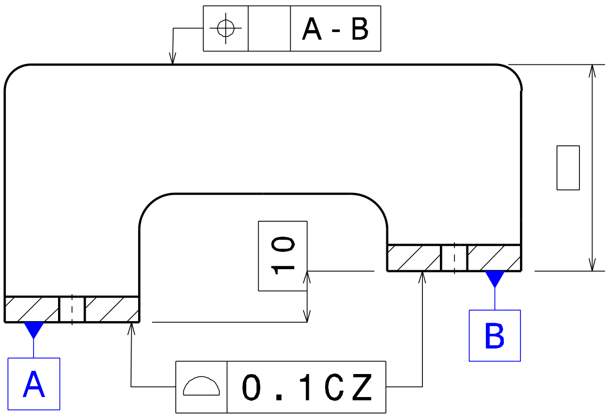


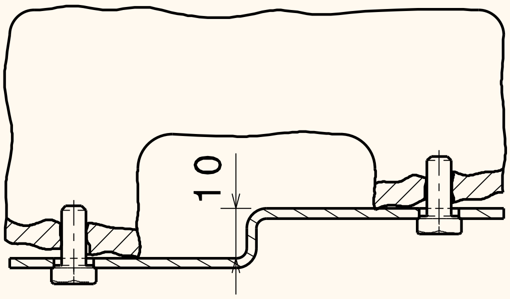
Combined Zone:
When several combined tolerance zones (specified using the same tolerance indicator) are applied to several separate features simultaneously (in an interdependent manner), the requirement must be indicated using the CZ (Combined Zone) symbol. These zones are in theoretically exact locations.





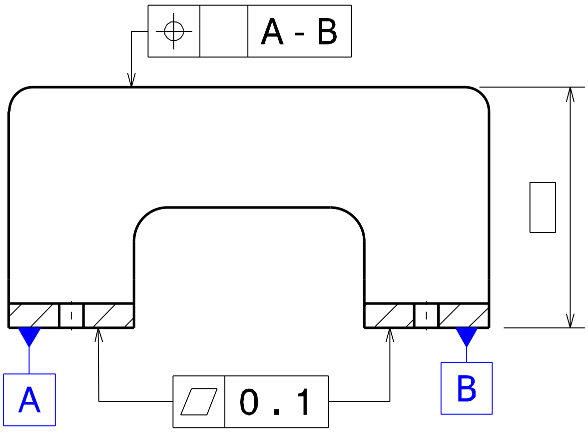
With the CZ modifier, the independency principle **no longer applies**.



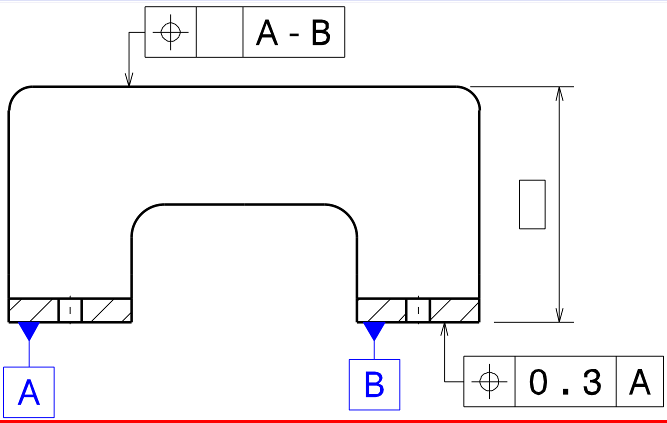


The CZ modifier also applies to offset planes.

Common errors



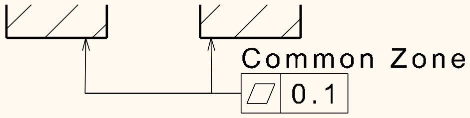
Without the CZ modifier, the independency principle **applies**



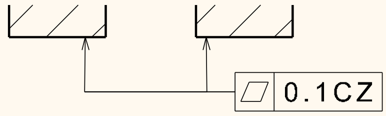
Do not dissociate a common datum.

Example: do not position B relative to A.

ISO 1101 - 1983

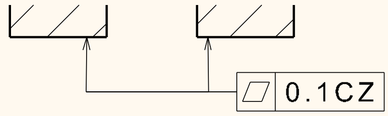


ISO 1101 - 2001

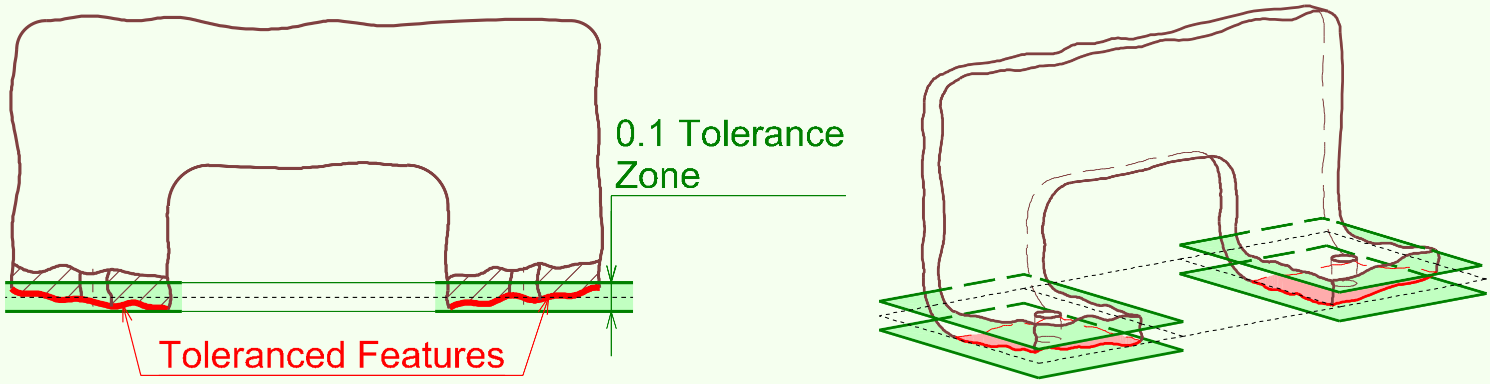


CZ: Common Zone

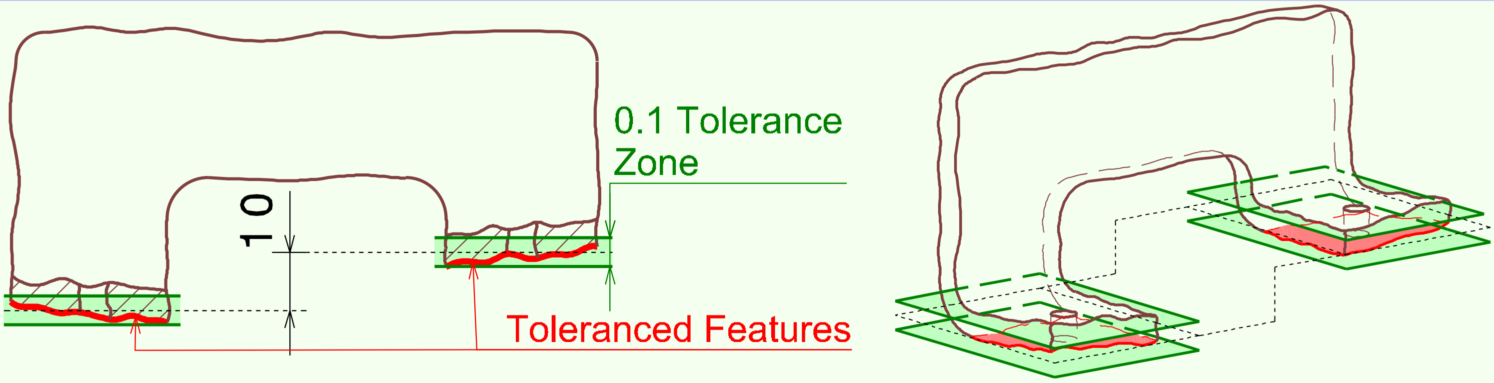
ISO 1101 - 2017



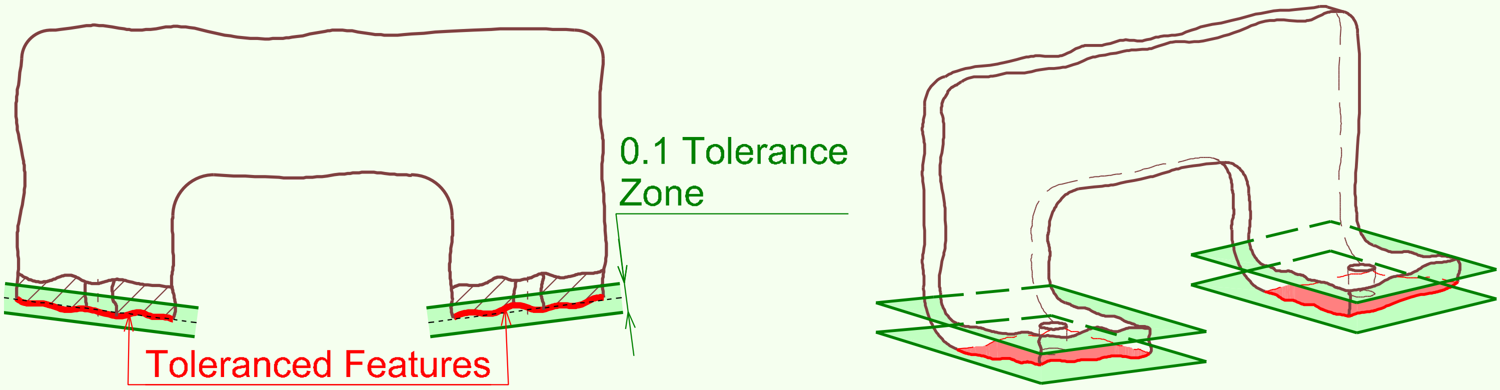
CZ: Combined Zone



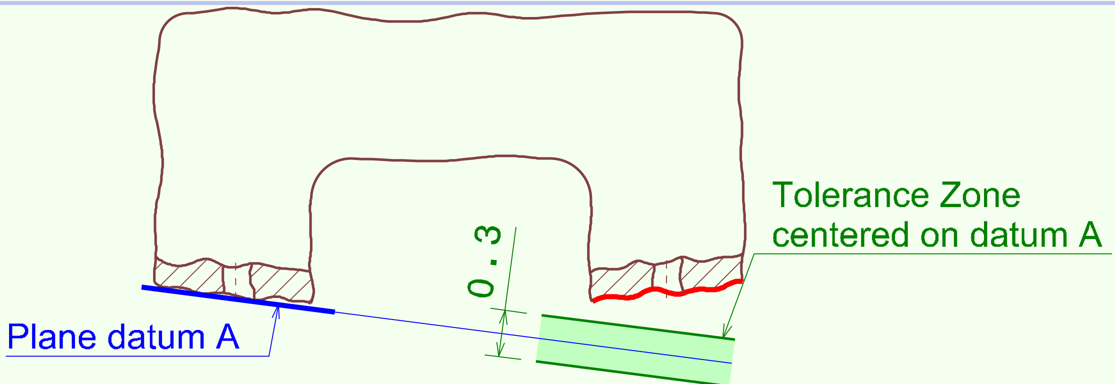
The tolerance zones are exactly aligned.



The tolerance zones are exactly parallel and offset by 10 mm.



The tolerance zones are independent to each other.

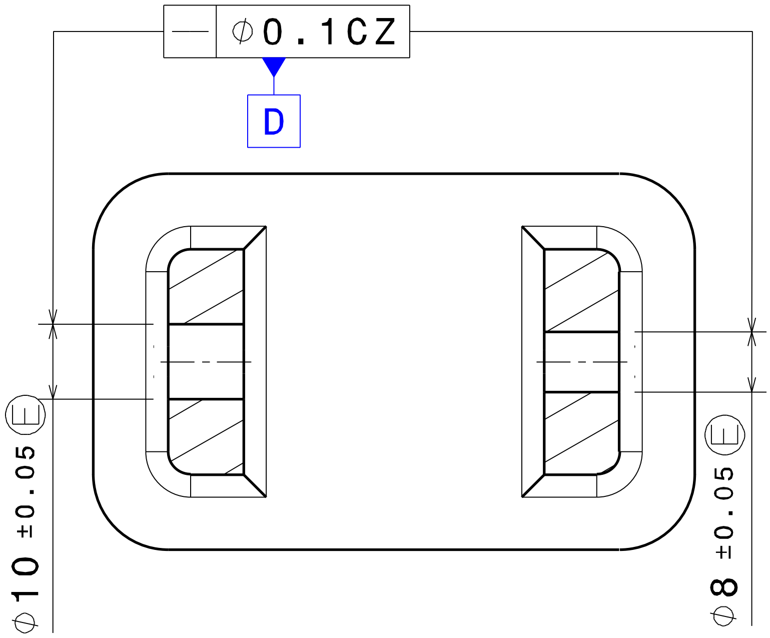


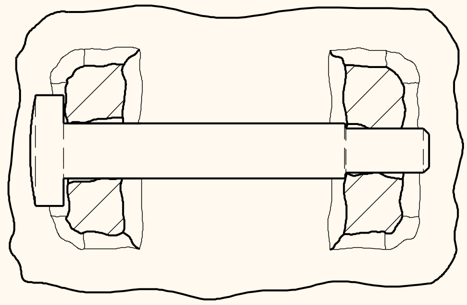
Inconsistent measurement relative to the operation of the part.

Forms in Combined Zones (Common Zone)

CZ

Straightness in Combined Zones

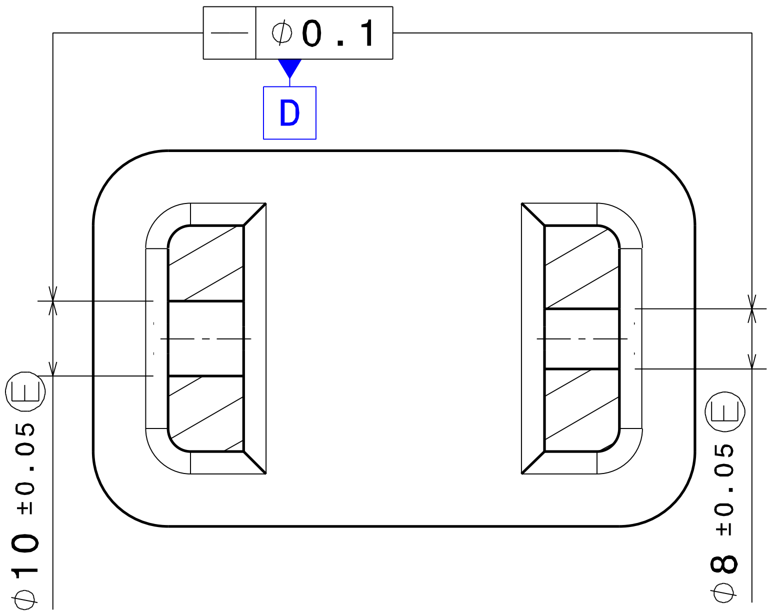




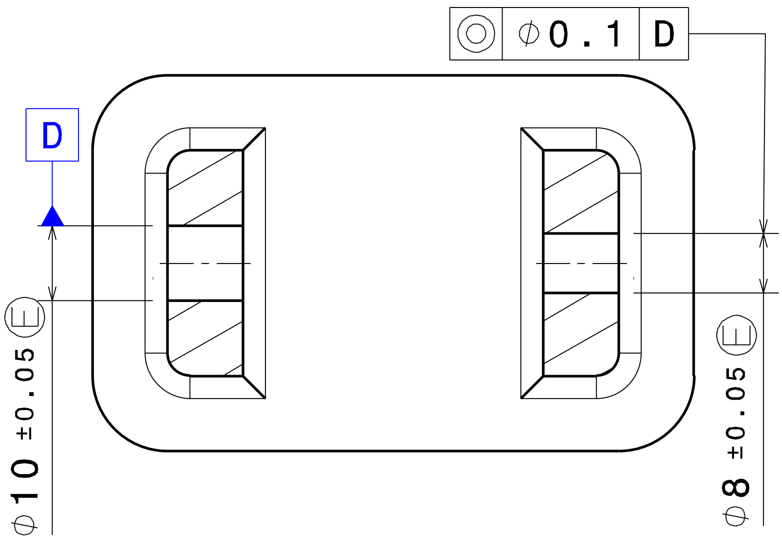
With the CZ modifier, the independency principle **no longer applies.**

Datum would be **D-D.**

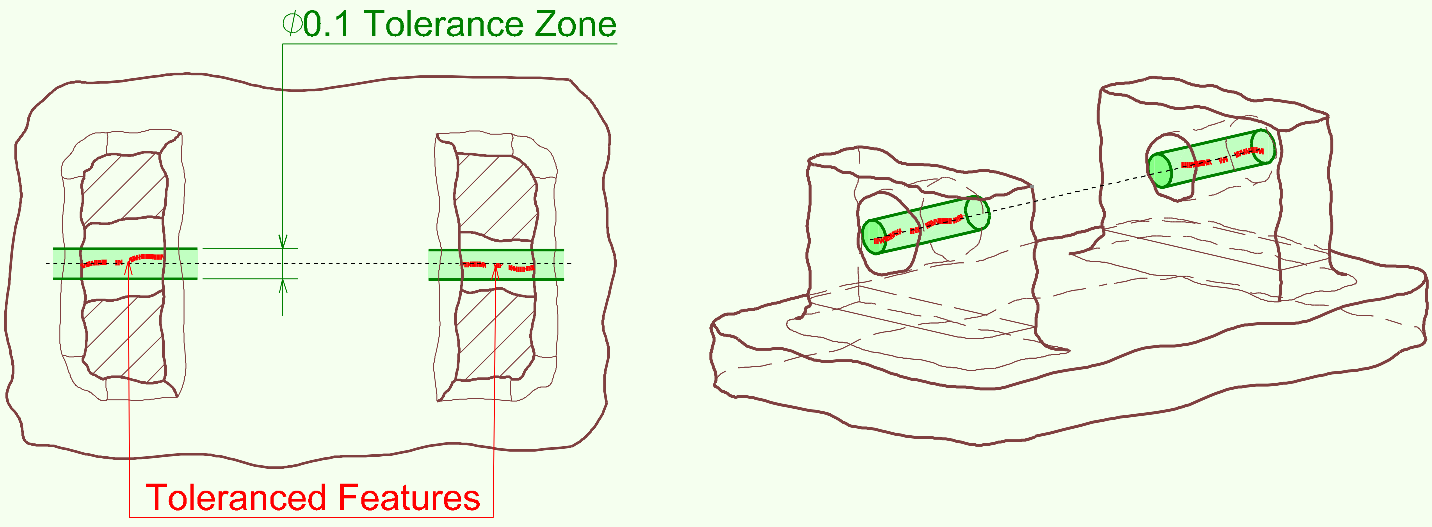
Common errors



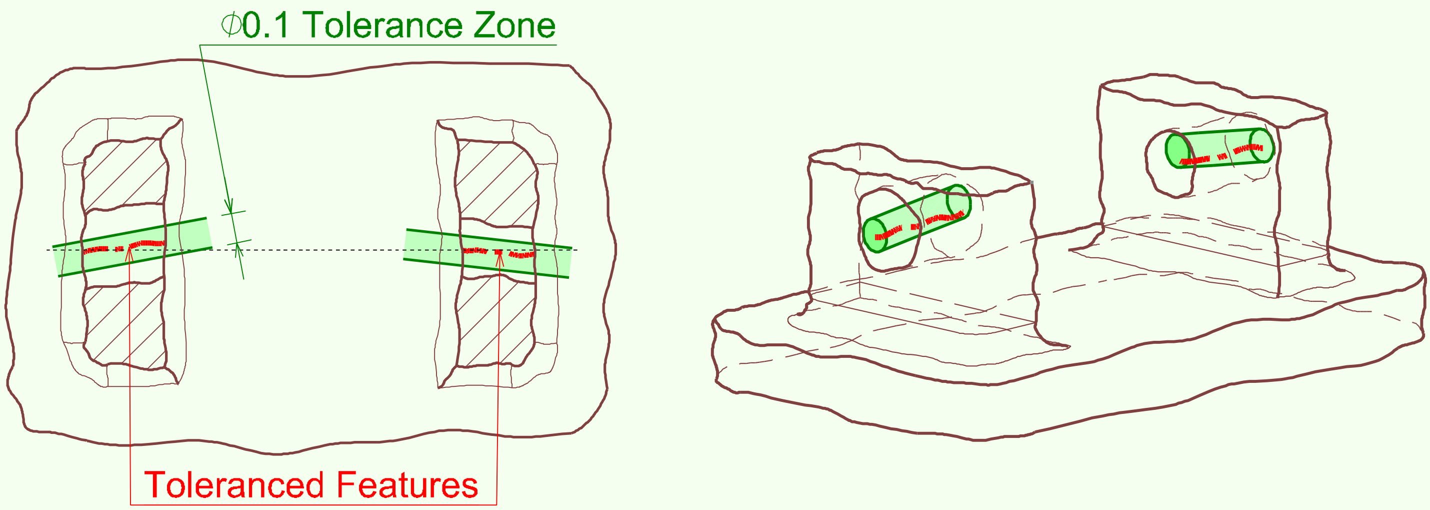
Without the CZ modifier, the independency principle **applies.**



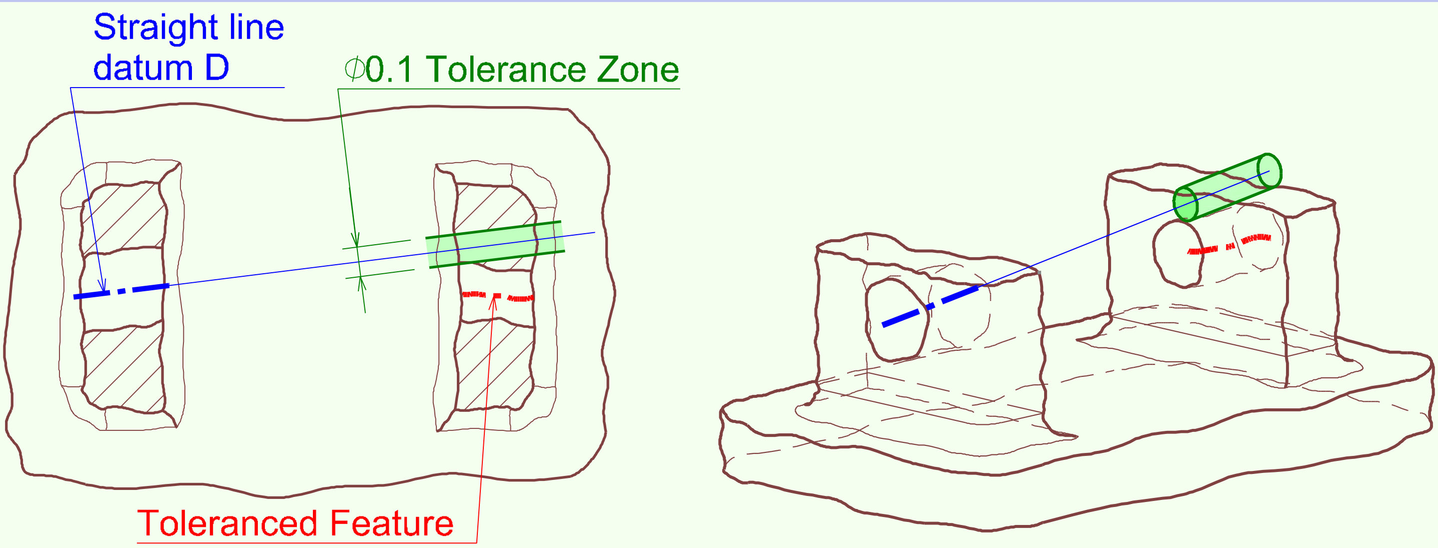
Do not dissociate a common datum.



The tolerance zones are exactly aligned.



The tolerance zones are independent to each other.



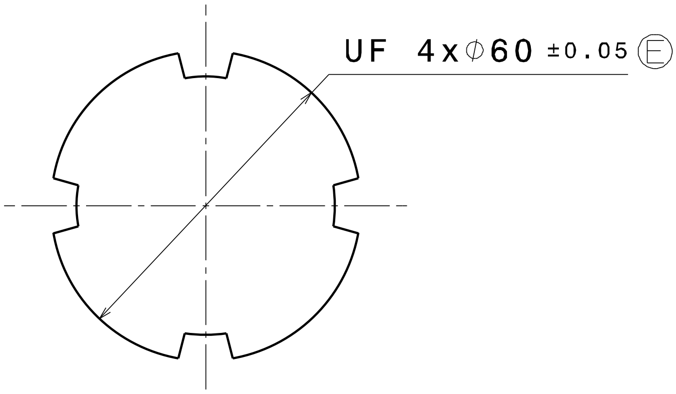
Inconsistent measurement relative to the operation of the part.

United Feature (UF)

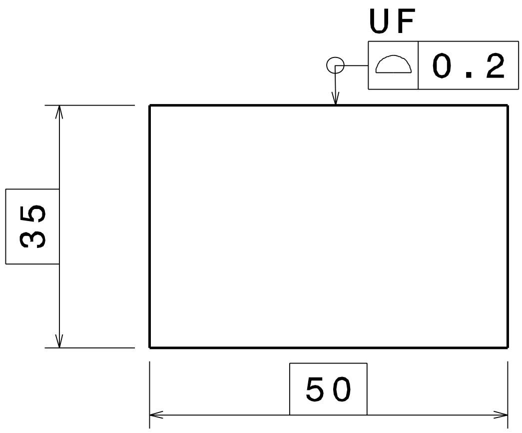
United Feature, All around, Between

UF

United feature:
The UF modifier combines the toleranced features as a single feature.
This is a compound feature, which may or may not be continuous.

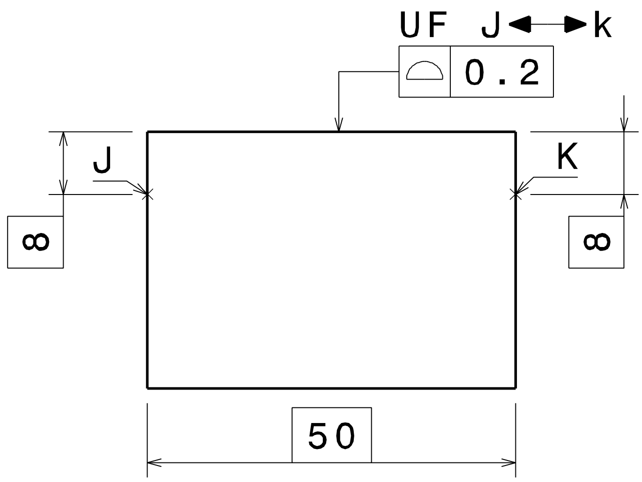


The size for a feature of size must be preceded by UF nx.



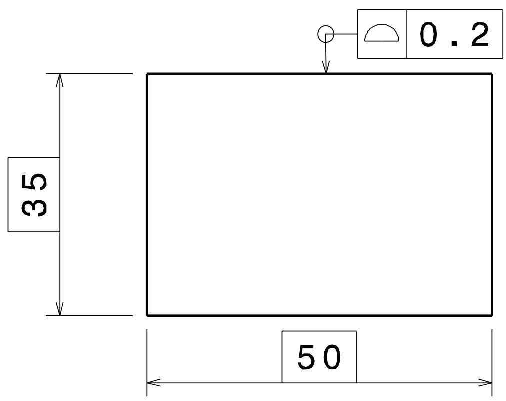
The "**all around**" symbol indicates that the specification applies to each feature of the outline.

The **UF** modifier unites the closed outline.



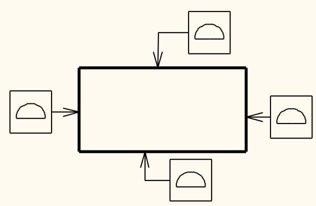
The "**between**" symbol ◄► must be used between two upper case letters defining the start and end of the toleranced feature.

The obtained feature consists of all segments or zones between the start and the end of identified features, or parts of features.



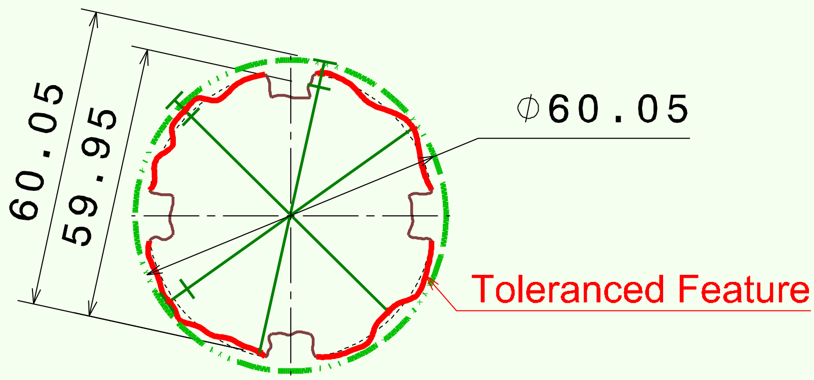
Without the UF modifier, the independency principle applies.

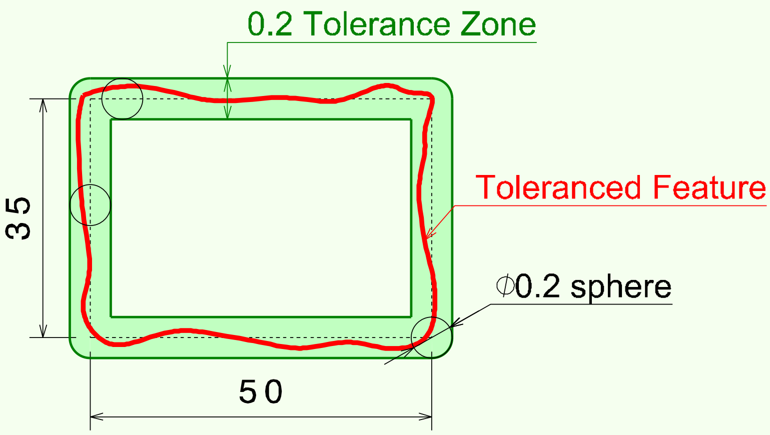
This entry is equivalent to:

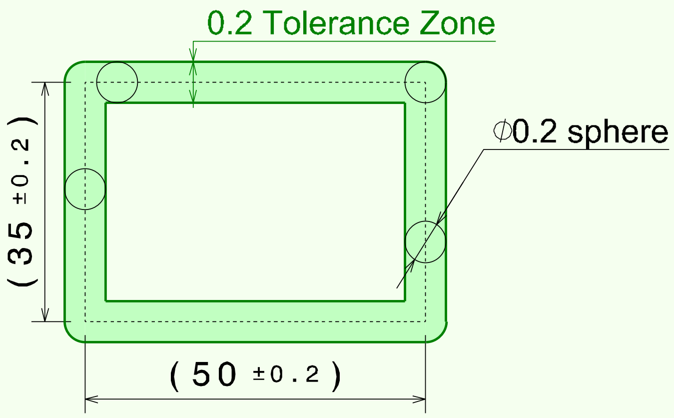


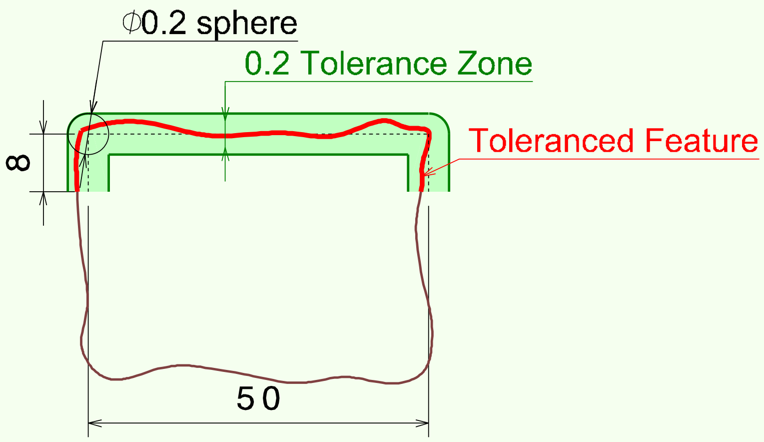
- A united feature can have a derived feature, e.g., an axis.
- The tolerance zone will be determined by rolling a sphere over the nominal feature.

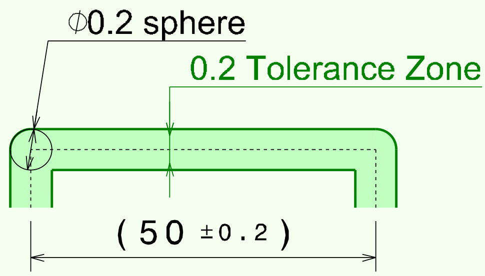
This approach is not valid for defining features consisting of several separate features. For example, two non-coaxial or coaxial parallel cylinders with different diameters.

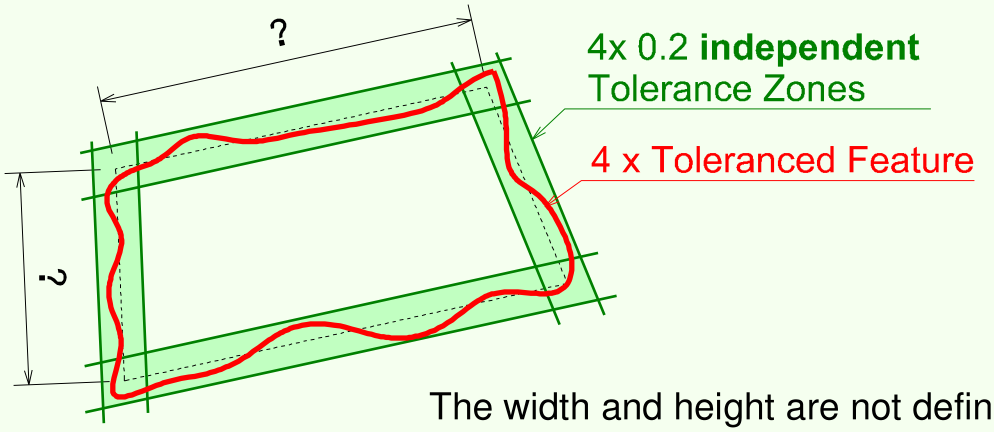












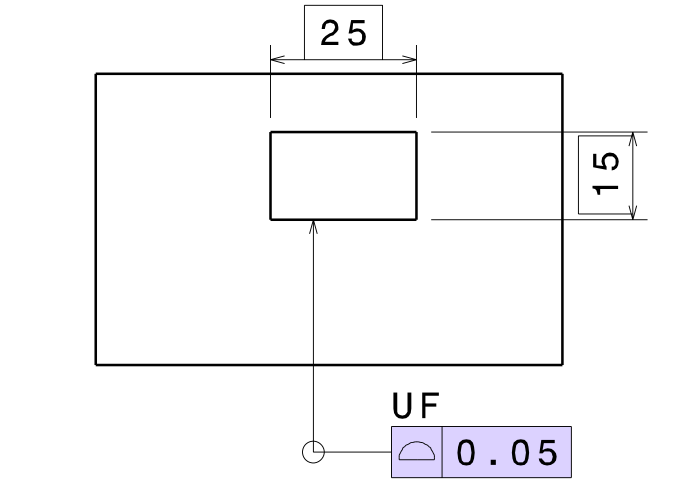
Profile tolerancing

UF

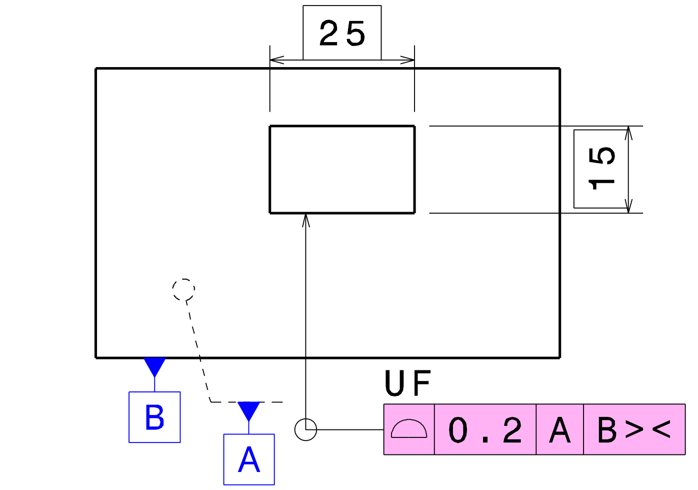
> <

United feature, All around, Orientation only

Application to the example of a hole in a window.



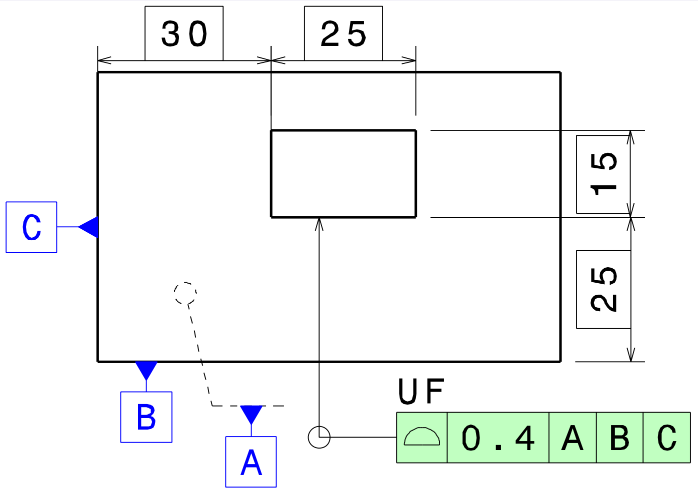
With this type of tolerancing, the profile **form** imperfection is limited to allow the window to be assembled with minor gaps.



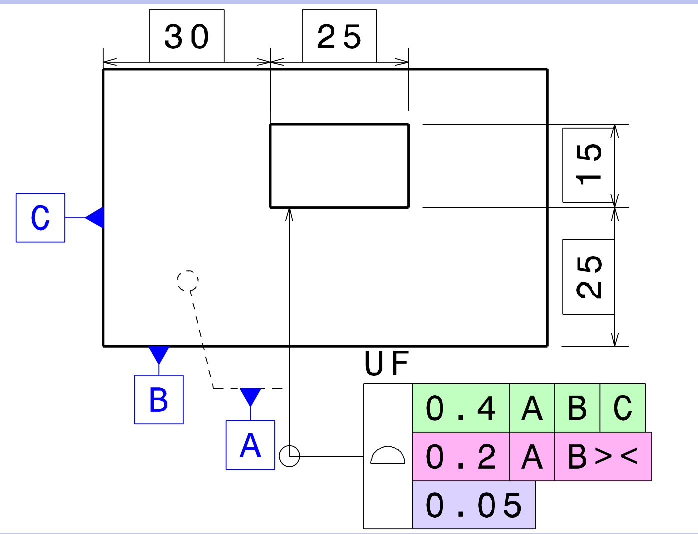
With this type of tolerancing, the hole of the window can be **oriented** relative to datum B.

The modifier **><** means:
Orientation constraint only.

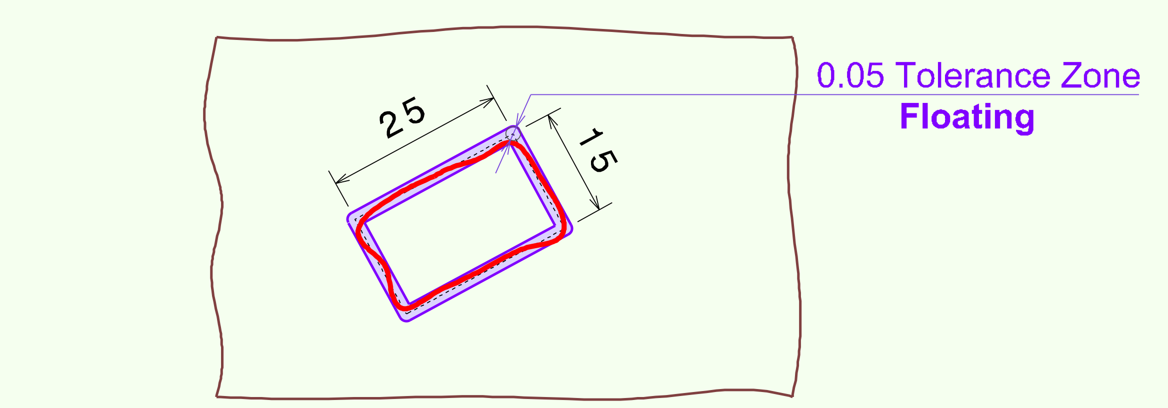
Datum B is used only for orientation.

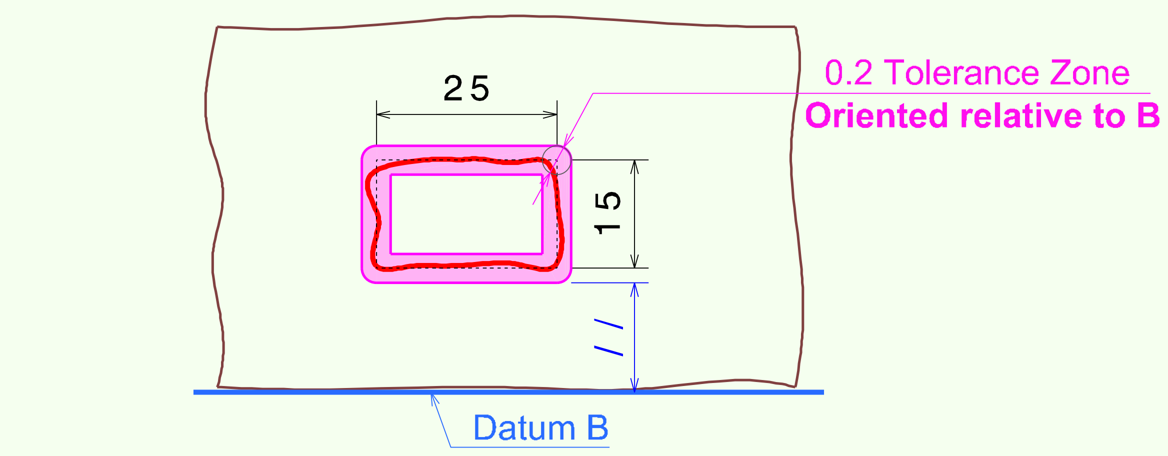


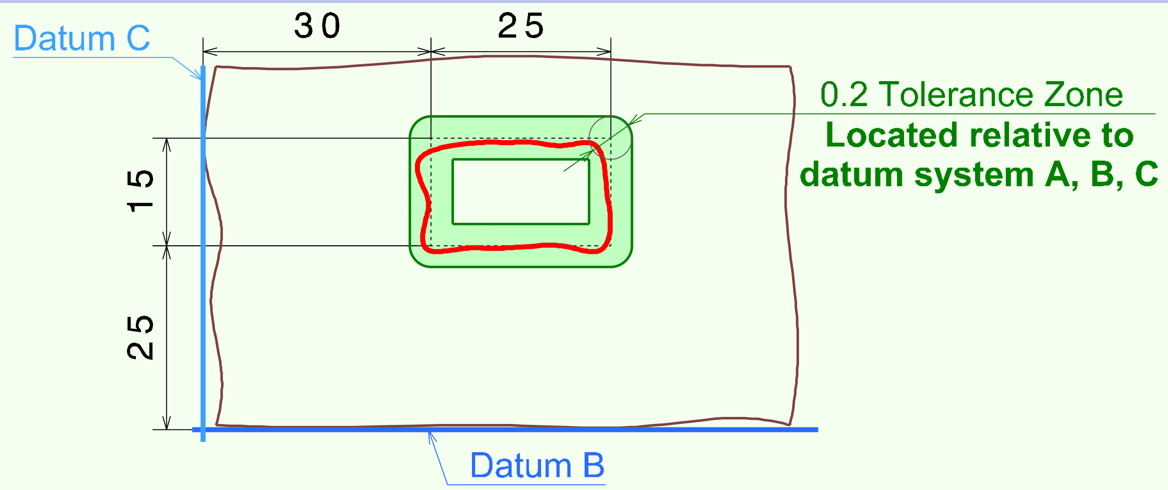
With this type of tolerancing, the hole of the window can be correctly **positioned** relative to the datum system A, B and C.

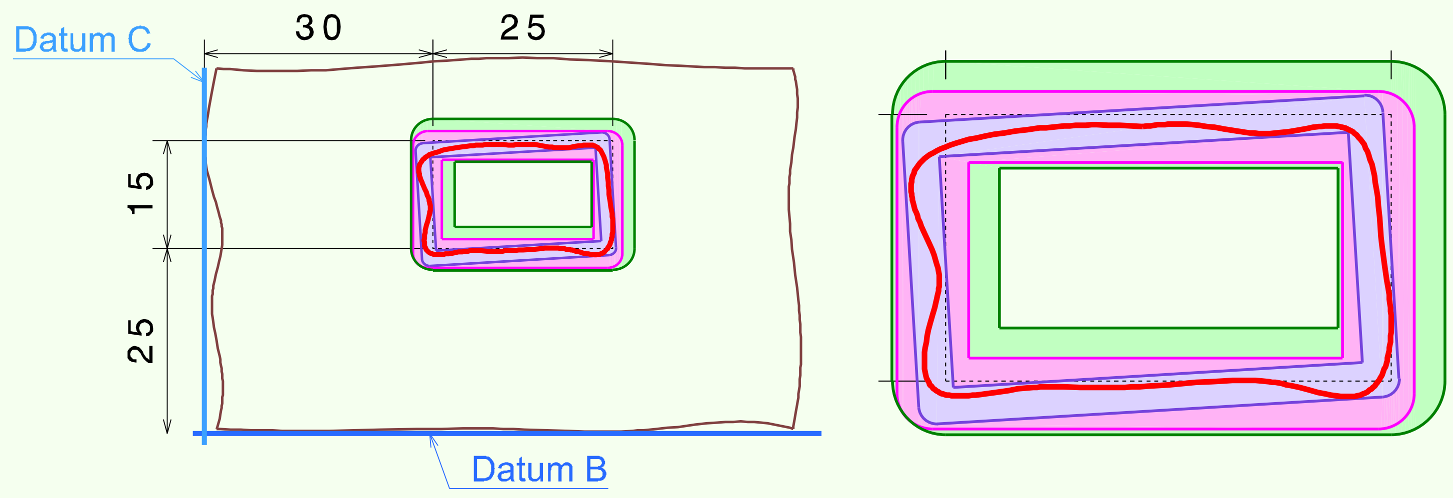


This maintains the **inclusion** logic for geometrical tolerances:
the **location** tolerance includes
the **orientation** tolerance which includes
the **form** tolerance.


2 5
1 5
0.05 Tolerance Zone
Floating


2 5
1 5
0.2 Tolerance Zone
Oriented relative to B
/ /
Datum B

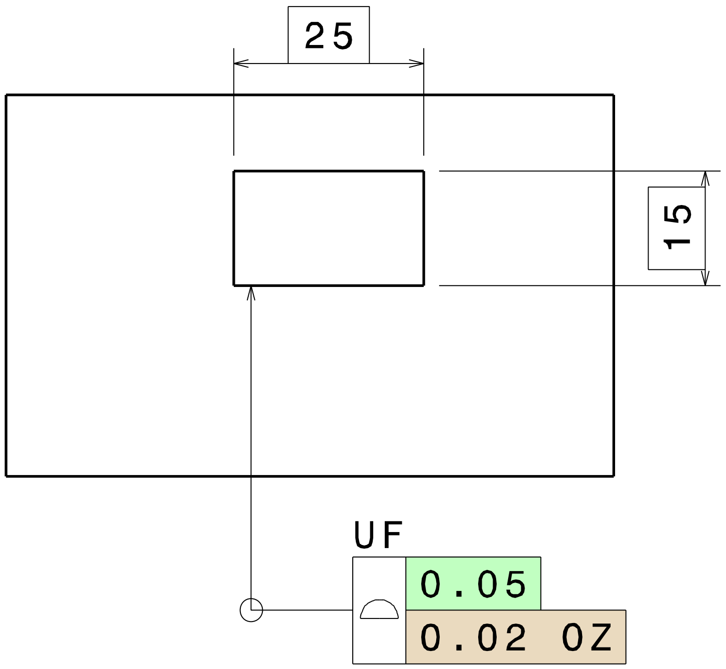

Datum C
3 0
2 5
1 5
2 5
0.2 Tolerance Zone
Located relative to
datum system A, B, C
Datum B


Datum C
3 0
2 5
1 5
2 5
Datum B

Tolerance zone offset

OZ

Unspecified linear tolerance zone offset



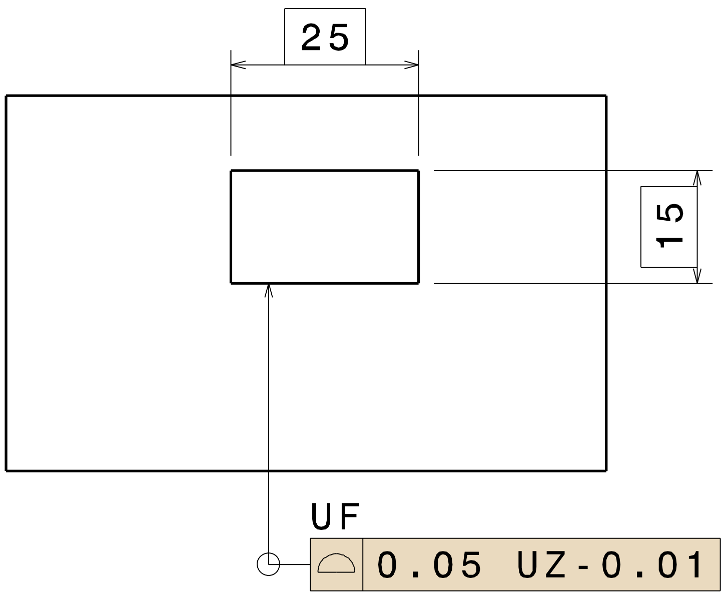
For profiles covering over 180°, in order to limit **the form imperfection without fixing the size**, the **OZ "Offset Zone"** modifier must be specified: unspecified linear tolerance zone offset.

This approach offsets the nominal profile by any constant.

Without the OZ modifier, the size is fixed for all forms covering more than 180°.

UZ

Specified tolerance zone offset

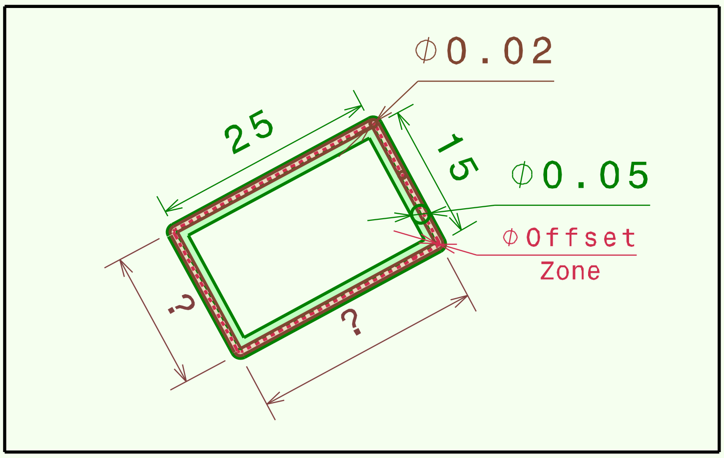


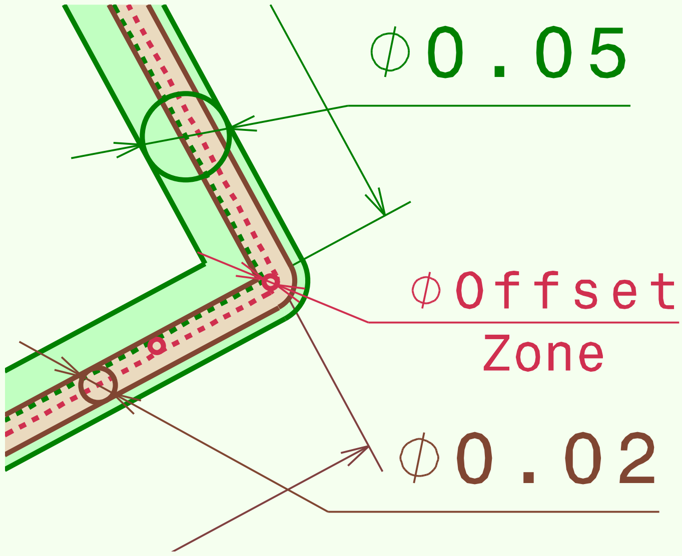
To offset the nominal profile of a **fixed value**, specify the **UZ** modifier: specified tolerance zone offset.

This modifier can be used to offset the nominal profile of a constant. If the constant is:

- Negative: the offset is inside the material.
- Positive: the offset is outside the material.

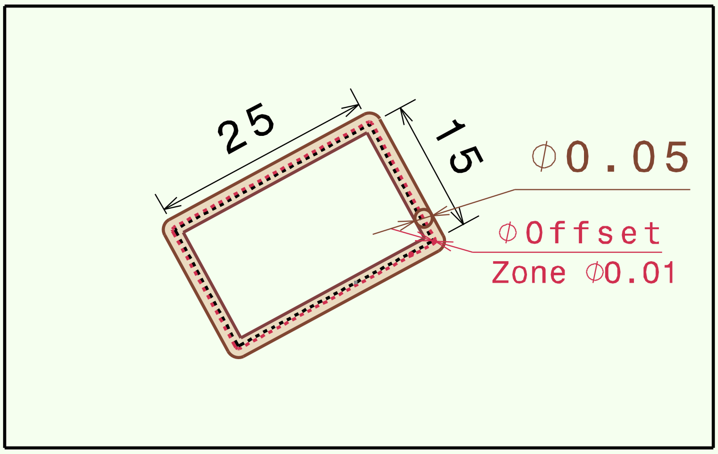
The numerical 3D model will not be centered on the tolerance zone.

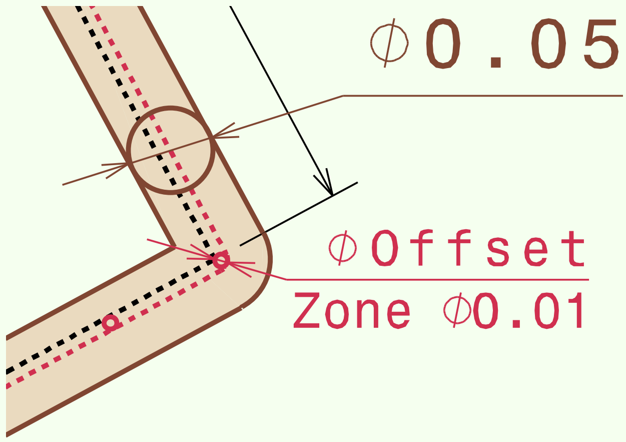




The 0.02 mm tolerance zone is prepared using a nominal profile offset by any constant.

Usage: OZ can be used to limit the form imperfection without fixing the size for features > 180°.

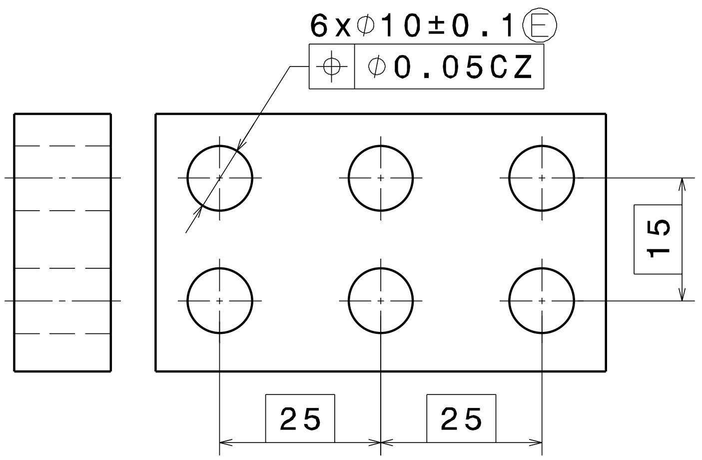
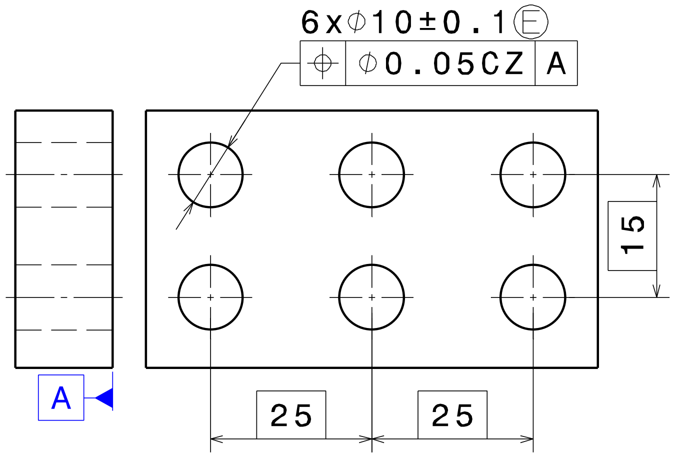
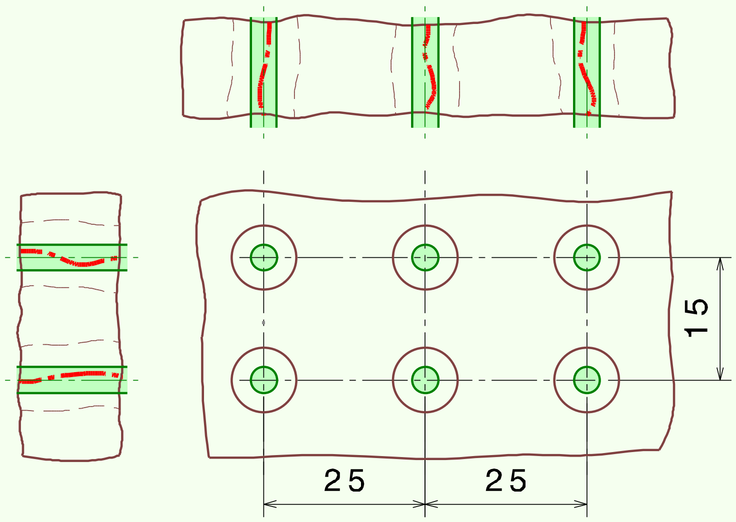
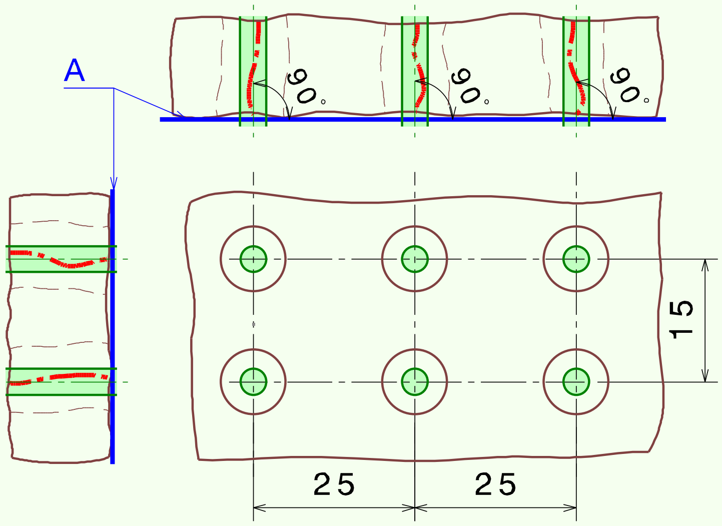
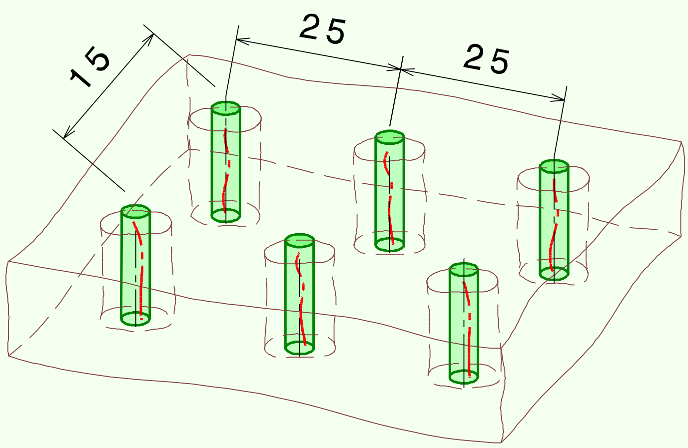
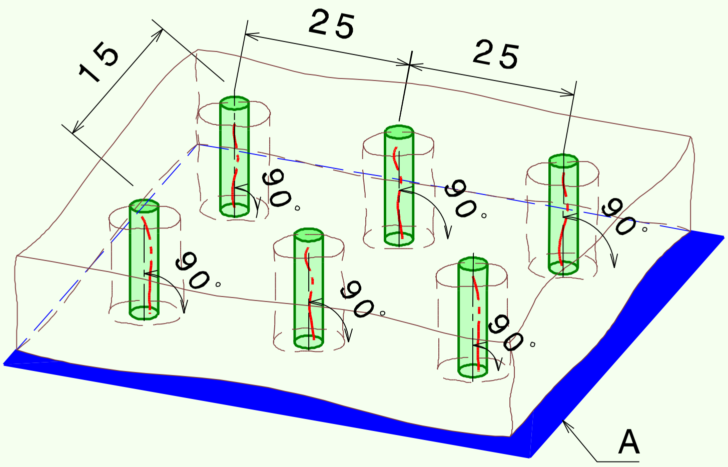




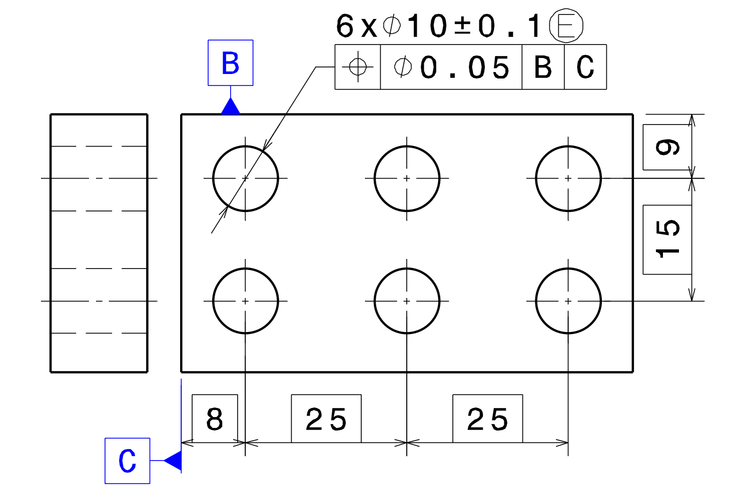
The 0.05 mm tolerance zone is prepared using a nominal profile offset by a constant of 0.01 mm inside the material.

Usage: UZ can be used to integrate coatings, extra thicknesses, etc.

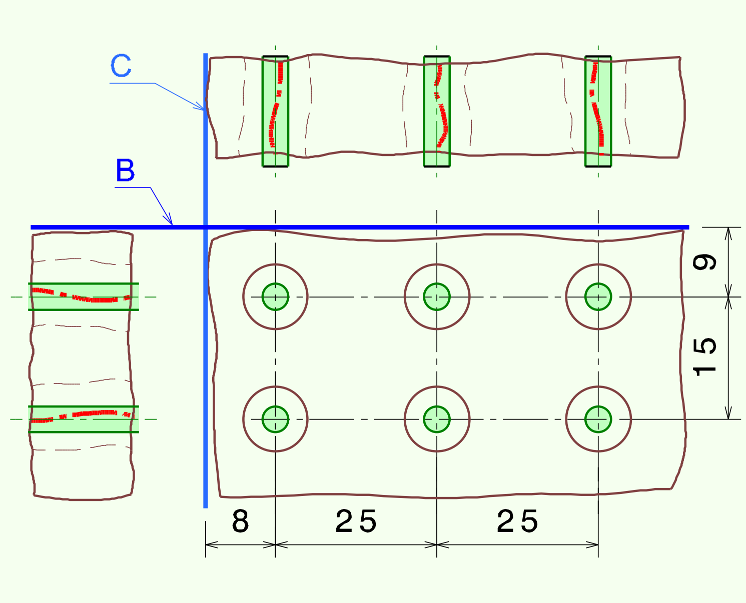
Pattern position

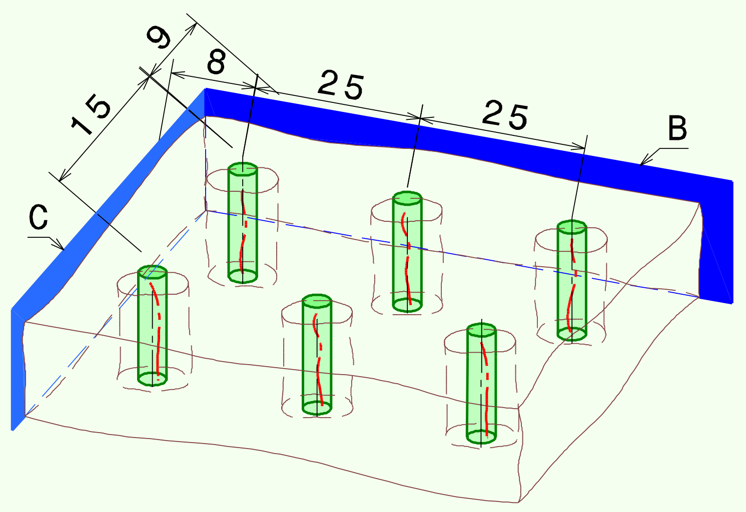
Position of the holes between them	Position of the holes between them relative to a plane datum
	
Floating pattern consisting of 6 tolerance zones exactly separated by 15 and 25 mm with no external requirements.	**Floating** pattern consisting of 6 tolerance zones exactly separated by 15 and 25 mm and **perpendicular** to plane A.
	
	

Position of the holes between them relative to a dihedral datum

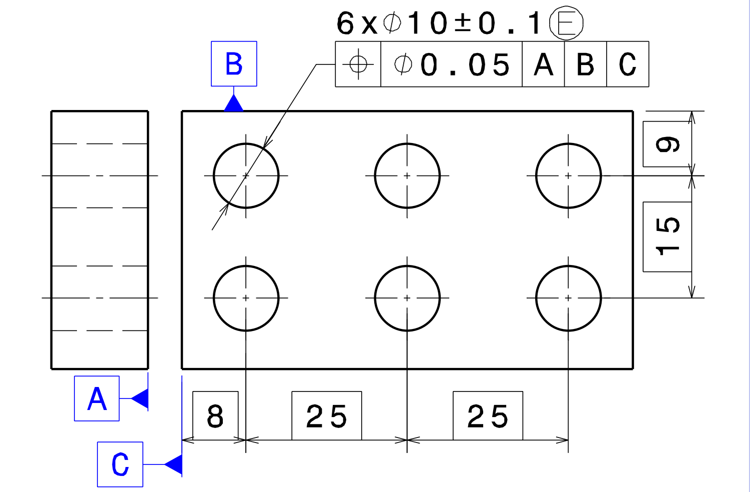


Fixed pattern consisting of 6 tolerance zones exactly separated by 15 and 25 mm. The pattern is **located** 9 mm from B and 8 mm from C.

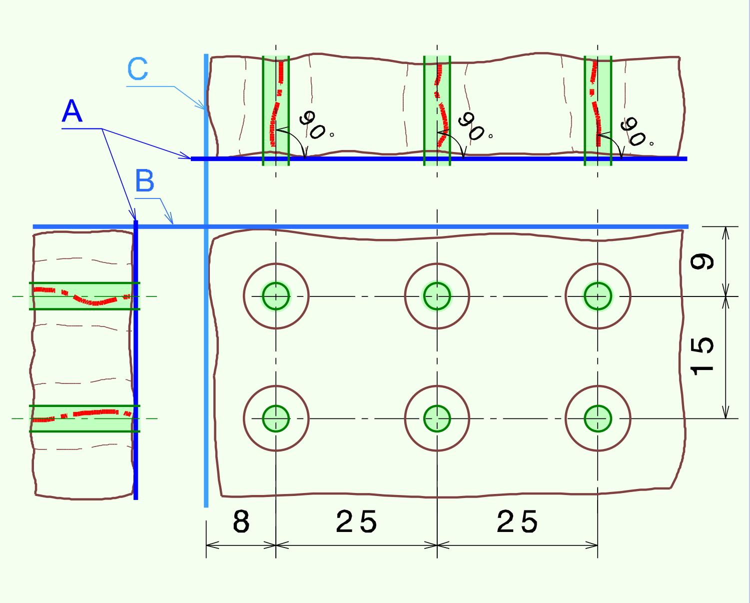


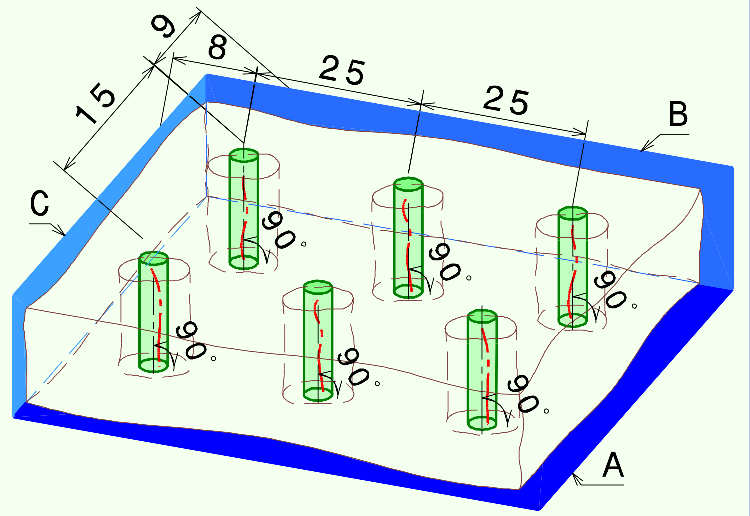


Position of the holes between them relative to a trihedral datum



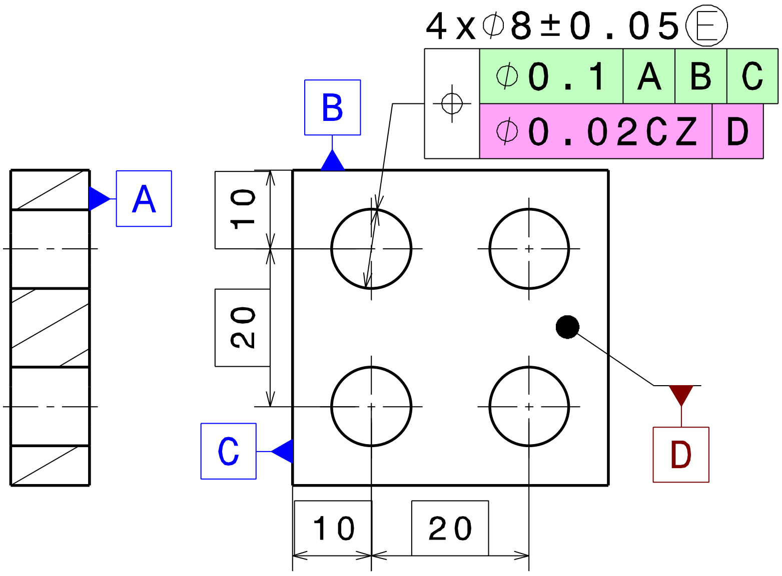
Fixed pattern consisting of 6 tolerance zones exactly separated by 15 and 25 mm and **perpendicular** to A.
The set is **located** 9 mm from B and 8 mm from C

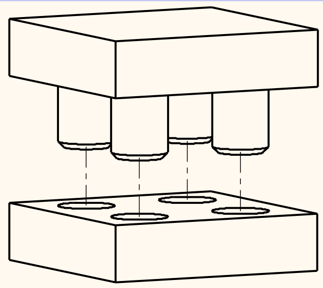




Dual pattern position

Assembling and positioning



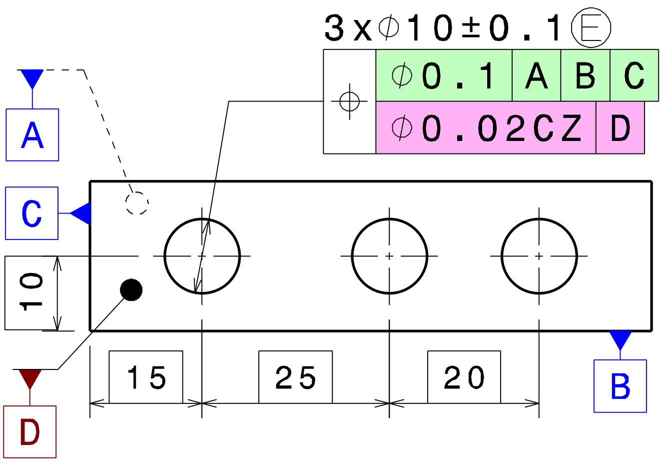


Initial positioning relative to | A | B | C | allows the interface for the upper part to be **positioned**. This process is applied to each hole individually relative to the edges of the part (the pattern is **fixed**).

The second positioning phase relative to D allows to **assemble**. This process only limits the locations of the holes between them normally to D (the pattern is **floating**).

The **common error** is to specify only one single position for positioning and assembling.

Non-cumulative tolerances

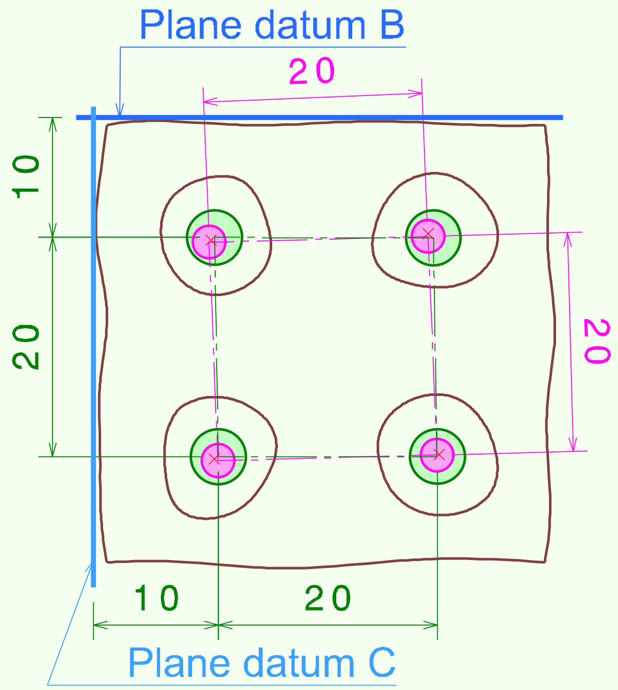


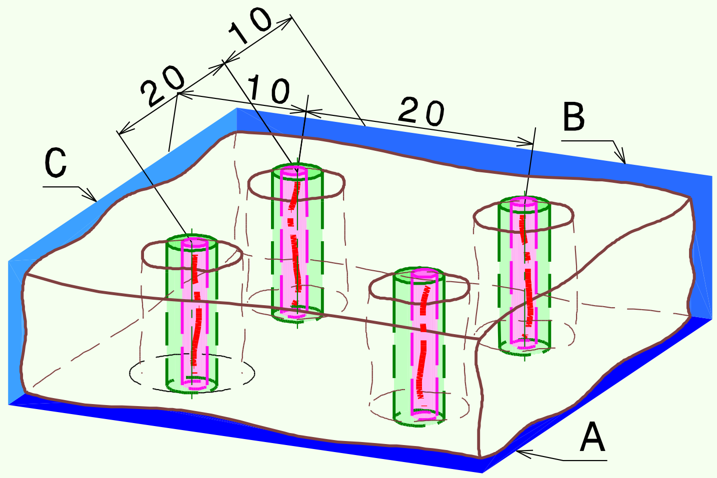
For the **position of Ø0.1** relative to | A | B | C |, the tolerance between:

- Each pair of holes is ± 0.1 (± Position tolerance).
- Each hole is located ± 0.05 from the edges of the part $(\pm \frac{\text{Tolerance}}{2}$ of the position).

For the **position of Ø0.02 CZ** relative to D, the tolerance between:

- Each pair of holes is ±0.02 (± CZ position tolerance).

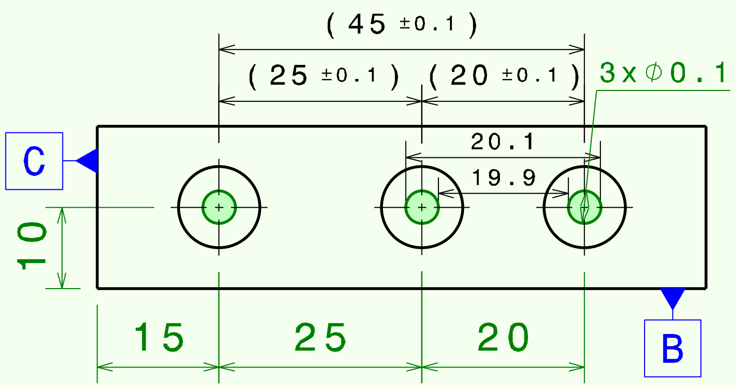


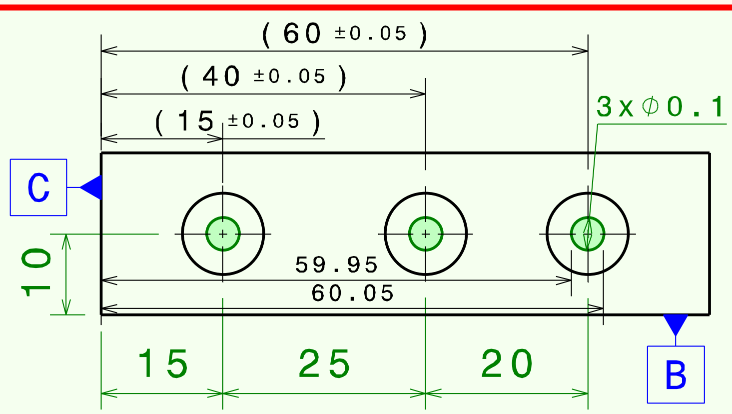


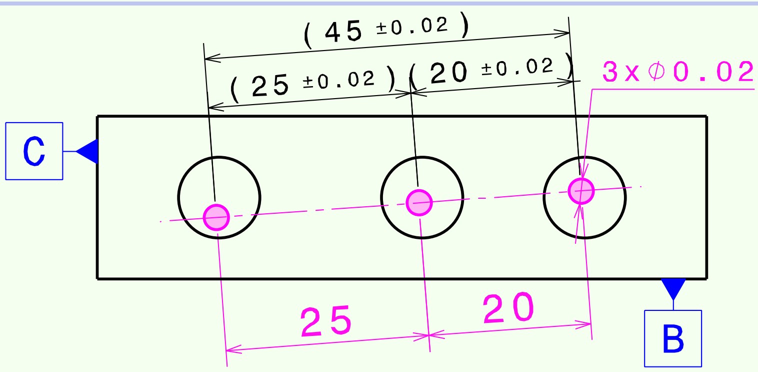
4xΦ8±0.05Ⓔ

⌖	Φ0.02	A	B	C

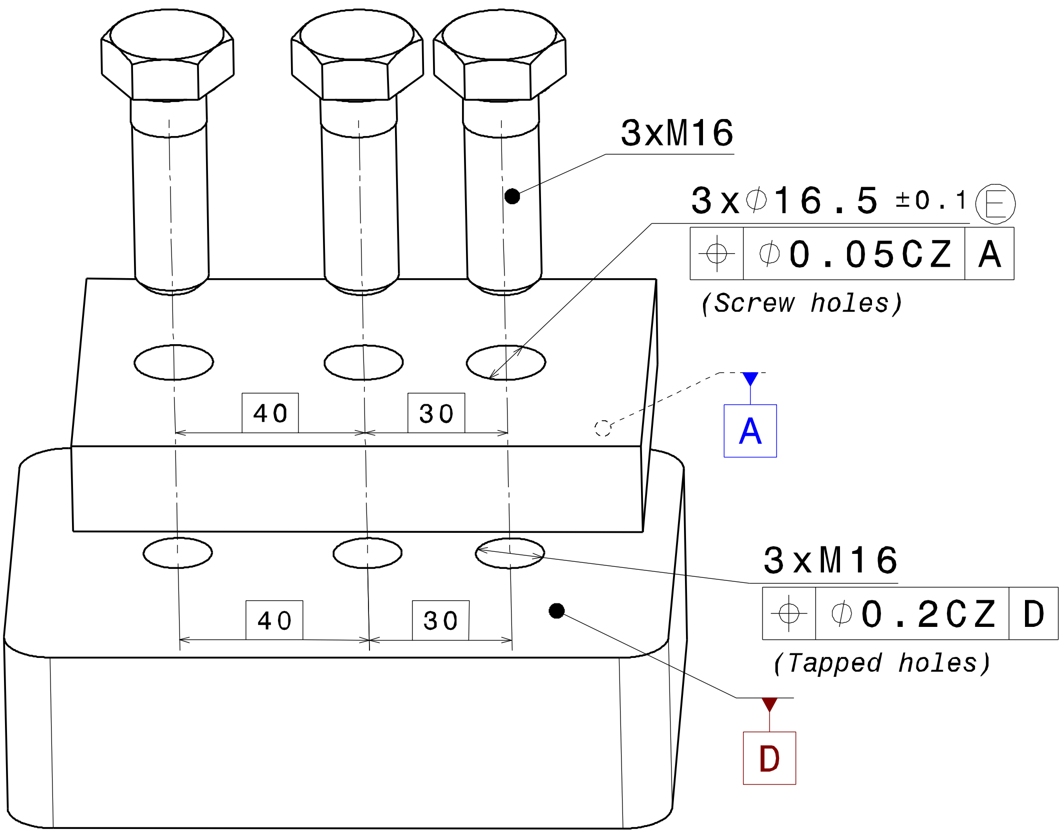
Specifying an assembly tolerance for positioning an interface can be complex to achieve during production.







tolerances are not cumulative.



Formula for validating screw-on assemblies:

$$G_{min}\,(Ø_{Holes} - Ø_{Screws}) > \text{Tol Pos}_{\text{ screws holes}} + \text{Tol Pos}_{\text{ tapped holes}}$$

Min. diametral gap between holes and screws must be greater than total positions

Application: $16.4 - 16 > 0.05 + 0.2$

➔ $0.4 > 0.25$

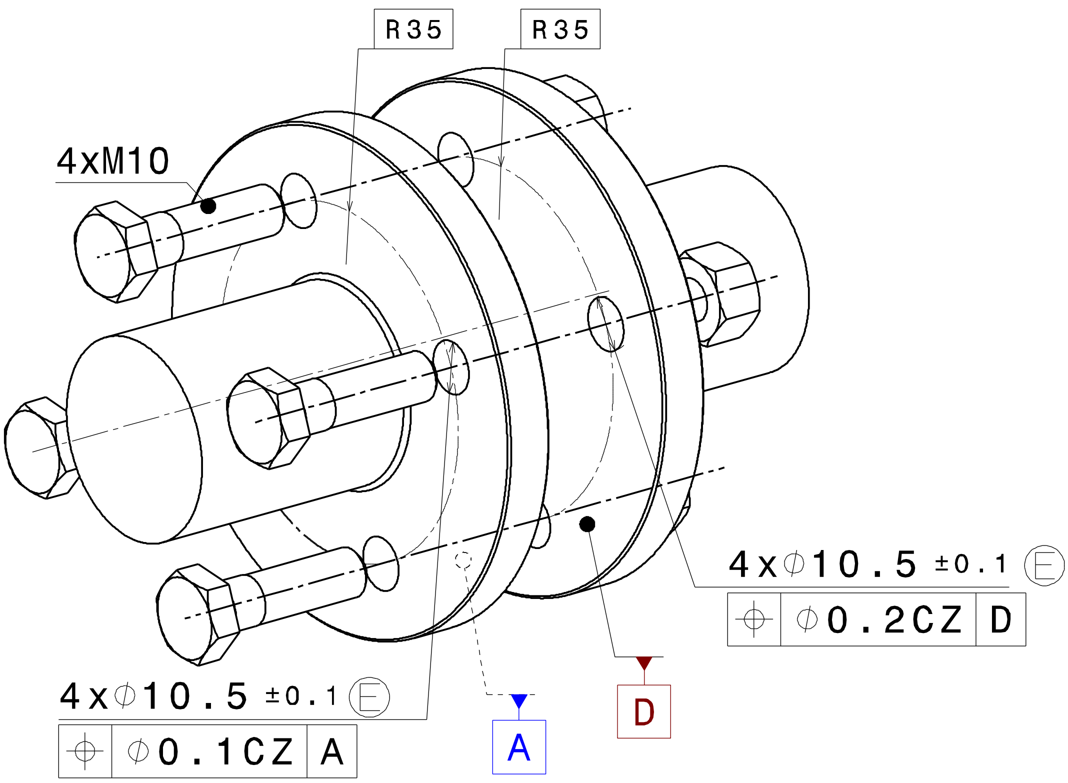
➔ A diametral Gap of 0.15 remains for screw holes.

Note 1: The max. screw diameter does not generally exceed its designation (E.g.: M6, Ømax = 6).

Note 2: The position of a tapped hole is determined based on pitch diameter, which can be simulated by a threaded insert.

Note 3: For screw-in assemblies:
- the head contact surface must be maximized (friction, mating),
- a screw acts as a tensile spring, therefore the length between the head contact and the start of the thread must also be maximized.

Note 4: In the rare cases where the tapping can be centered and with a high thickness of the upper plate:
- it is necessary to restrict the perpendicularity imperfections of the tapped holes,
- integrate projected perpendicularities into the calculation.



Formula for validating bolted or riveted assemblies:

$$G_{min}\,(\varnothing_{Holes}-\varnothing_{Bolts}) > \frac{1}{2}\left(\text{Tol Pos}_{\text{ bolt holes 1}} + \text{Tol Pos}_{\text{ bolt holes 2}}\right)$$

Min. diametral Gap between holes and bolts must be greater than half of total positions

Application: $10.4 - 10 > \frac{1}{2}(0.1 + 0.2)$

➔ $0.4 > 0.15$

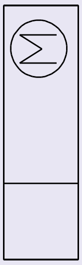
➔ A diametral gap of 0.25 remains for screw holes.

Note: If hole diameters differ:

$$\frac{1}{2}\left(\varnothing_{\text{Min hole1}}+\varnothing_{\text{Min hole 2}}\right)-\varnothing_{\text{Max bolt}} > \frac{1}{2}\left(\text{Tol Pos}_{\text{ bolt holes 1}} + \text{Tol Pos}_{\text{ bolt holes 2}}\right)$$

Maximum material for the toleranced feature

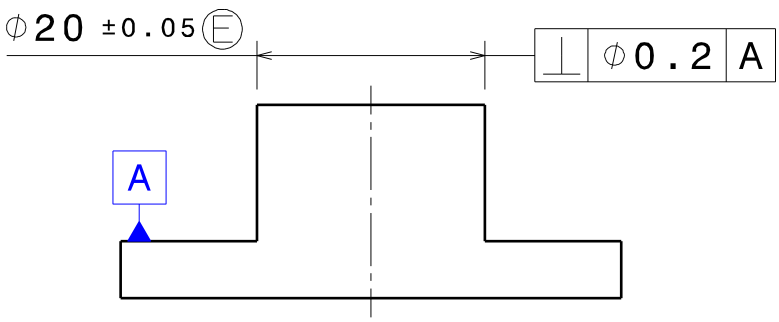
Maximum material

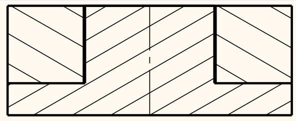


Maximum material virtual condition:

This condition identifies the overall dimensions based on the combination of a maximum material type size dimension and a geometrical tolerance for form, orientation or location.

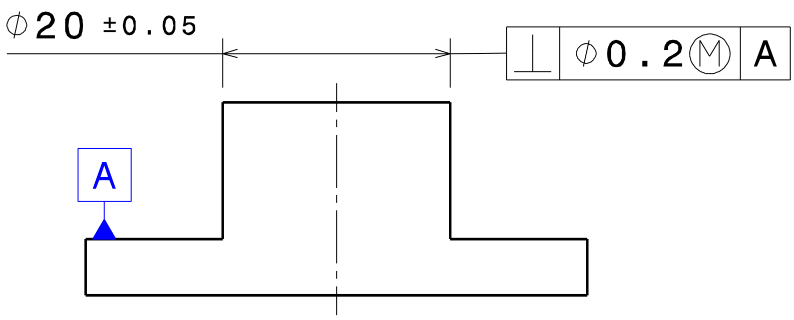
Conformity conditions: The dimension must be conform and the toleranced feature must not exceed the **virtual condition**.





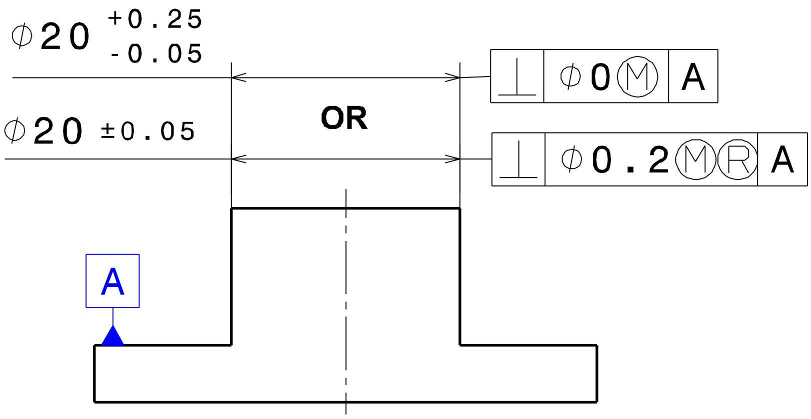
Without maximum material

If the dimension is maximum, then the boundary dimension is a cylinder with Ø20.25.
If the dimension is minimum, then the boundary dimension is a cylinder with Ø20.15.



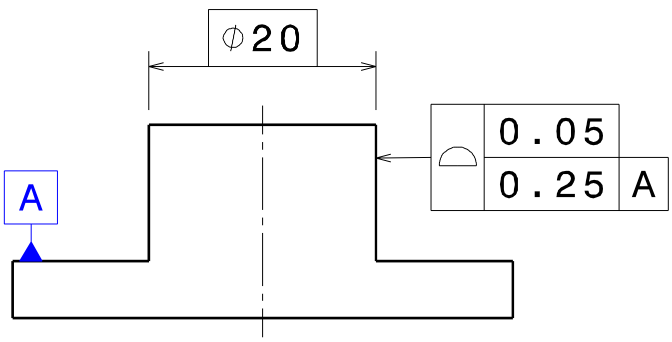
With maximum material

The real cylinder of Ø20 ±0.05, must not exceed the maximum material **virtual condition** (Ø20.25), regardless of the perpendicularity imperfection.



The perpendicularity imperfection is zero if the part dimension is at maximum material (Ø20.25).

Note: The max. material and reciprocity ⓂⓇ are equivalent to 0Ⓜ.



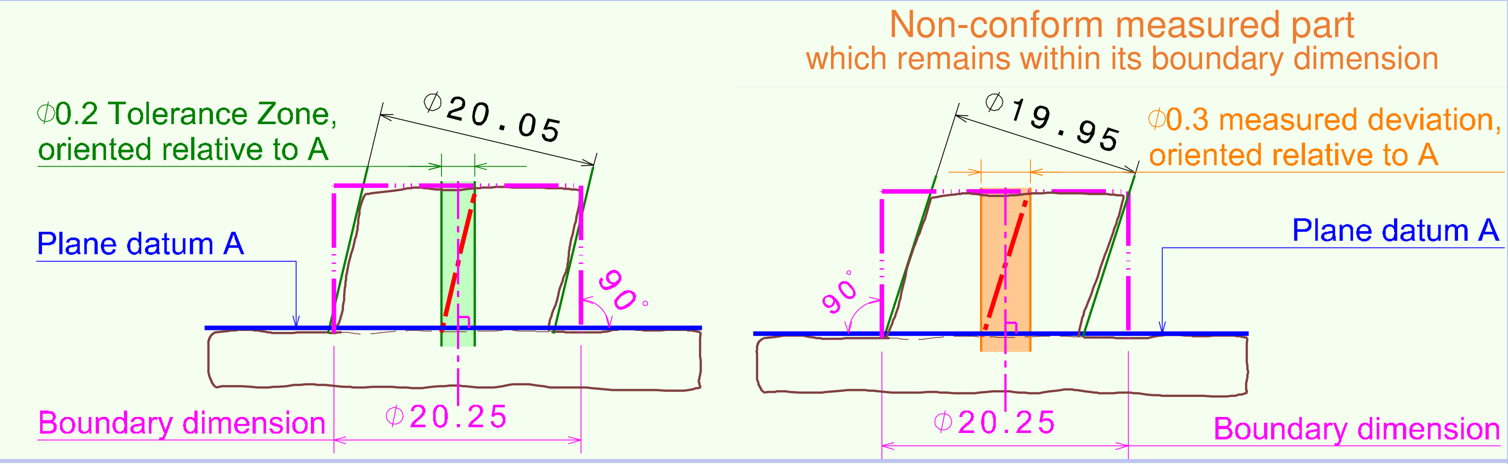
Comment:
Profile tolerancing

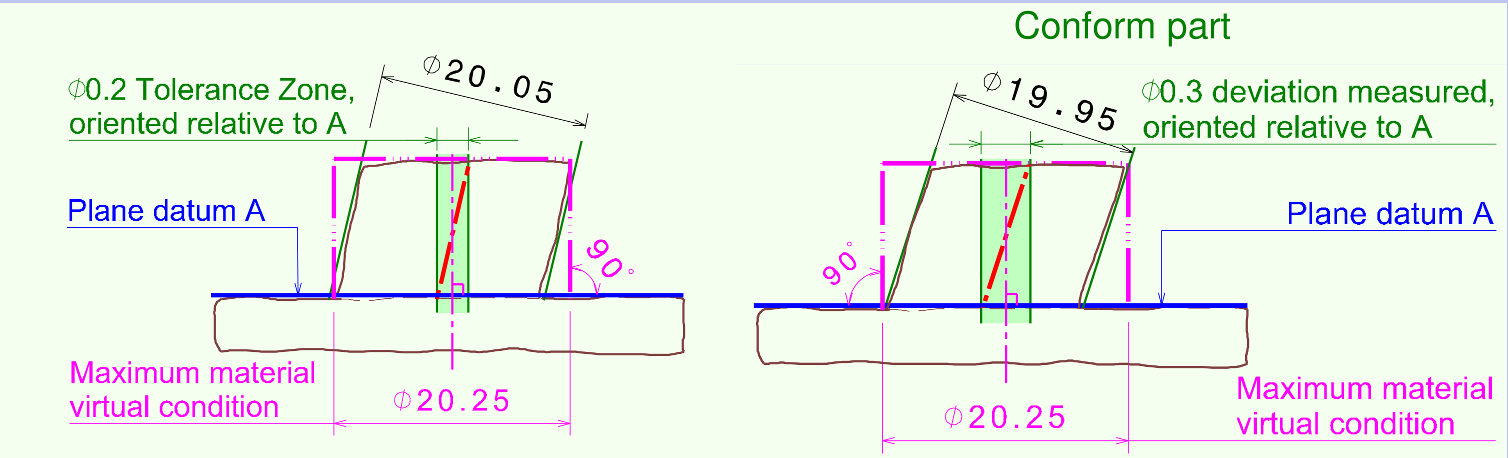
The maximum Ⓜ and least Ⓛ material **virtual condition** is equivalent to profile tolerancing.

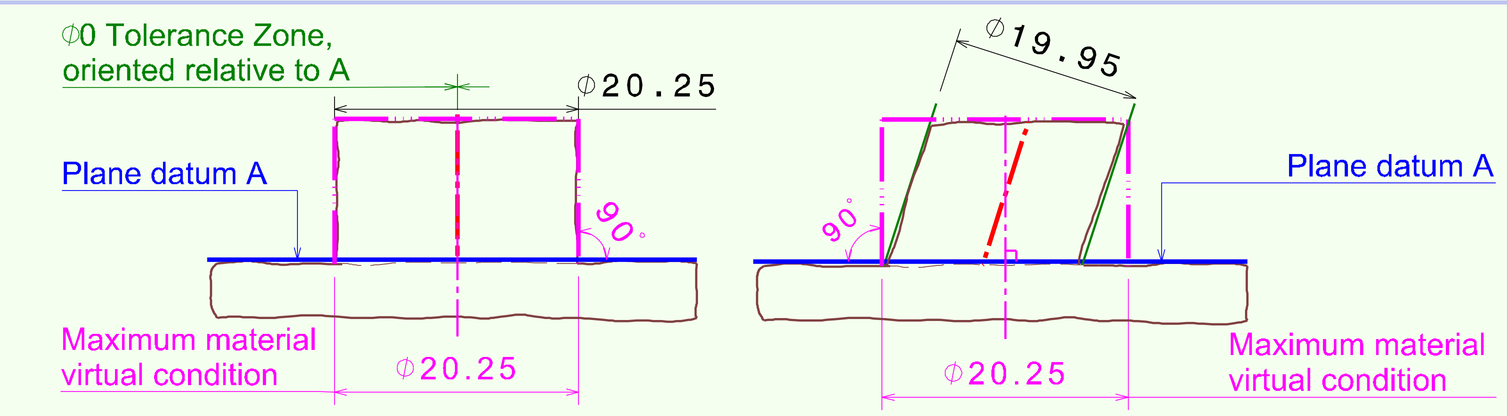
Dimension at maximum material: Maximum diameter of a shaft and minimum diameter of a bore hole (dimension for the heaviest part).

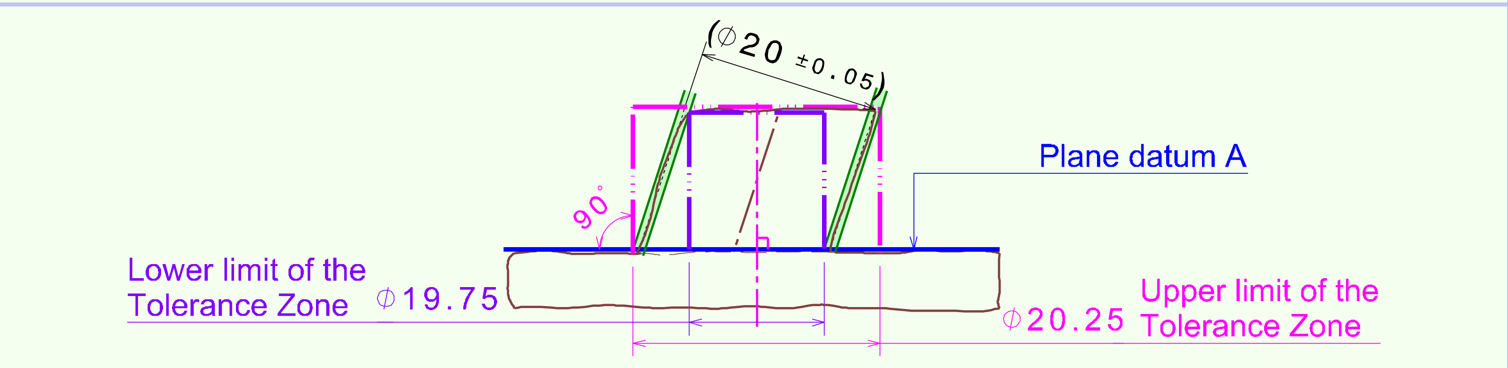
The maximum material **virtual condition** is an ideal form feature condition. It is exactly oriented and located relative to the datum system.

Use only for assembly functions with a **gap**, when two specifications applied for the same function: dimension + geometrical tolerance.









Maximum and Least material

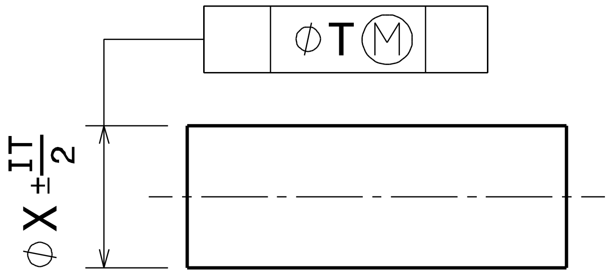
The **virtual condition** is systematically constructed in terms of theoretical form, orientation and location

Maximum material

Ⓜ

Maximum material for the toleranced feature

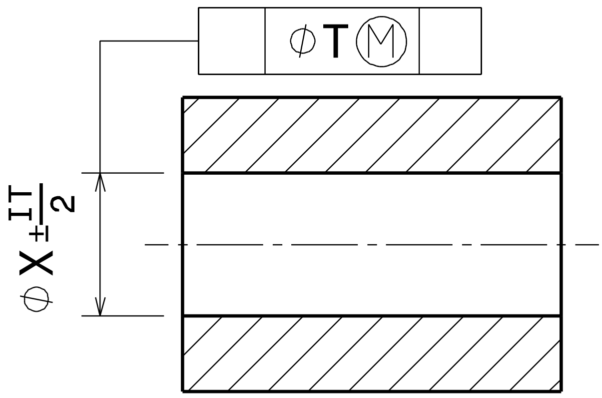
Solid form:



Condition:

The **virtual condition** must be outside of the material.

Hollow form:



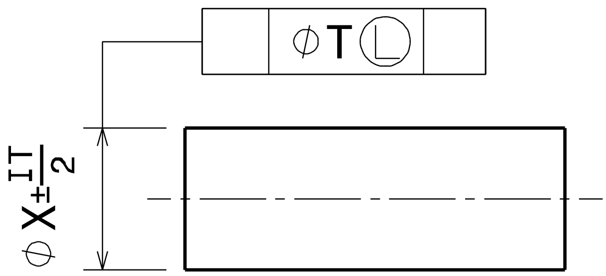
The **virtual condition** must be outside of the material.

Least material

Ⓛ

Least material for the toleranced feature

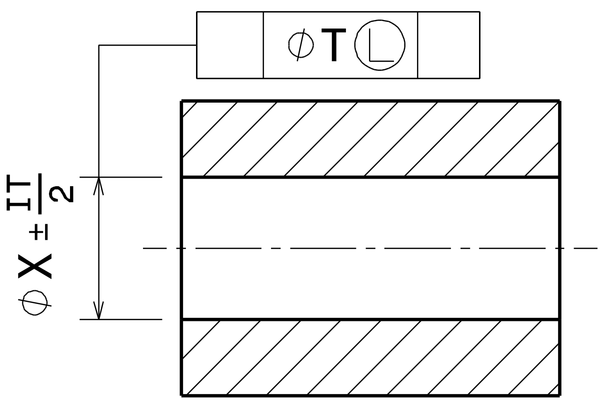
Solid form:



Condition:

The **virtual condition** must be inside the material.

Hollow form:



The **virtual condition** must be inside the material.

Local dimensions must satisfy the condition: Xmin ≤ DLi ≤ Xmax.
Measurements (or capabilities) must verify that the **real surface** which corresponds to the toleranced feature does not exceed the **virtual condition**.
Example: the edge of a cylinder must remain inside its maximum material virtual condition.

Use if the gap is appropriate for operations (e.g.: assembly function with a gap).
Never use maximum material on tight adjustments or threads/tappings.

Dimension at maximum material:	**Dimension of the maximum material virtual condition:**	**Maximum permissible geometrical tolerance:** The toleranced feature must not exceed the virtual condition
Xmax	Xmax + T	IT + T If X=Xmin
Xmin	Xmin - T	IT + T If X=Xmax

Use if the gap is inappropriate for operations (e.g.: position of equipment).

Dimension at least material:	**Dimension of the least material virtual condition:**	**Maximum permissible geometrical tolerance:** The toleranced feature must not exceed the virtual condition
Xmin	Xmin - T	IT + T If X=Xmax
Xmax	Xmax + T	IT + T If X=Xmin

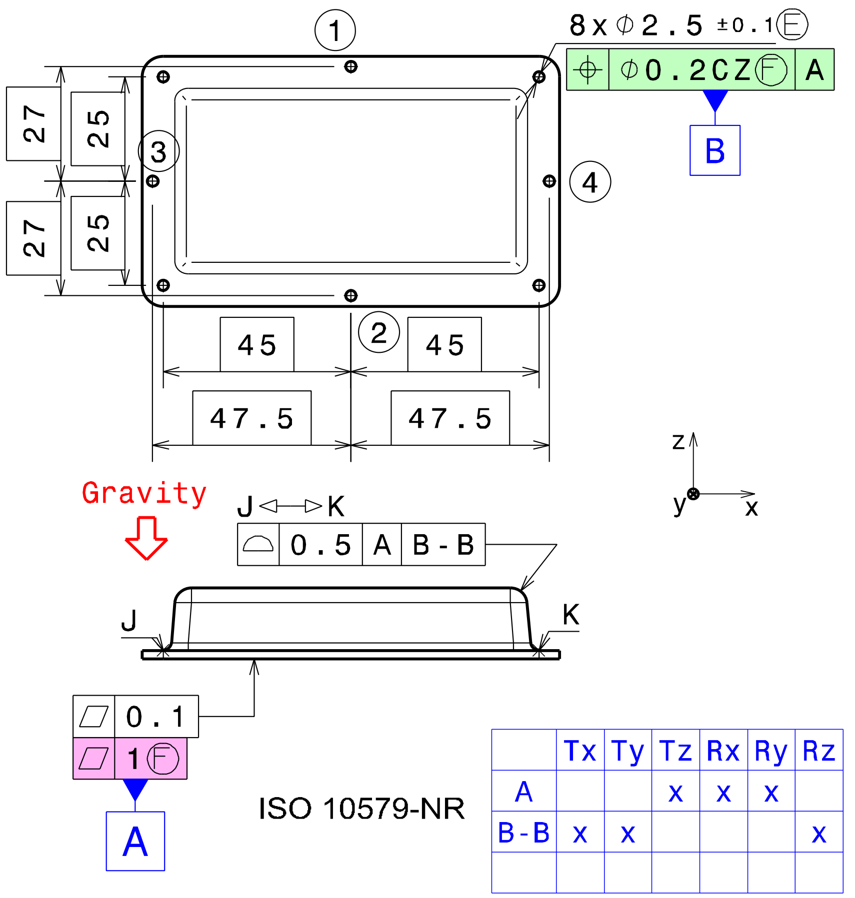
Non-rigid part:

Part which deforms to an extent that in the free state is beyond the dimensional and/or geometrical tolerances on the drawing.

Free state Ⓕ:

Condition of a part subjected only to the force of gravity.

This type of tolerancing can require specific test tools



	Tx	Ty	Tz	Rx	Ry	Rz
A			x	x	x	
B-B	x	x				x

The **pattern position** of screw holes is checked in free state as they must remain accessible during testing and deformation has little effect on their location.

Flatness is checked in free state and under positioning constraint.

Check that the toleranced features can be accessed under constraint.

Restrained conditions:

The surface indicated as datum A is fitted with 8 x M2 screws tightened to a torque of 0.2 N.m in the following order:

- ① & ②
- ③ & ④
- then the rest.

Note: the free state can be applied to one dimension.

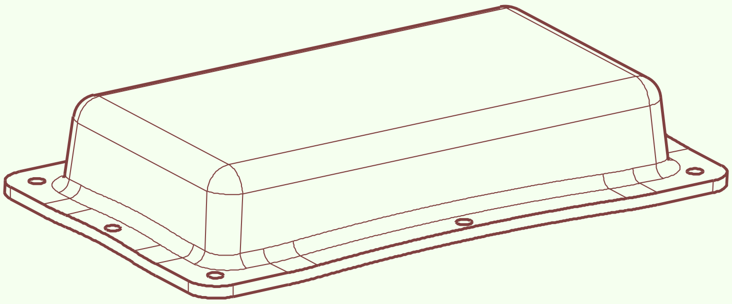
If standard **ISO 10579-NR** is indicated,
all specifications are defined under constraint.

Note: Drawings of non-rigid parts must indicate the following, as applicable:

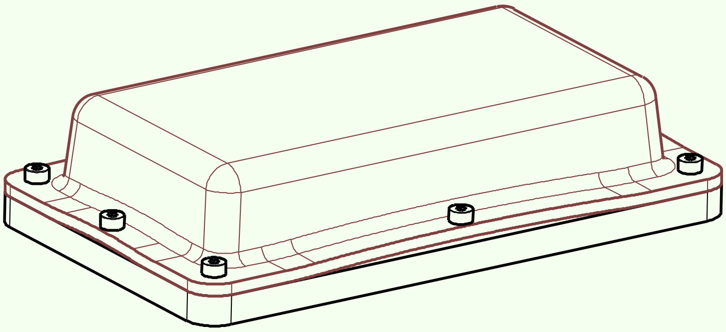
- The reference to standard **ISO 10579-NR,**
- Restrained conditions,
- Free state verifications Ⓕ,
- Conditions maintaining the geometrical tolerance in free state (gravity, part orientation, etc.).

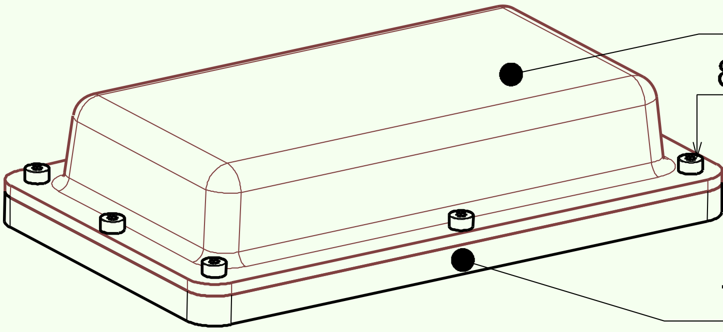
Front view

Left side view



The part deforms when the mold is removed,
but will straighten out during assembly with screws.



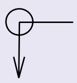
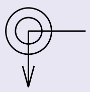


The Ⓕ modifier can be used
to check if free state deformations are excessive
and could lead to damage to the part during assembly.

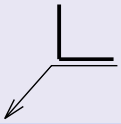
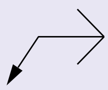
Summary of symbols and modifiers

Symbols	Description	Standards
Ⓟ	Projected tolerance zone	1101: Geometric tolerances
	Projected	5459: Datums
Ⓕ	Free state (non-rigid parts)	10579: Non-rigid parts
		1101: Geometric tolerances
		14405-1: Linear dimensional tolerancing
		14405-3: Angular dimensional tolerancing
CZ	Combined Zone	1101: Geometric tolerances
		5458: Pattern specification
		1660: Profile tolerancing
		2692: Max & min material and reciprocity
SZ	Separate Zones	1101: Geometric tolerances
		5458: Pattern specification
		1660: Profile tolerancing
		2692: Max & min material and reciprocity
SIM*i*	Simultaneous requirement n°i	5458: Pattern specification
		2692: Max & min material and reciprocity
CZR	Combined Zone Rotational only	5458: Pattern specification
UZ	Specified tolerance zone offset (Unequal Zone)	1101: Geometric tolerances
		1660: Profile tolerancing
OZ	Unspecified linear tolerance zone offset (Offset Zone)	1101: Geometric tolerances
		1660: Profile tolerancing
VA	Unspecified angular tolerance zone offset (Variable Angle)	1101: Geometric tolerances
		1660: Profile tolerancing

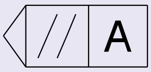
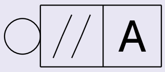
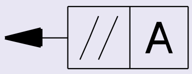
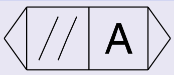
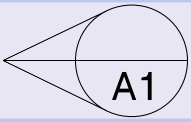
Summary of symbols and modifiers

Symbols	Description	Standards
	Between	1101: Geometric tolerances
		1660: Profile tolerancing
		14405-1: Linear dimensional tolerancing
		14405-3: Angular dimensional tolerancing
		129-1: Presentation of dimensions and tol.
UF	United Feature	1101: Geometric tolerances
		5458: Pattern specification
		1660: Profile tolerancing
		14405-1: Linear dimensional tolerancing
	All around (profile)	1101: Geometric tolerances
		1660: Profile tolerancing
	All over (profile)	1101: Geometric tolerances
		1660: Profile tolerancing
><	Orientation constraint only	1101: Geometric tolerances
		5459: Datums
		1660: Profile tolerancing
CF	Contacting Feature	1101: Geometric tolerances
[CF]	Contacting Feature	5459: Datums
Ⓜ	Maximum material requirement	2692: Max & min material and reciprocity
		1101: Geometric tolerances
		5459: Datums
Ⓛ	Least material requirement	2692: Max & min material and reciprocity
		1101: Geometric tolerances
		5459: Datums

Summary of symbols and modifiers

Symbols	Description	Standards
Ⓡ	Reciprocity requirement	2692: Max & min material and reciprocity
		1101: Geometric tolerances
Ⓜ[ϕd] Ⓛ[ϕd]	Direct indication of virtual size	2692: Max & min material and reciprocity
Ⓐ	Derived feature	1101: Geometric tolerances
Ⓔ	Envelope requirement	14405-1: Linear dimensional tolerancing
		286-1: ISO code system for tolerances of linear sizes
CT	Common Toleranced feature of size	14405-1: Linear dimensional tolerancing
	Common Toleranced feature of angular size	14405-3: Angular dimensional tolerancing
NC	Not Convex	1101 (2013): Geometric tolerances
	Requirements for an undefined edge of a part	13715: Edges of undefined shape
	Requirements for an edge (defined or not), *for example to guarantee interference-free assembly*	21204: Transition specification
LD	Minor Diameter	1101: Geometric tolerances
MD	Major Diameter	
PD	Pitch Diameter	
[LD]	Minor Diameter	5459: Datums
[MD]	Major Diameter	
[PD]	Pitch Diameter	
ACS	Any Cross-Section	1101: Geometric tolerances
	Any Cross-Section	14405-1: Linear dimensional tolerancing
[ACS]	Any Cross Section	5459: Datums

Summary of symbols and modifiers

Symbols	Description	Standards
SCS	Specific fixed Cross Section	14405-1: Linear dimensional tolerancing
		14405-3: Angular dimensional tolerancing
ALS	Any Longitudinal Section	14405-1: Linear dimensional tolerancing
[ALS]	Any Longitudinal Section	5459: Datums
	Intersection plane indicator	1101: Geometric tolerances
		1660: Profile tolerancing
		14405-1: Linear dimensional tolerancing
	Collection plane indicator	1101: Geometric tolerances
	Direction feature indicator	1101: Geometric tolerances
		1660: Profile tolerancing
		14405-1: Linear dimensional tolerancing
	Orientation plane indicator	1101: Geometric tolerances
	Moveable datum target	5459: Datums
[DV]	Variable Distance (for common datum)	5459: Datums
/Length	Any restricted portion of feature	14405-1: Linear dimensional tolerancing
/linear distance **/angular distance**	Any restricted portion of angular feature of size	14405-3: Angular dimensional tolerancing
0.1-0.2 **0.1/8** **0.1/8x8** **0.1/⌀8** **0.1/8x30°** **0.1/8°x30°**	Width and extent of the tolerance zone	1101: Geometric tolerances

Summary of symbols and modifiers

Symbols	Description	Standards
	Situation feature of type:	5459: Datums
[PT]	Point	
[SL]	Straight Line	
[PL]	Plane	
LE	Line Element	1101 (2013): Geometric tolerances
⊳	Rate of taper	3040: Cones
SØ	Spherical diameter	1101: Geometric tolerances 129-1: Presentation of dimensions and tol.
RS	Spherical Radius	1101: Geometric tolerances 129-1: Presentation of dimensions and tol.
↧	Depth (holes, counterbore)	129-1: Presentation of dimensions and tol.
⌴	Cylindrical counterbore	
⌵	Countersink	
t=	Thickness (of thin objects)	
⌒	Arc length	
○→	Developed length	
⬡1	Flagnote (*to indicate a complementary requirement to a dimensional specification*)	14405-1: Linear dimensional tolerancing
⟨ST⟩	Tolerance value obtained by a statistical calculation method	18391: Population specification
△1	Prioritization class	E04-009: Hierarchical organization of product/process characteristics
◯△1	Severity class	

Summary of symbols and modifiers

Symbols	Description	Standards
Associated toleranced feature specification elements (for orientation and location specifications)		
Ⓒ	Minimax (Chebyshev) associated without material constraint	1101: Geometric tolerances
Ⓖ	Least squares (Gaussian) associated without material constraint	
Ⓝ	Minimum circumscribed	
Ⓣ	Tangent outside the material	
Ⓧ	Maximum inscribed	
Reference feature association specification elements (for form specifications or with degree of freedom)		
C	Minimax (Chebyshev) (by default)	1101: Geometric tolerances
CE	Minimax (Chebyshev) with external material constraint	
CI	Minimax (Chebyshev) with internal material constraint	
G	Least squares (Gaussian)	
GE	Least squares (Gaussian) with external material constraint	
GI	Least squares (Gaussian) with internal material constraint	
X	Maximum inscribed	
N	Minimum circumscribed	
Parameter specification elements (for form specifications or with degree of freedom)		
T	Total range of deviations (by default)	1101: Geometric tolerances
P	Peak height	
V	Valley depth	
Q	Standard deviation	

Summary of symbols and modifiers

Symbols	Description	Standards
Local sizes		
LP	Two-point size (size by default) (Local Point)	14405-1: Linear dimensional tolerancing
LS	Local size defined by a sphere (Local Sphere)	
LC	Two-line angular size with minimax association criterion (size by default)	14405-3: Angular dimensional tolerancing
LG	Two-line angular size with least squares association criterion (Local Gauss)	
Global sizes		
GG	Least-squares association criterion (Global Gauss)	14405-1: Linear dimensional tolerancing
	Global angular size with least squares association criterion	14405-3: Angular dimensional tolerancing
GX	Maximum inscribed association criterion (Global maXimum)	14405-1: Linear dimensional tolerancing
GN	Minimum circumscribed association criterion (Global miNimum)	
GC	Minimax (Chebyshev) association criteria	14405-1: Linear dimensional tolerancing
	Global angular size with minimax association criterion	14405-3: Angular dimensional tolerancing
Calculated sizes		
CC	Circumference diameter (Calculated Circumference)	14405-1: Linear dimensional tolerancing
CA	Area diameter (Calculated Area)	
CV	Volume diameter (Calculated Volume)	

Summary of symbols and modifiers

Symbols	Description	Standards
Sizes according to rank		
SX	Maximum size	14405-1: Linear dimensional tolerancing
	Maximum angular size	14405-3: Angular dimensional tolerancing
SN	Minimum size	14405-1: Linear dimensional tolerancing
	Minimum angular size	14405-3: Angular dimensional tolerancing
SA	Average size	14405-1: Linear dimensional tolerancing
	Average angular size	14405-3: Angular dimensional tolerancing
SM	Median size	14405-1: Linear dimensional tolerancing
	Median angular size	14405-3: Angular dimensional tolerancing
SD	Mid-range size	14405-1: Linear dimensional tolerancing
	Mid-range angular size	14405-3: Angular dimensional tolerancing
SR	Range of sizes	14405-1: Linear dimensional tolerancing
	Range of angular sizes	14405-3: Angular dimensional tolerancing
SQ	Standard deviation of sizes	14405-1: Linear dimensional tolerancing
	Standard deviation of angular size	14405-3: Angular dimensional tolerancing

Ⓤ	Unequally Disposed Profile	ASME Y14.5
Ⓘ	Independency	ASME Y14.5
Ⓢ	Regardless of Feature Size	ASME Y14.5
▷	Datum Translation	ASME Y14.5

Table summarizing datum systems

A
B
C

The summary table defines the required tolerancing to maintain the assembly function depending on the type of datum feature (1st column) and in defined order (primary, secondary or tertiary). The datum feature identifier should be adapted.

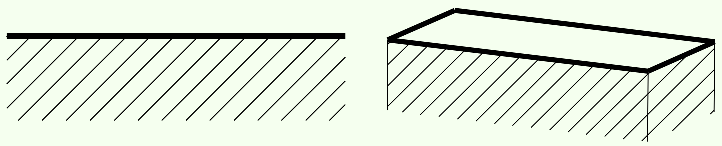
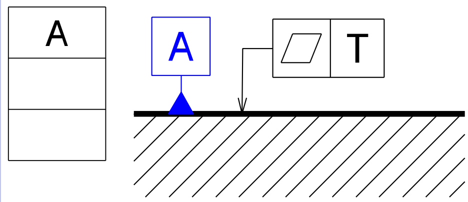
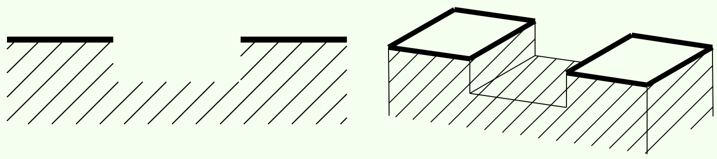
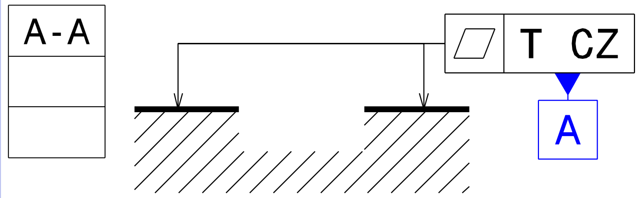
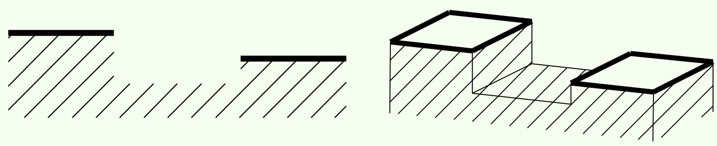
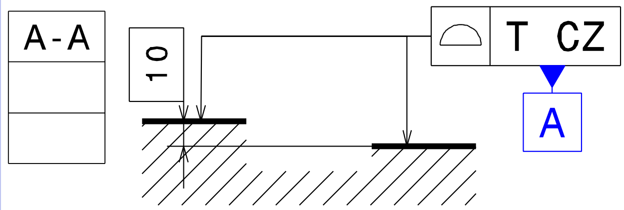
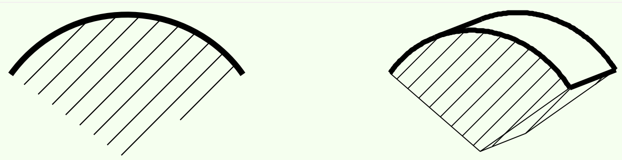
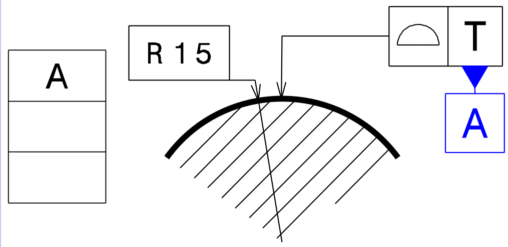
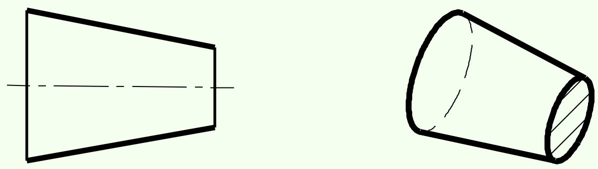
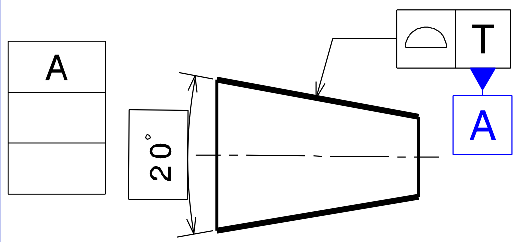
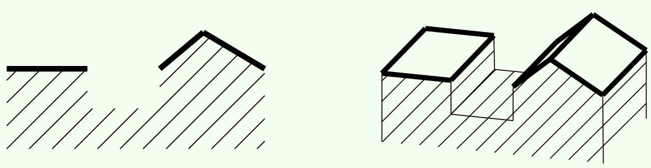
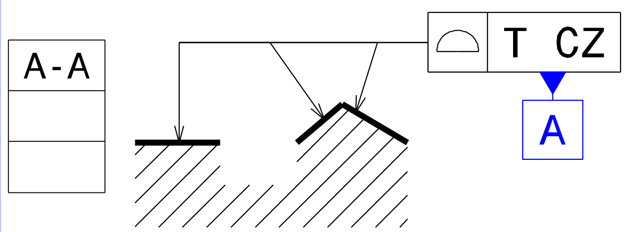
Note: This table can be used to create hundreds datum systems.

Example: Primary datum: plane ➔ ⏥ | T

Secondary datum: cylinder ➔ ϕ5± it/2 Ⓔ ⊥ | ϕT | A

Tertiary datum: holes pattern ➔ 2xϕ10± it/2 Ⓔ ⌖ | ϕT CZ | A | B

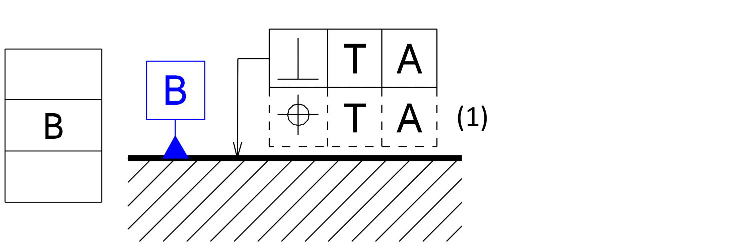
A
B
C-C

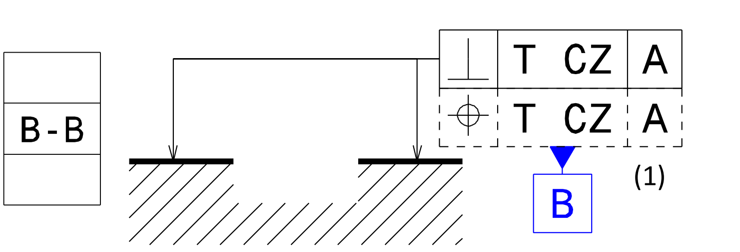
Surface features	Primary datum
Plane 	
Coplanar planes 	
Offset planes 	
Single surface (sphere edge, cylinder edge …<180°) 	
Conic single surface 	
Combined single surfaces 	

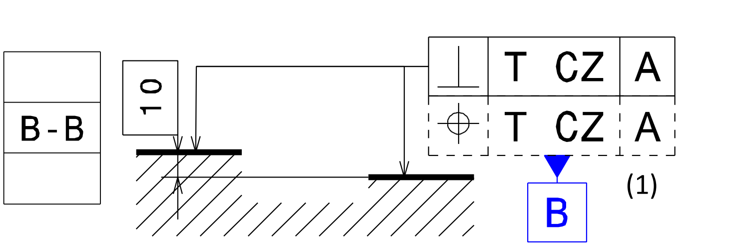
Note: For size type elements with appropriate gaps for assembly, it may be recommendable to specify the maximum material Ⓜ for the geometrical tolerance (remove CZ if used: *standard 2692-2015*, keep CZ if used: *standard 2692-2021*), and to eliminate the envelope requirement for the linear size.

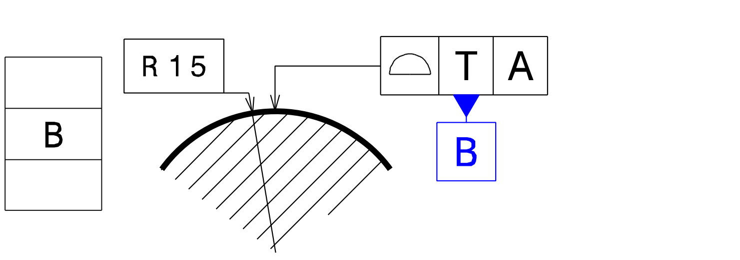
[| T |] (1) The location specification replaces the orientation if the toleranced surface runs parallel to one of the datum or if a location requirement applies for assembly.

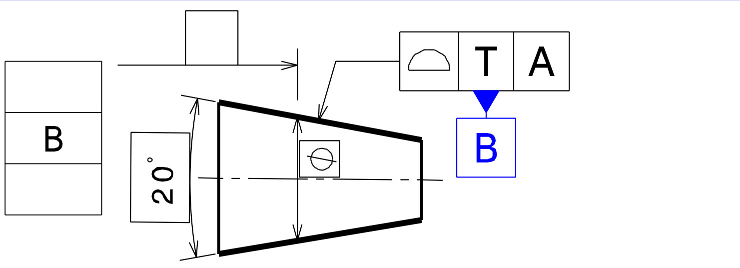
Secondary datum

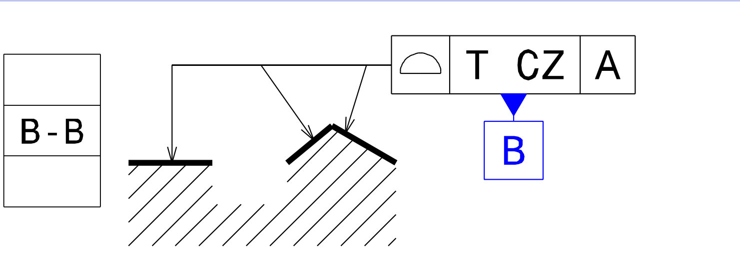




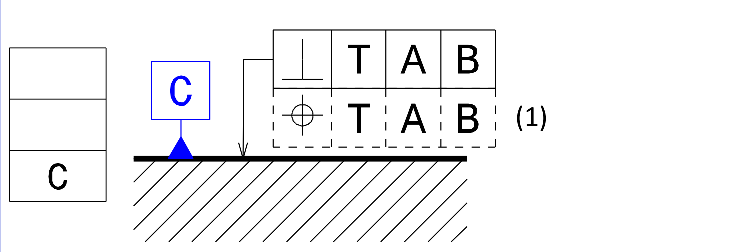


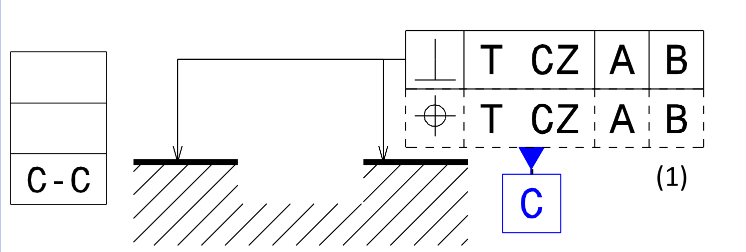


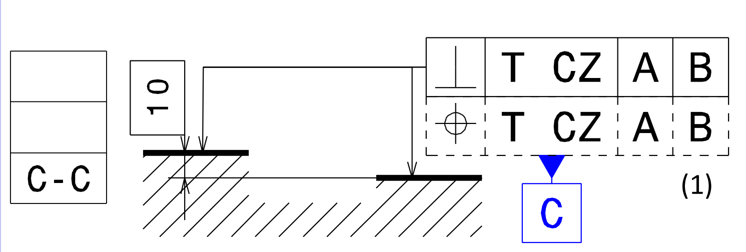


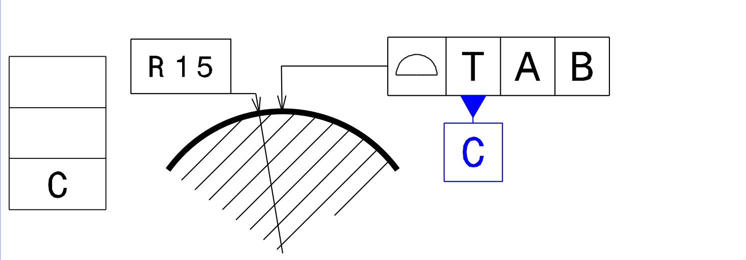


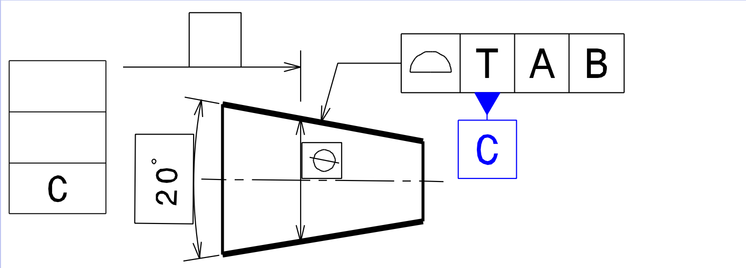
Tertiary datum

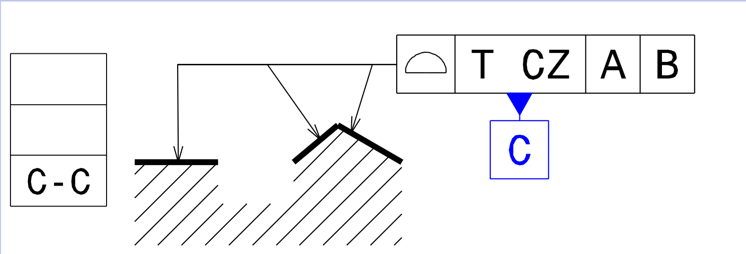




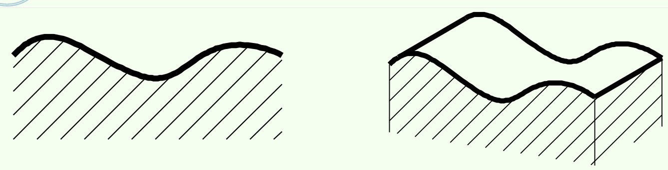




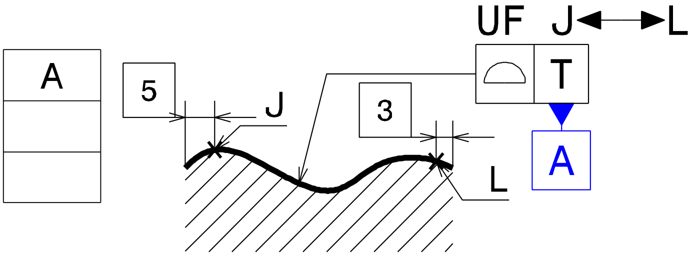




77 Complex surface or united surfaces

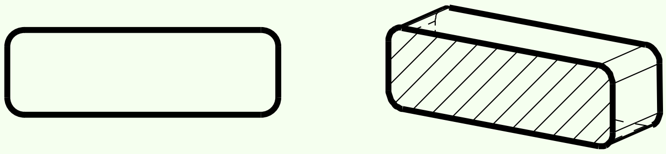


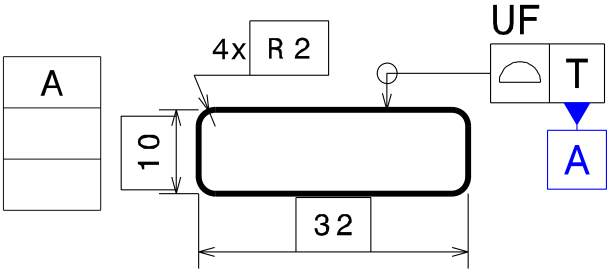
Theoretical definition: see 3D for mean dimensions



Closed outline

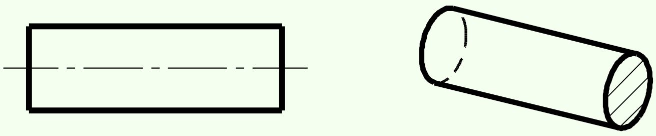
The datum is obtained by applying the least squares mean criterion [GM]

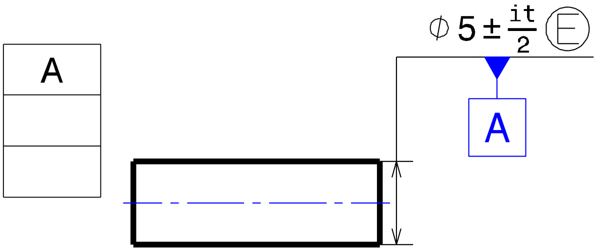




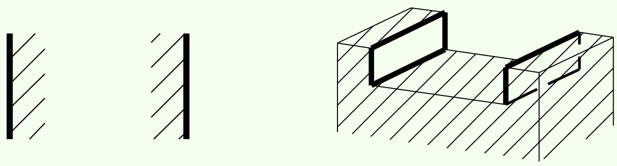
Features of size	Primary datum

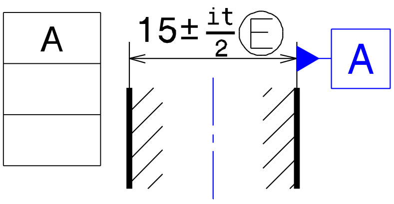
Cylinder or cylindrical hole



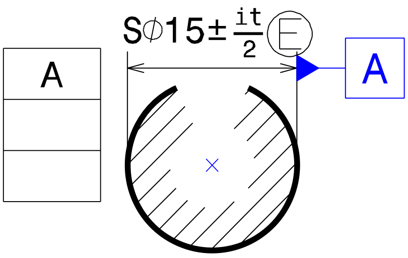


Symmetrical parallel planes or slot hole

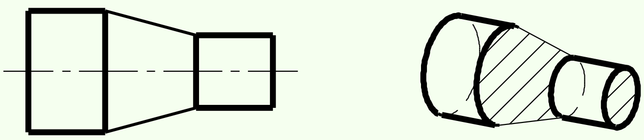


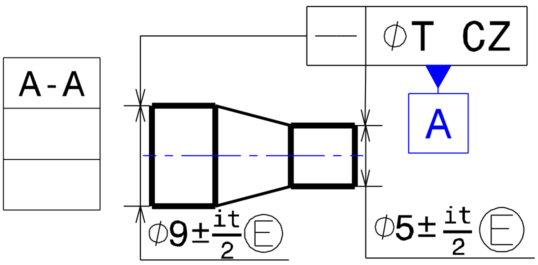


Sphere (>180°)

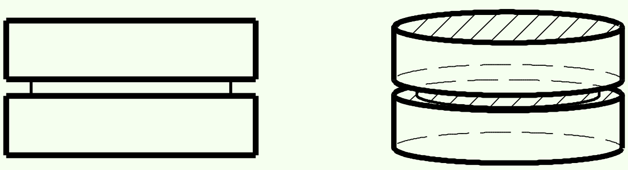


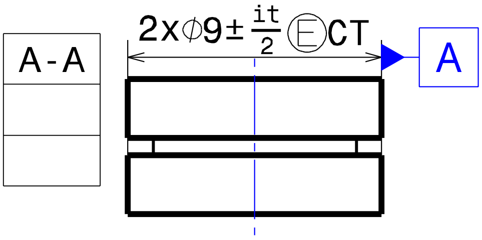
Separated coaxial cylinders

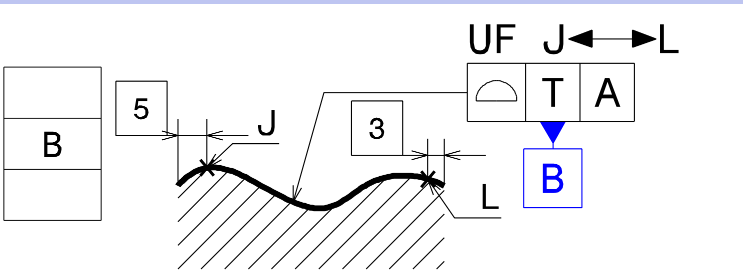


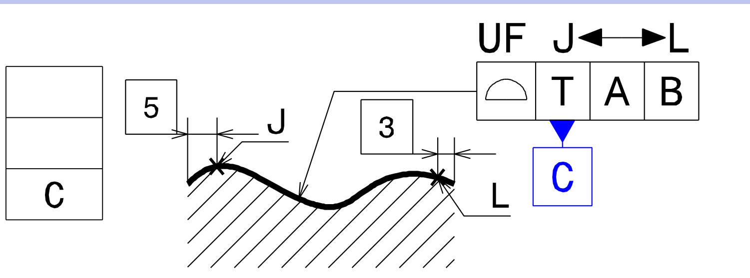


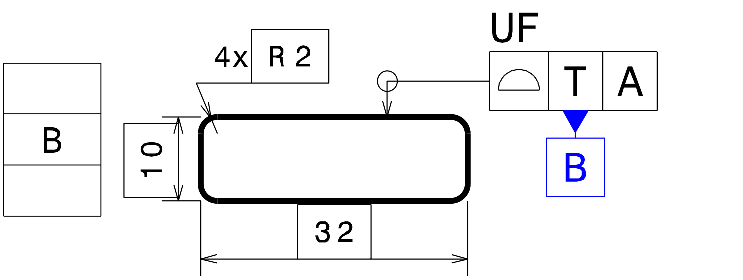
Close coaxial cylinders

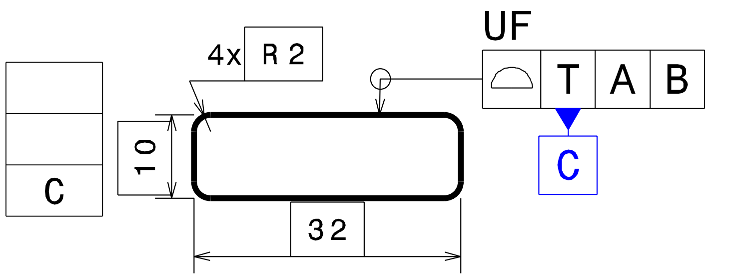


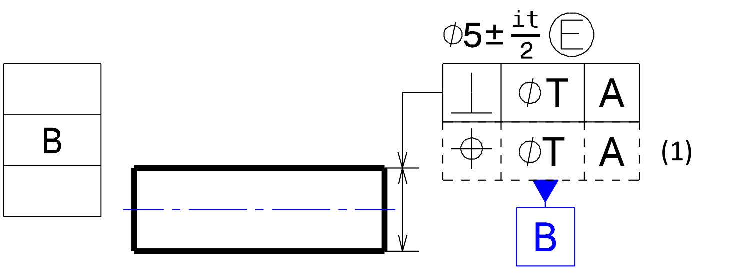
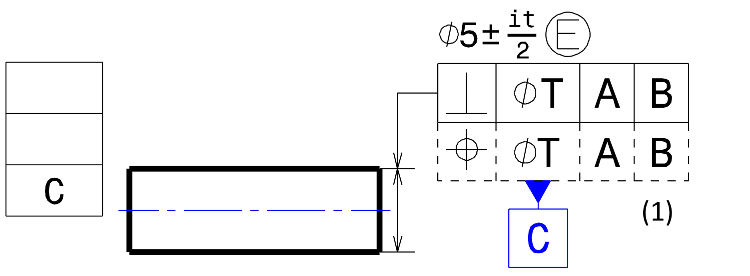
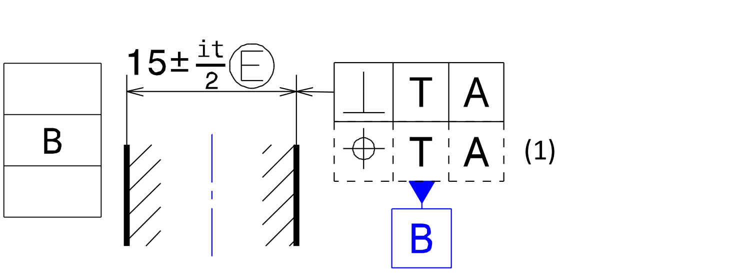
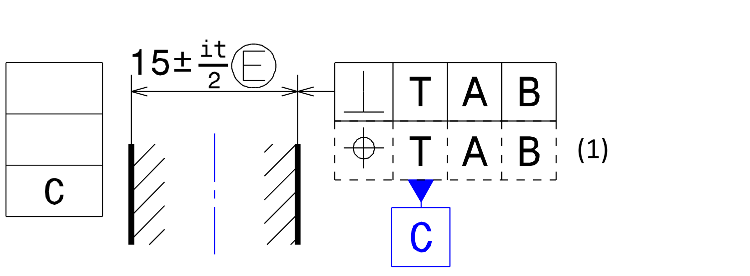
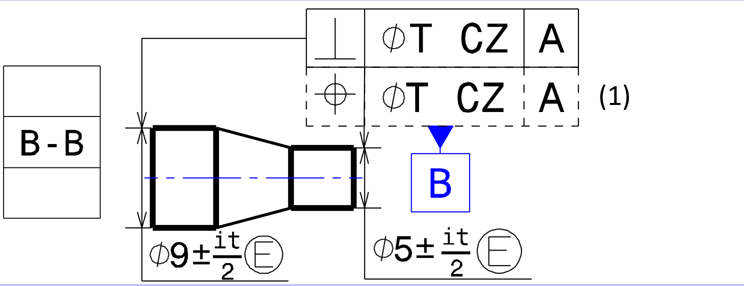
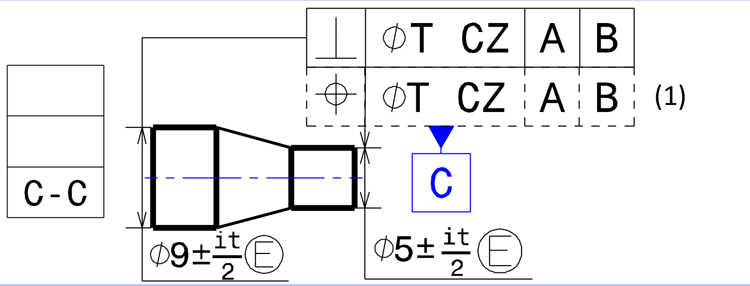




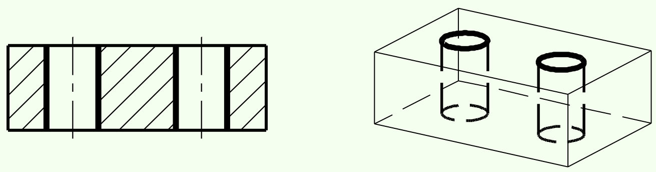


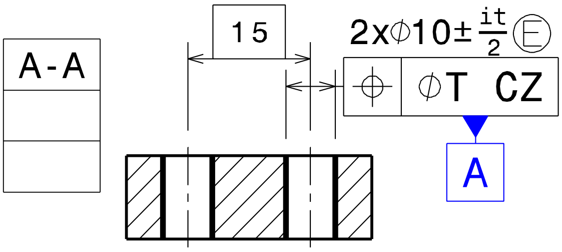




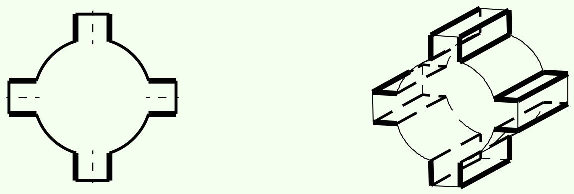
Secondary datum	Tertiary datum
	
	
No sphere in secondary datum	**No sphere in tertiary datum**
	

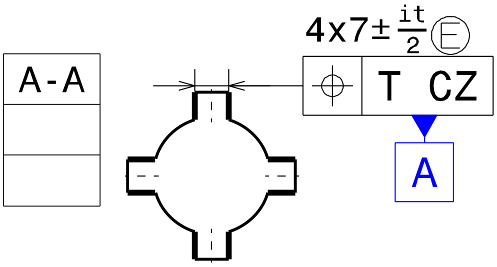
79 **Pattern of non-coaxial cylinders**





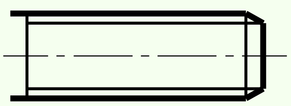
Pattern of symmetrical parallel planes

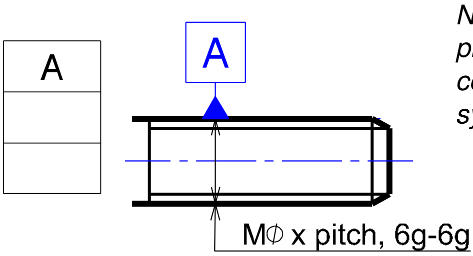




Threads / Tapping features	Primary datum

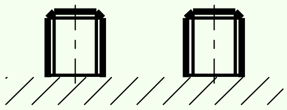
Threads

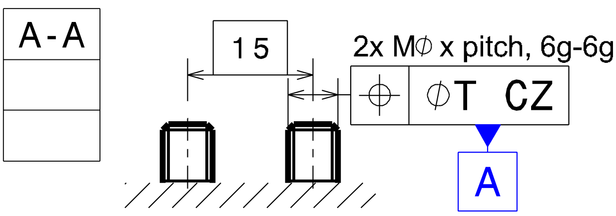




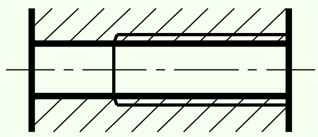
Note: a thread in primary datum, only centers in specific systems

Pattern of threads

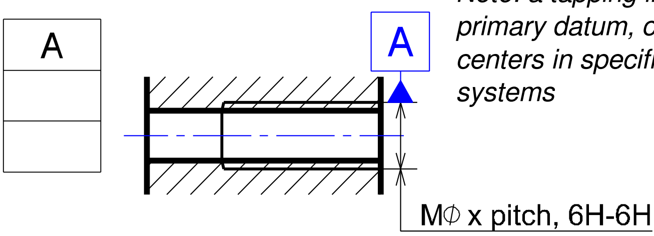




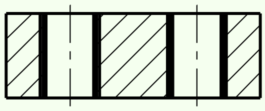
Tapping

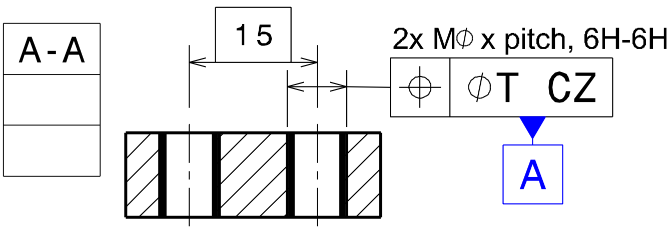


Note: a tapping in primary datum, only centers in specific systems



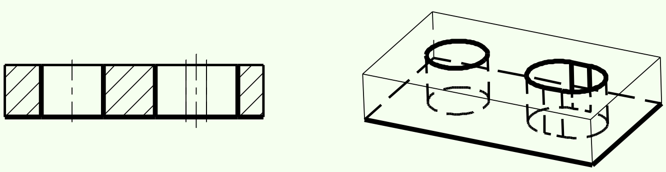
Pattern of tappings

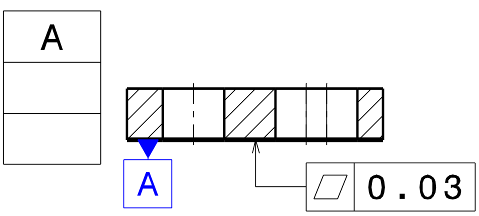


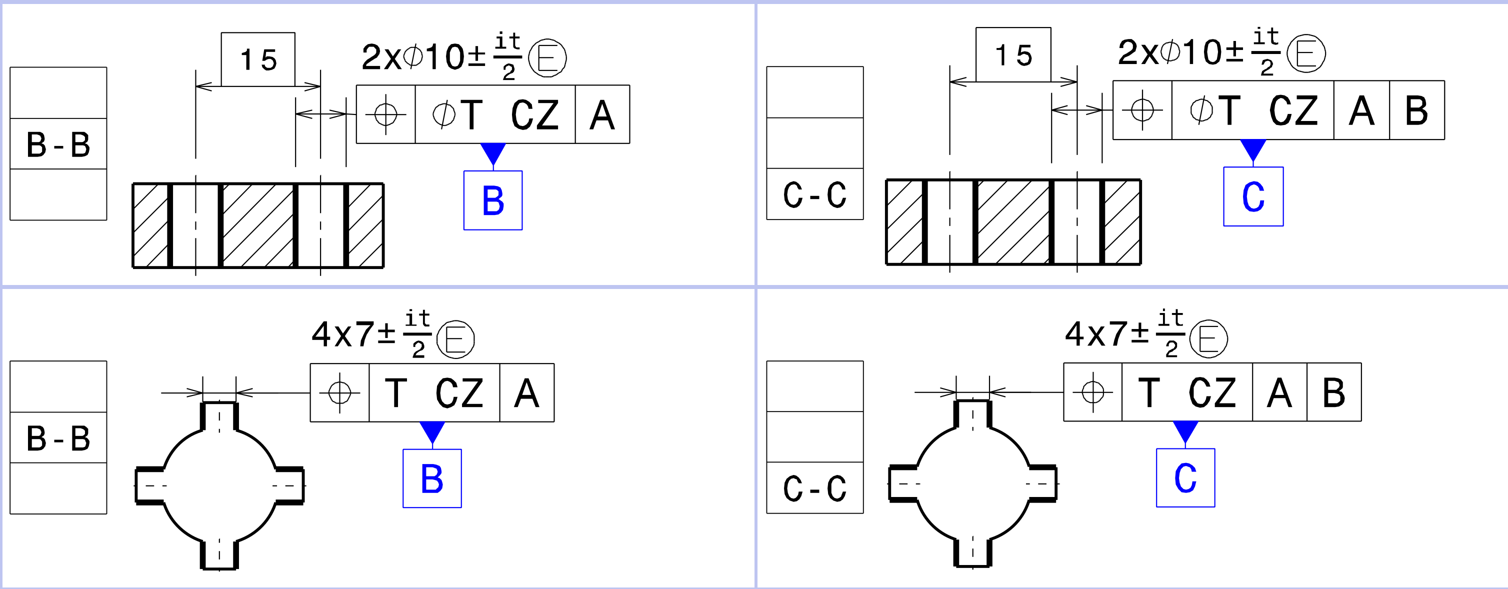


Example of application

Primary datum: Plane

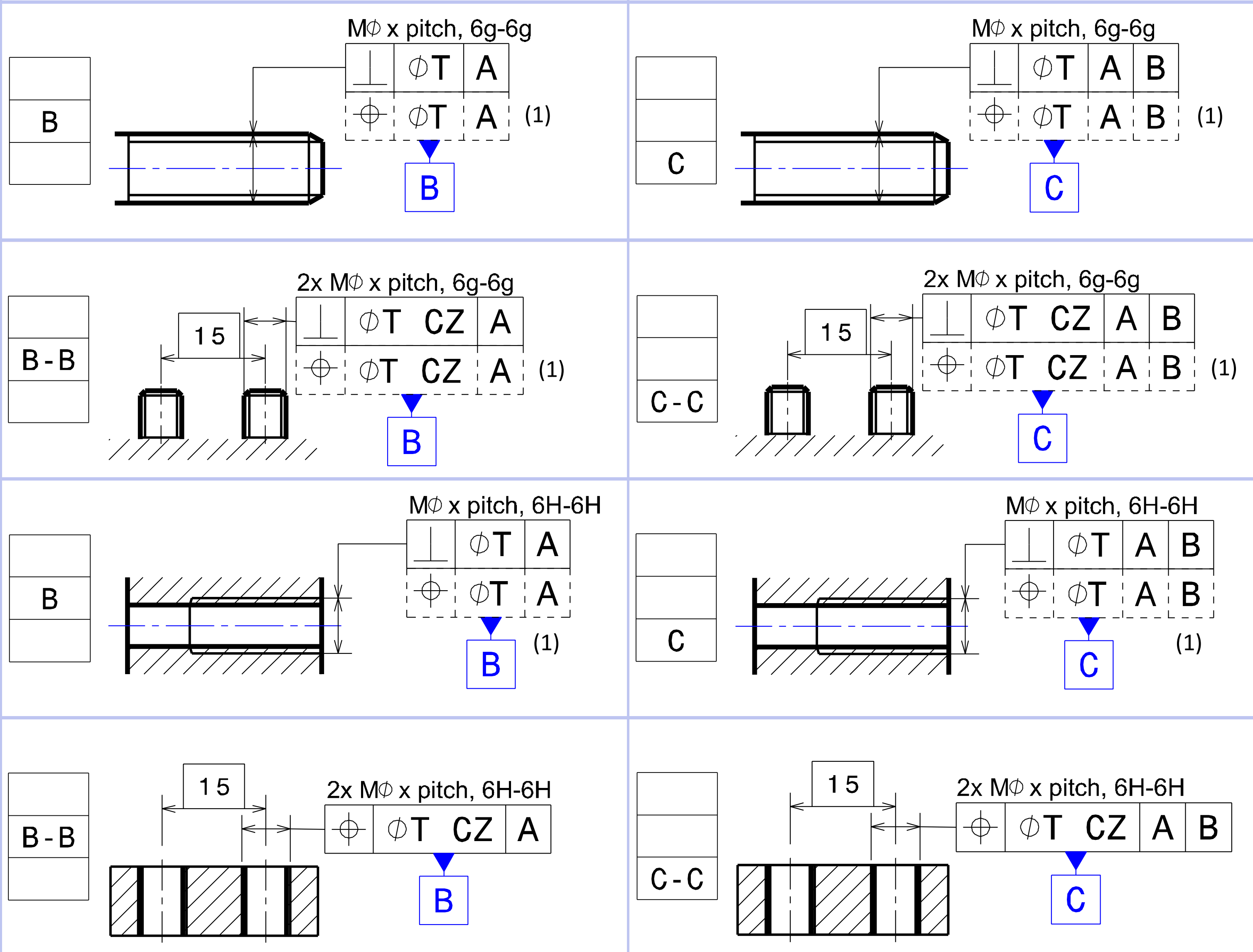




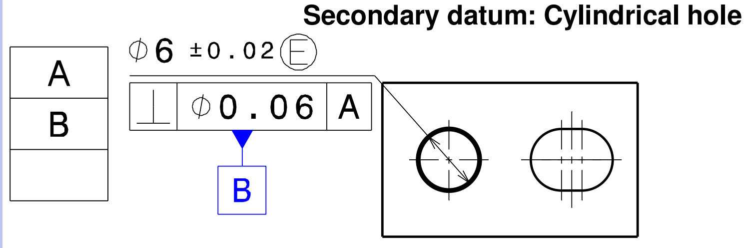


Secondary datum

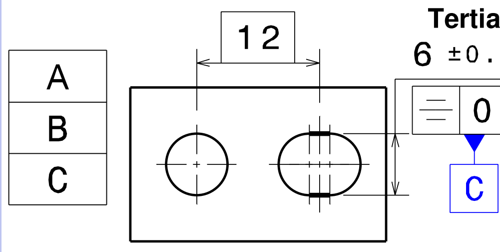
Tertiary datum



Secondary datum: Cylindrical hole



Tertiary datum: Slot hole



Note: oblong rounding is specified under the general profile tolerance

Checklist: **Preparation of drawings**

Step 1: required input

- ☐ 3D of the part and its environment (parts in contact or with functional connections)
- ☐ The assembly method
- ☐ The different operating modes (functional analysis if available)

Step 2: establish and name product functions (F01…)

- ☐ Assembly or Mounting options (priority point)
- ☐ Appearance (e.g. the consistency of a gap)
- ☐ Resistance (to forces, ambient conditions, etc.)
- ☐ Comfort-Ergonomics (play detected, noise, etc.)
- ☐ Leak tightness
- ☐ Operation (manoeuvring)
- ☐ Regulations or Safety

Step 3: establish the main datum system and related isostatism table

The main datum system identifies the ideal environment establishing the final location of the part in the space during operation. The environment may be a part in contact or a means of assembly.

⇒ If several phases of operating life apply, several main datum systems may exist

- ☐ Limit the **F**orm imperfection of the primary datum feature (in CZ if several features exist)
  - *⇒ Less than 1/3 of the smallest location tolerance associated with the datum feature considered*
  - *⇒ Establish the link with the Mounting options function*
- ☐ Limit the **O**rientation or location imperfection of the secondary datum relative to the primary
  - *⇒ Assembly tolerance stack-up + Establish the link with the Mounting options function*
- ☐ Limit the **L**ocation or orientation imperfection of the tertiary datum/to the primary&secondary
  - *⇒ Assembly tolerance stack-up + Establish the link with the Mounting options function*
- ☐ Place the isostatism table near to the title block

Step 4: establish the equipment datum systems

These systems identify the interfaces of components assembled onto the part to be toleranced

- ☐ Limit the form, orientation and location imperfection of datum features (**F.O.L.**)
  - *⇒ As for the main datum system*
  - *⇒ Full validation of interfaces and assembly functions*
- ☐ Name each system and write the names above the isostatism table

Step 5: position the equipment and process the other product functionst

- ☐ Position the equipment in locations which give the shortest tolerance stack-up
- ☐ Identify non-linear behaviour and limit the orientation imperfections affected
- ☐ Distribute the IT with IT=Σ(IT) or with a statistical calculation
- ☐ Check consistency with sector-specific standards in the sectors in question
- ☐ Establish the link with functions

Step 6: Maximum material

- ☐ Specify maximum material on the toleranced feature only for assembly functions with a gap

Step 7: general tolerances

- ☐ Specify general tolerances for non-functional features
  - *⇒ Use a profile geometrical tolerance relative to the main reference system (standard 22081)*

Step 8: check

- ☐ That each item of equipment is correctly located relative to the main datum system, or relative to an equipment datum system
- ☐ That each geometrical tolerance satisfies the order of the datum systems established
- ☐ The layout and clarity of the views (one view or foliot per interface, isometric views)
  - *⇒ Always put yourself in the place of the reader who discovers the drawing*
- ☐ Unclear dimensions
- ☐ The 3D drawing for mean dimensions (excluding fits)

Checklist: **Checking drawings**

Step 1: use a highlighter

- [ ] Use Yellow for sections, Blue for datum and Green for functional tolerances

Step 2: datum systems

- [ ] Note all datum systems mentioned on the drawing under the geometrical tolerances
- [ ] Check consistency (e.g. |A|B|C| or |A|B| or |A|) (e.g. |D-E|F|G| or |D-E|F| or |D-E|)

Step 3: main datum system

- [ ] Identify the main datum system (isostatism table) and assembly method

⇒ Identifies the location of the part in space during operation
(for production, measuring and assembly procedures)

- [ ] **F**orm imperfection of the primary datum feature
- [ ] **O**rientation or location of the secondary datum feature relative to the primary datum
- [ ] **L**ocation or orientation of the tertiary datum feature relative to the primary and secondary

Step 4: equipment datum systems (component interfaces)

- [ ] Identify the equipment datum systems and attempt to name them
- [ ] Check the **F**orm, **O**rientation and **L**ocation imperfection of equipment datum features
- [ ] Check that all equipment interfaces are correctly located

⇒ Either relative to the main datum system
⇒ Or relative to the datum system of another component

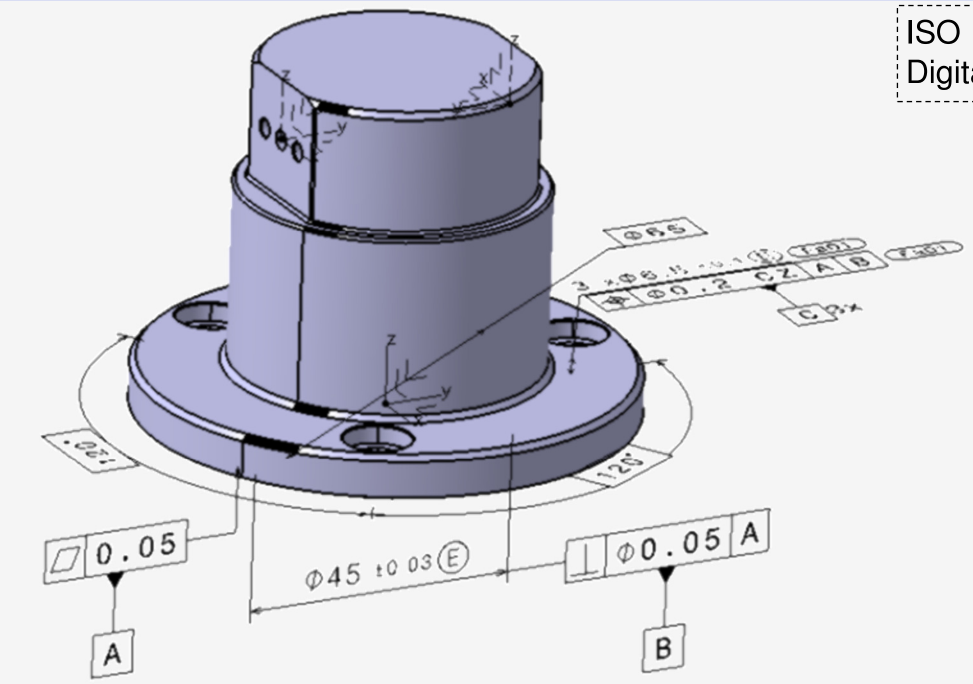
Step 5: check

- [ ] CZ (as part of the same operation as tolerances are not cumulative)
- [ ] Functional tolerances (identify tolerances which are complex to obtain during production or to measure)
- [ ] General tolerances and sector-specific standards
- [ ] Material, treatment or coating
- [ ] Free or limited state
- [ ] 3D for mean dimensions: see wrong dimensions or off-center dimensions
- [ ] Surface texture

Step 6: establish the ideal manufacturing range

- [ ] Machine the main datum system as part of the same operation
- [ ] Take up position on the main datum system
- [ ] Machine the equipment datum system as part of the same operation

⇒ Either relative to the main datum system or relative to a datum system of another component



ISO 16792
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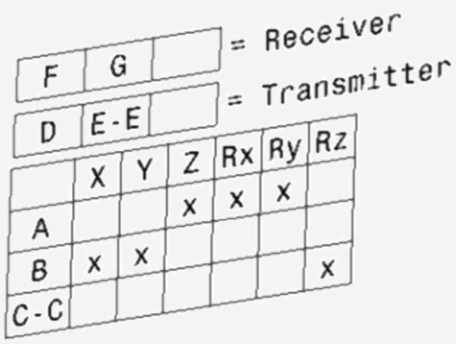

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This handbook is intended to complement the following training sessions:

- **CFiso1: Understanding an ISO definition drawing in the industry.**
  This training session is intended to help establish a process of understanding and relevant critical analysis of industrial drawing in ISO-GPS language.
- **CFiso2: Apply functional dimensioning and ISO-GPS tolerancing in industry.**
  This training session is intended to help establish a relevant tolerancing and critical analysis for industrial drawings.
- **CFiso3: Apply ISO-GPS tolerancing to your products.**
  This training session allows you to apply a structured industrial tolerancing approach to your parts.

This handbook is a useful tool for mechanical engineering industry.

It was created to be made freely available to all technicians.

We ensure its development and distribution free of charge.

For this handbook to be used in the best conditions, it is preferable to have followed the Cetiso training courses.

It is not exhaustive.
It is not intended to replace technical drawing standards and must be supplemented by referring the ISO-GPS standards.

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