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# Geometrical product specification guide

Olli-Pekka Kirjavainen 2.3.2022

# ISO 8015 (GPS) – Fundamentals – Concepts, principles and rules

## ISO 14405 (GPS) Linear sizes

- ISO 286-1 (GPS) ISO code system for tolerances on linear sizes — Part 1, Basis of tolerances, deviations and fits.
- ISO 286-2 (GPS) ISO code system for tolerances on linear sizes — Tables of standard tolerance classes and limit deviations for holes and shafts.

## ISO 1101 (GPS) Geometrical tolerancing — Form, orientation, location and run-out

- ISO 5459 (GPS) Datums and Datum systems
- ISO 2692 (GPS) Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)
- ISO 5458 (GPS) Positional tolerancing

## ISO 1302 (GPS) Indication of surface texture in technical product documentation

## ISO 22081 (GPS) General geometrical specifications and general size specifications

## ISO 22768-1 Tolerances for linear and angular dimensions without individual tolerance indications

## ISO 1660 (GPS) Profile tolerancing

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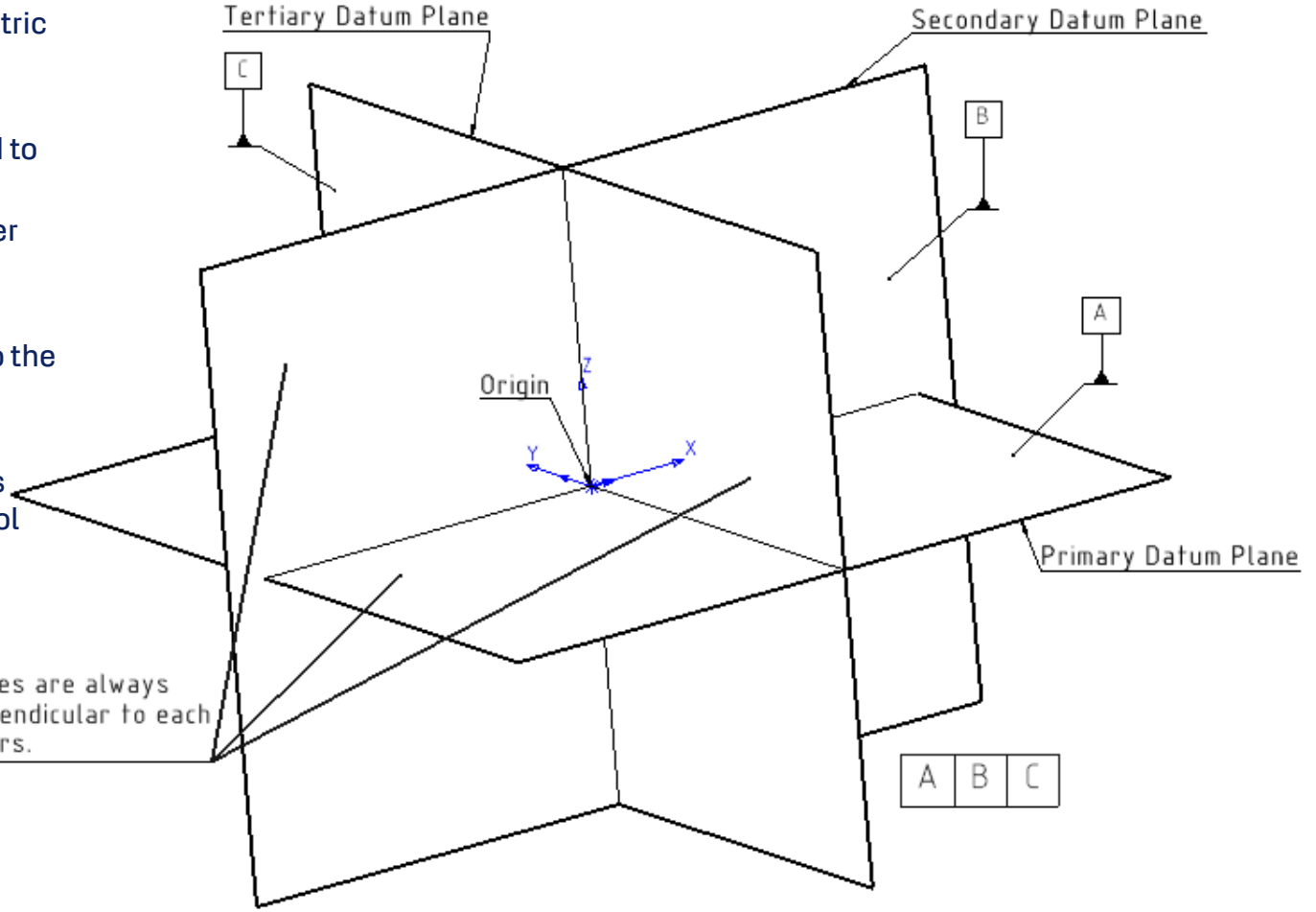
# DATUM SYSTEM(s)

# General Datum System

- **Datum**
  - A theoretically exact geometric reference such as a point, axis or plane to which toleranced features are related. Datums may based on one or more datum features of a part. It is the origin from which the location of geometric characteristics of the part are established.
- **Datum Feature**
  - Real feature of a part (such as an edge, a surface, or a hole), which is used to establish the location of a datum.
  - As a general rule, datum feature is the feature which locates a part to other parts or assembly.
- **Datum and measurement orientation**
  - Datums not only define the position of the origin of the part itself but also the orientation of the part in the measuring equipment.
- **General Datum Reference Frame.**

DRF is the coordinate system for part and measurement created by the datums specified in the drawing. The order of the datums referenced in a feature control frame is important for the measurement of the part.

- *Primary Datum (commonly* **A***)*
  - Controls three degrees of freedom
  1. Translation Along Z –axis
  2. Rotation about X –axis
  3. Rotation about Y -axis
- *Secondary Datum (commonly* **B***)*
  - Controls two degrees of freedom
  4. Translation along Y –axis
  5. Rotation about Z -axis
- *Tertiary Datum (commonly* **C***)*
  - Controls one degree of freedom
  6. Translation along X -axis

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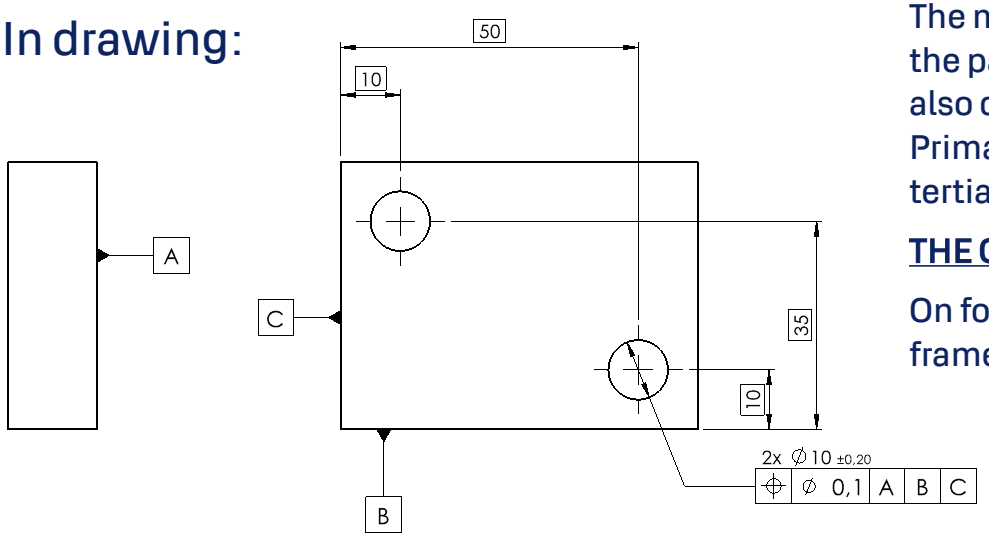
# Order of Datums.

In drawing:

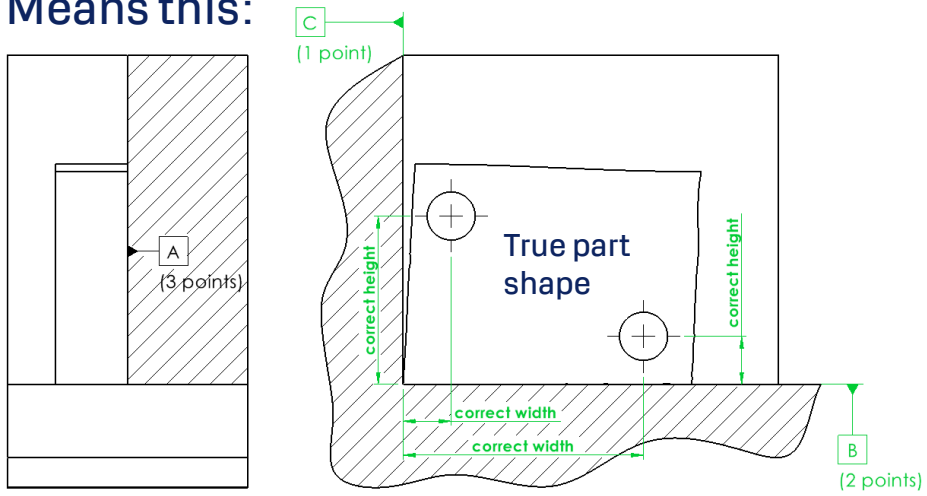



The main function of the datum reference frame is to specify a foundation for the inspection of the part. It is not only the common coordinate system of all geometrical tolerance zones but also determines orientation of coordinate system for linear dimensions.
Primary datum [A] has 3 points of contact, secondary datum [B] has 2 points of contact and tertiary datum [C] one point of contact.

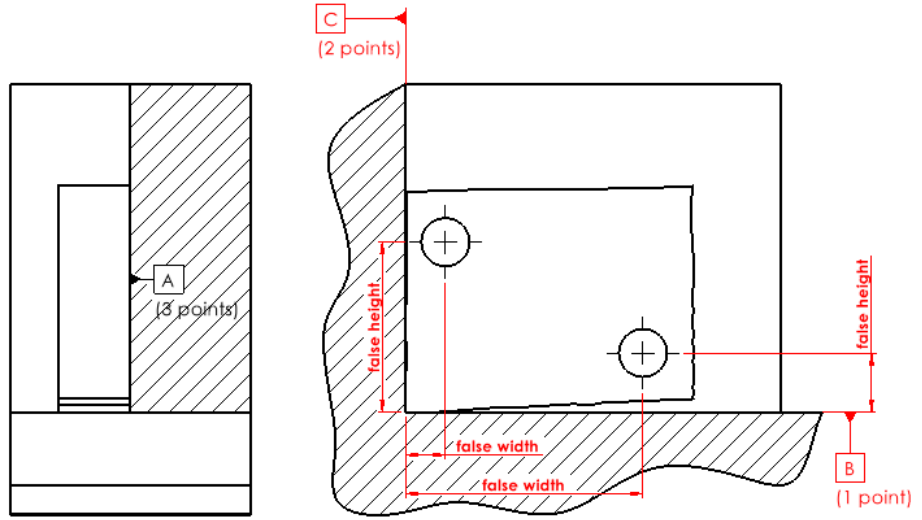
**THE ORDER OF THE DATUMS DEFINED IN DRAWING IS CRITICAL, AND MUST BE FOLLOWED!**

On following pages are presented an examples of common cases of establish datum reference frame.

Means this:




Correct inspection procedure




Incorrect inspection procedure

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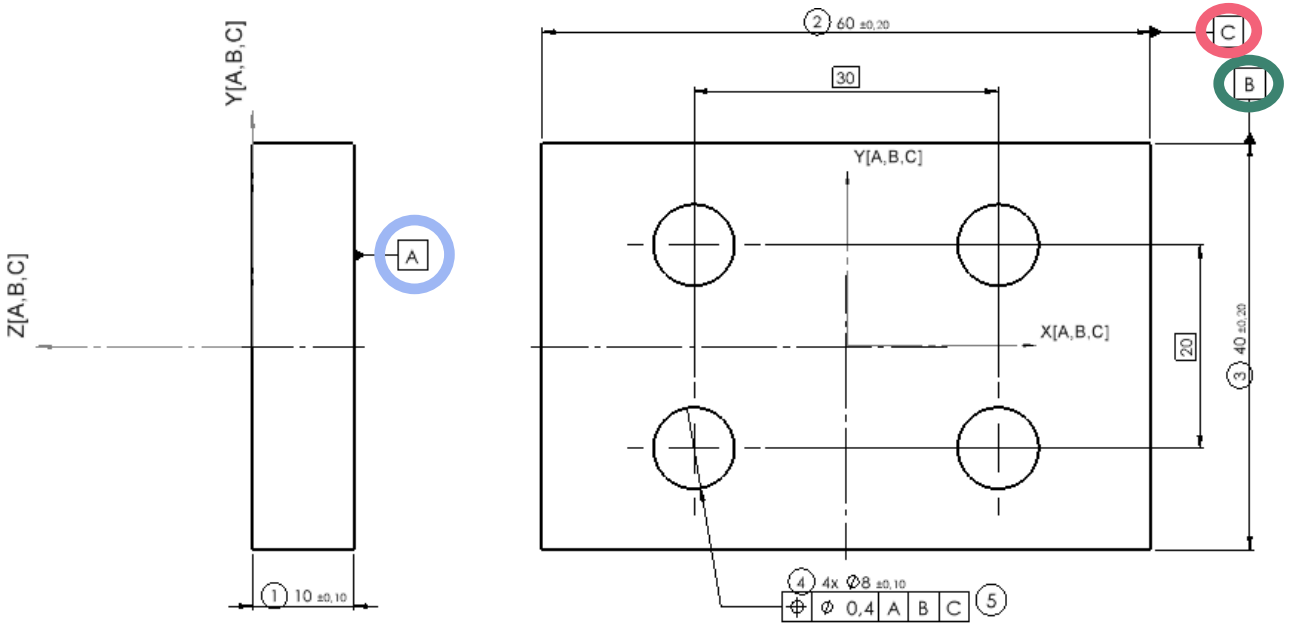
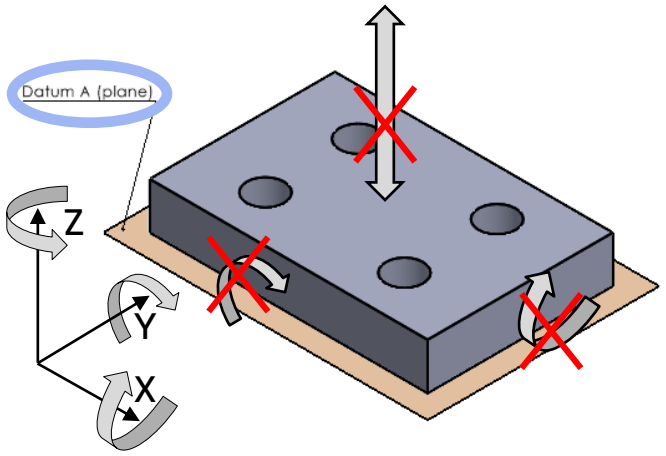
# General 3–2–1 Datum Reference Frame.

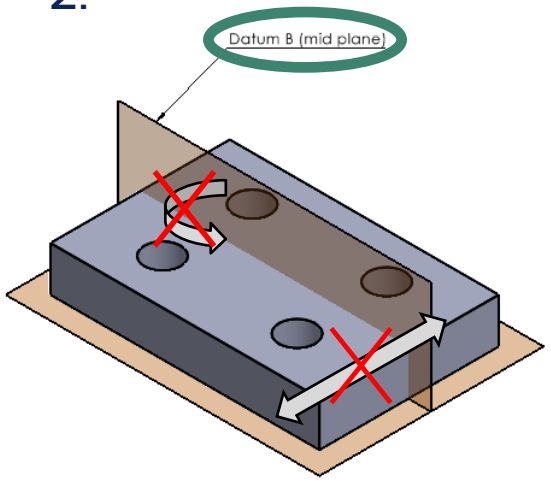



1. The bottom surface of the part defines the primary datum plane [A], which controls three *Degrees Of Freedom*: **Translation along Z-axis and rotation about axes X and Y.**
2. Datum [B] is defined by datum feature 40±0,2 (dim.3). Datum [B] is perpendicular to datum plane [A] and controls two *DOFs*: **Translation along axis Y and rotation about axis Z.**
3. Datum [C] is defined by datum feature 60±0,2 (dim.2) Datum [C] is perpendicular to datums [A] & [B] and controls the last degree of freedom: **Translation along X –axis.**

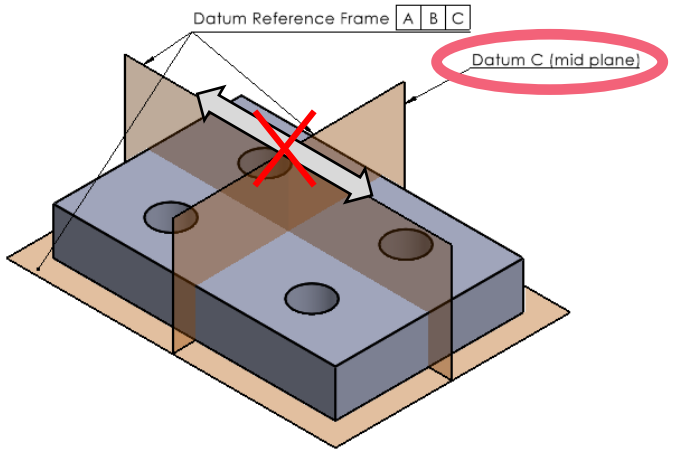
1.




2.




3.

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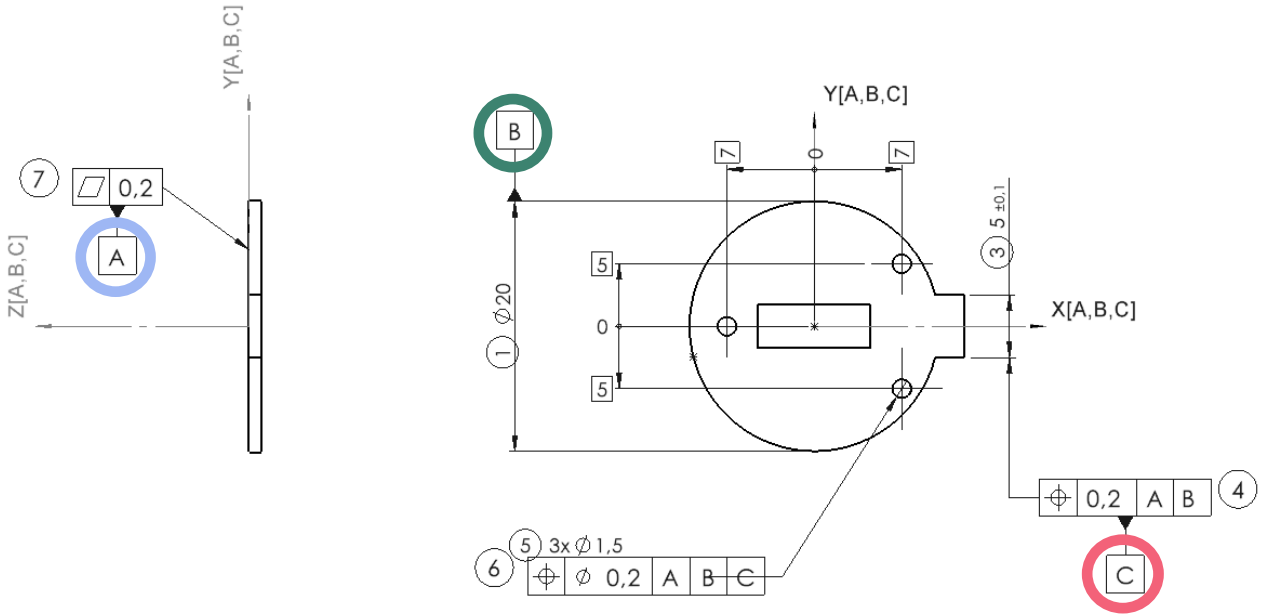
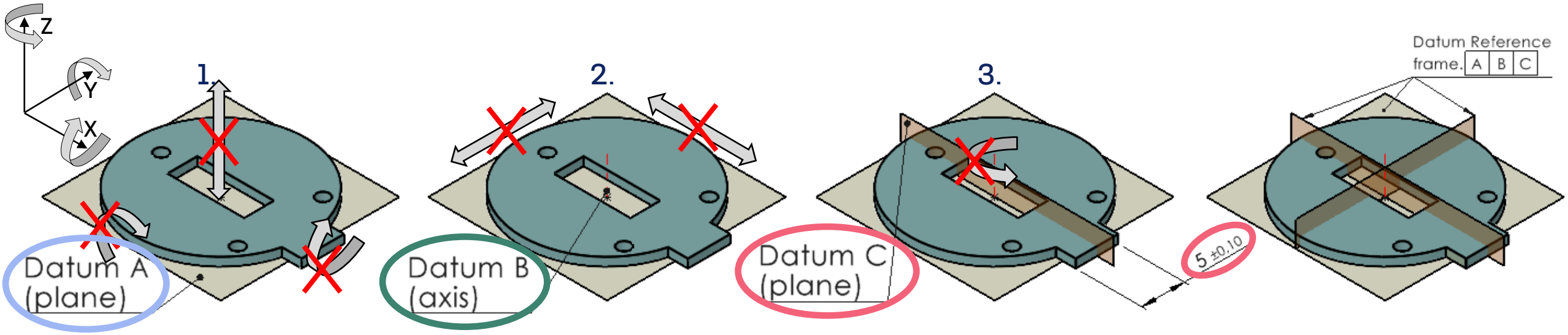
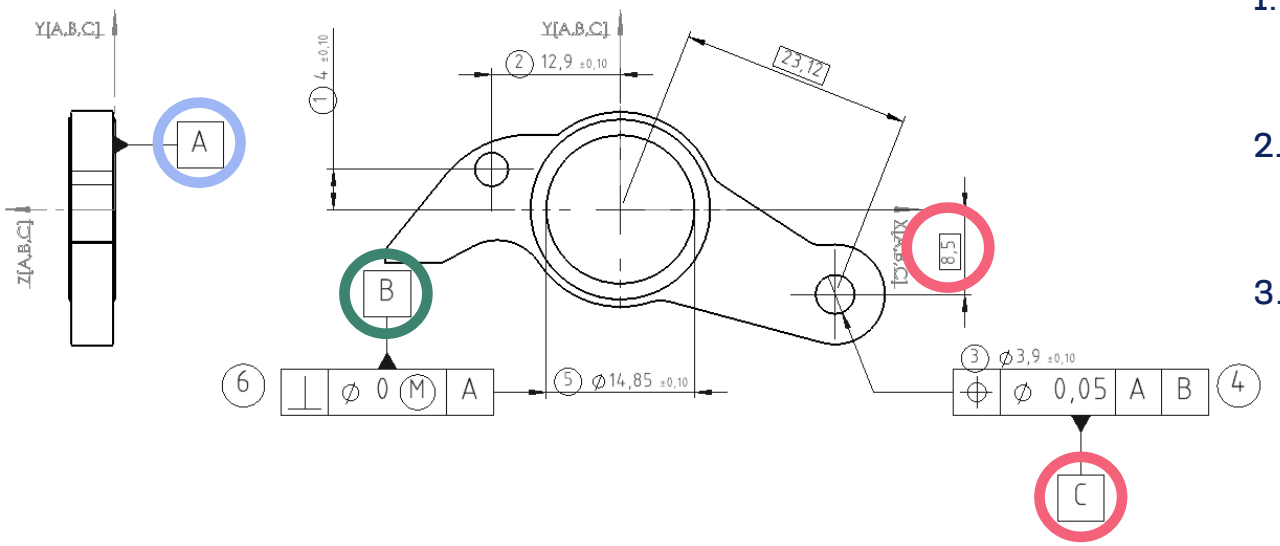
# General 3–2–1 Datum Reference Frame with rotational constraint.



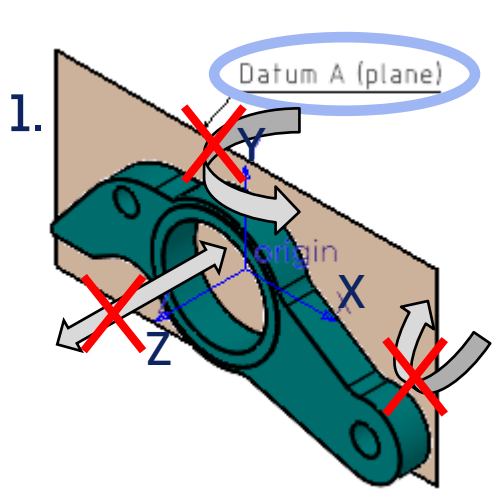

1. The bottom surface of the part defines the primary datum plane [A], which controls three *Degrees Of Freedom*: **Translation along Z–axis and rotation about axes X and Y.**
2. Datum axis [B] is defined by datum feature ø20 (dim.1). This datum is perpendicular to datum plane [A] and controls two *DOFs*: **Translation along axes Y and X.**
3. Datum [C] is defined by mean point of mid plane of datum feature 5±0,1 (dim.3). Datum [C] is coplanar with datum (axis) [B] and perpendicular to datum A. This datum controls the last degree of freedom: **Rotation about Z – axis** and determines the angular position of datum reference frame.

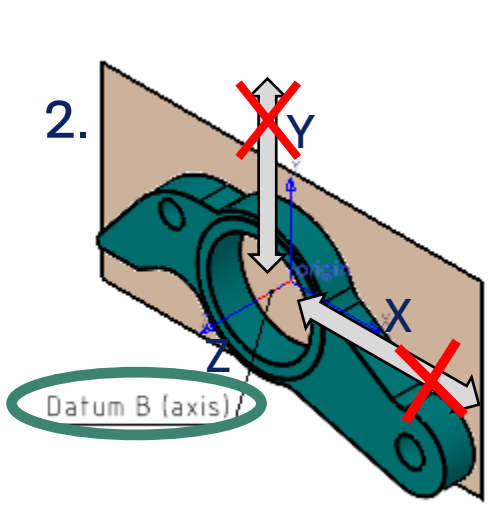


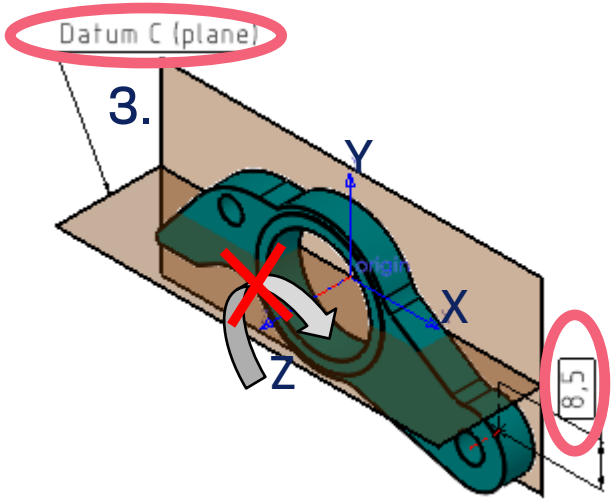
# Customized 3–2–1 Datum Reference Frame with rotational constraint by TED

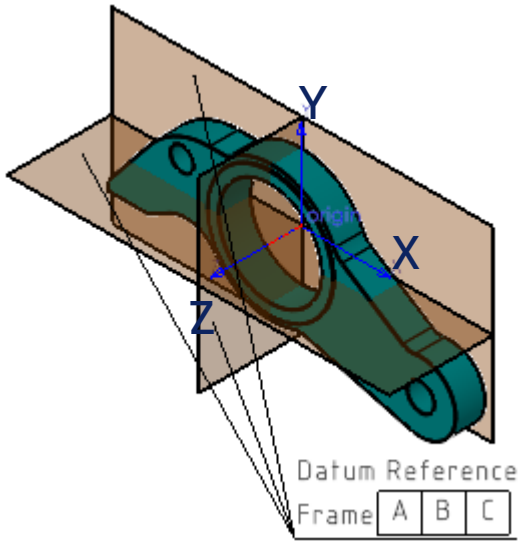



1. The side surface of the part defines the primary datum plane [A], which controls three *Degrees Of Freedom*: **Translation along Z–axis and rotation about axes X and Y.**
2. Datum axis [B] is defined by datum feature ø14,85 (dim.5). This datum is perpendicular to Datum plane [A]. Datum [B] controls two *DOFs*: **Translation along axes Y and X.**
3. Datum [C] is defined by mean point of axis of datum feature ø 3,9 (dim.4). Datum is coplanar with datum axis [B] and perpendicular to datum plane [A]. TED dimension 8,5 determines the angular position of Datum [C] and the datum reference frame. This is the last datum of DRF and controls the last degree of freedom: **Rotation about Z –axis.**

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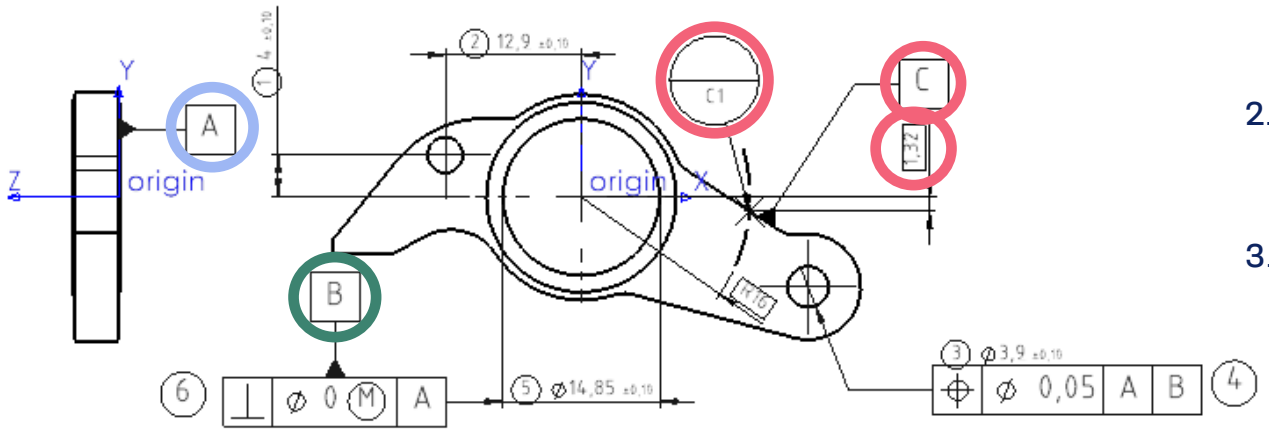
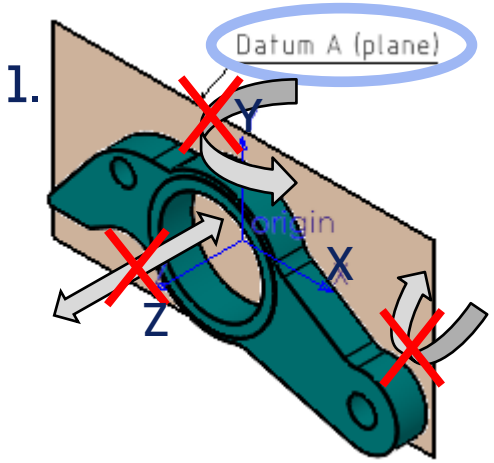
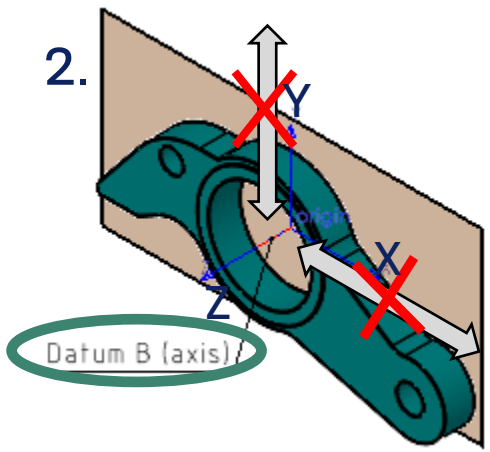
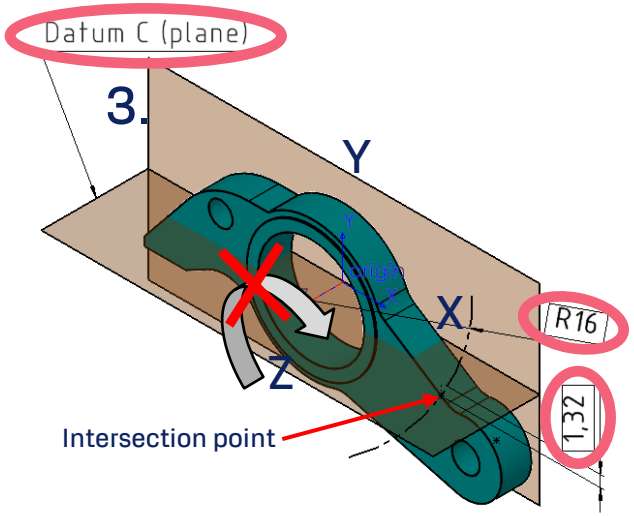
# Customized 3–2–1 Datum Reference Frame with rotational constraint by specific point.

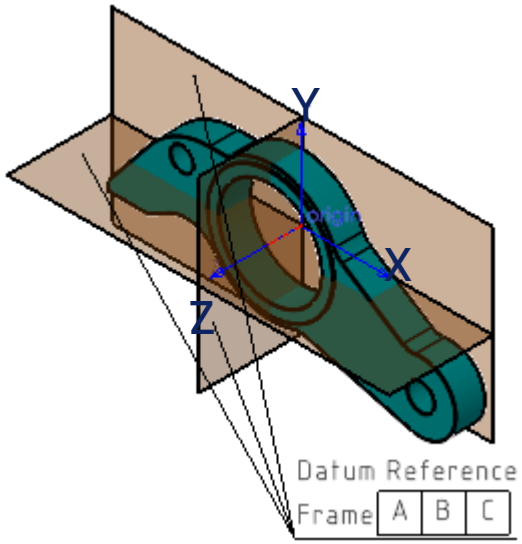



1. The side surface of the part defines the primary datum plane [A], which controls three *Degrees Of Freedom*: **Translation along Z–axis and rotation about axes X and Y.**
2. Datum axis [B] is defined by datum feature ø14,85 (dim.5). This datum is perpendicular to Datum plane [A]. Datum [B] controls two *DOFs*: **Translation along axes Y and X.**
3. The angular position of datum [C] is defined by specifying the position of intersection of R16 and the part outline to 1,32mm perpendicular from the X – axis of the coordinate system. Datum is coplanar with datum axis [B] and perpendicular to datum plane [A]. This is the last datum of DRF and controls the last degree of freedom: **Rotation about Z –axis.**

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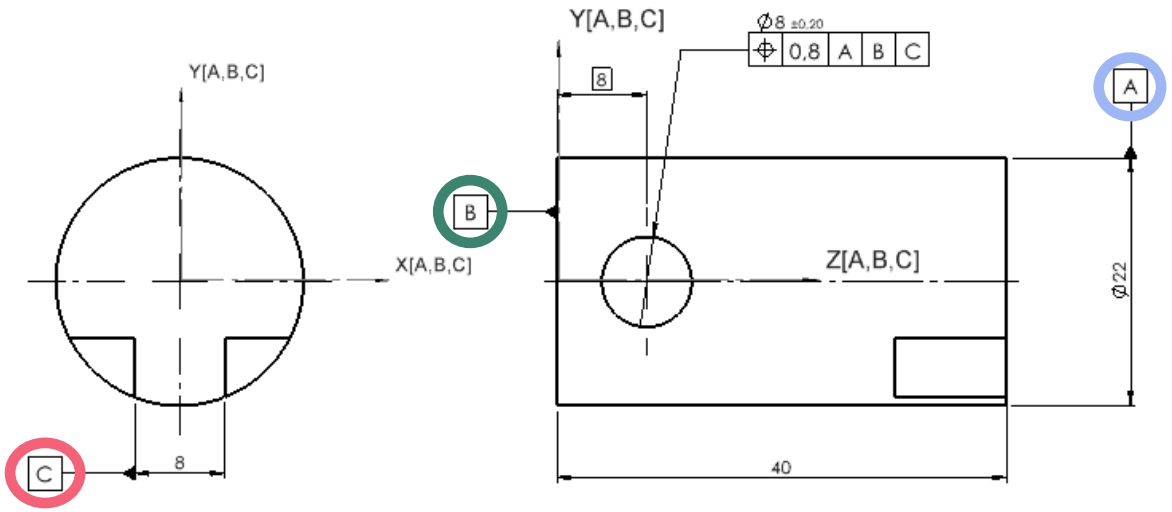
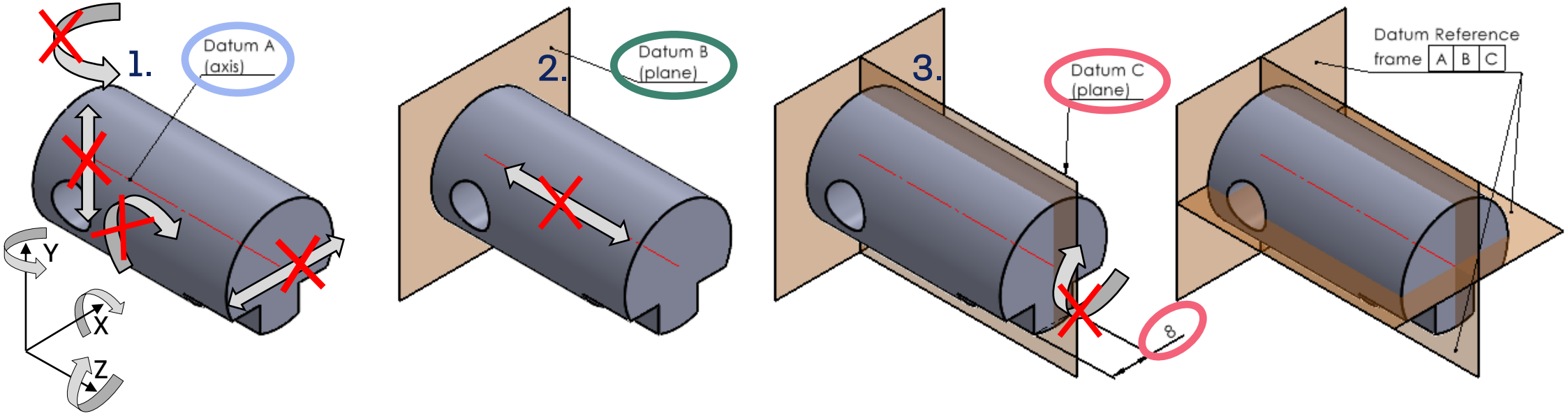
# General 4–1–1 Datum Reference Frame with rotational constraint for axis




1. ø22mm cylinder feature defines the primary datum axis [A], which controls four *Degrees Of Freedom*:
   - **Translation along axes X & Y.**
   - **Rotation about axes X & Y.**
2. Datum plane [B] is defined by the end surface of part. This datum is perpendicular to Datum axis [A] and controls one *Degree Of Freedom*: **Translation along axis Z.**
3. Datum [C] is defined by the mean point of mid plane of two surfaces 8mm apart. Datum [C] is coplanar with Datum axis [A] and perpendicular to Datum plane [B]. Datum [C] controls the last degree of freedom: **Rotation about Z –axis.**

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# DEFINITIONS AND REPORTING OF GEOMETRICAL TOLERANCES

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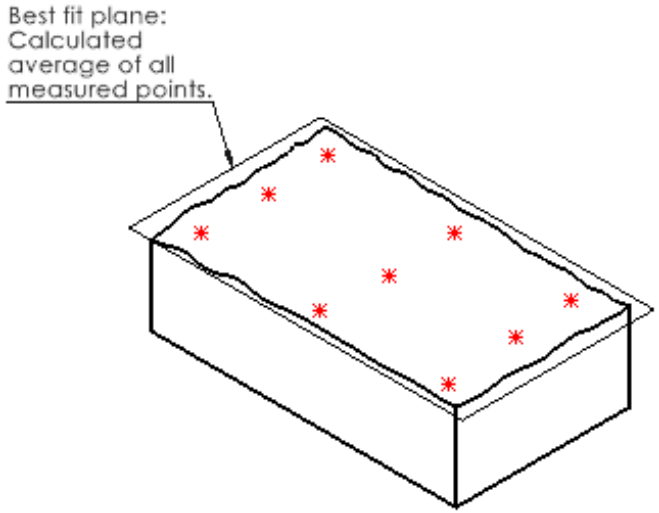
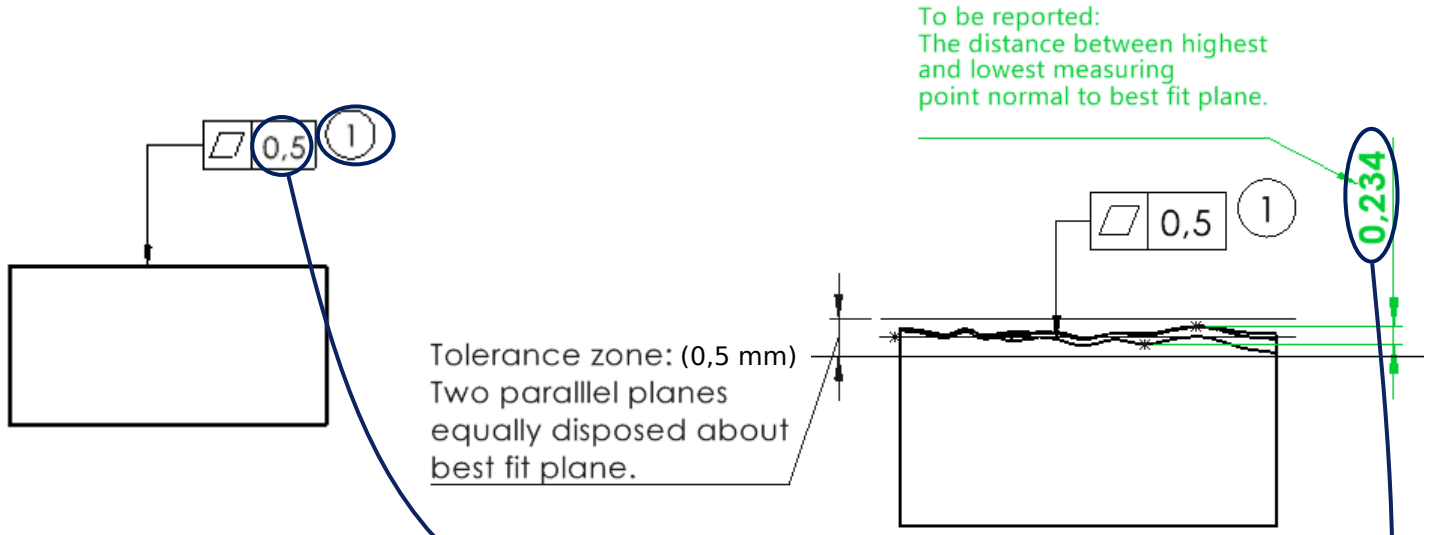
# Flatness

- The tolerance zone is limited by two parallel planes a distance 0,5 mm apart.
- The extracted (actual) surface shall be contained between two parallel planes 0,5 mm apart.




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | |
| **Drawing Rev:** | | | | | | | | |
| **Cavity number:** | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production ba |
| | | | | | | | | |
| DIM ID # | Ongoing insp/Cpk Study dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 |
| 1 | No | 0,000 | 0,375 | 0,0000 | 0,000 | 0,500 | 0,0000 | 0,2340 |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | |

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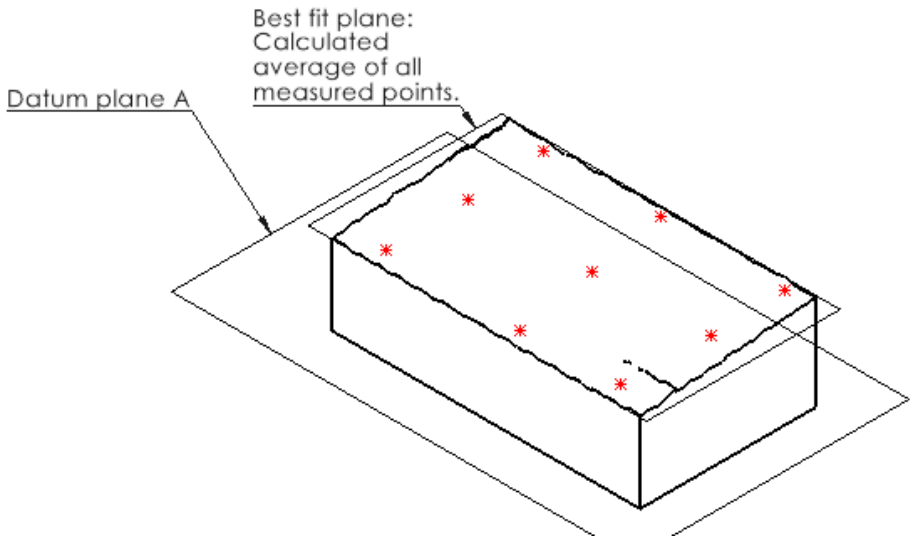
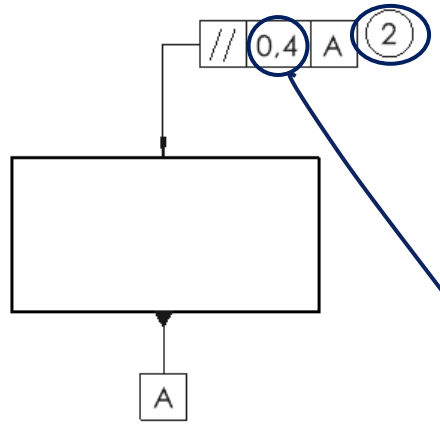
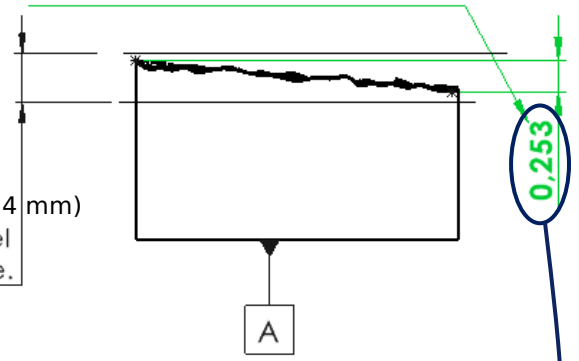
# Parallelism

- The tolerance zone is limited by two parallel planes a distance 0,4 mm apart and parallel to the datum plane A
- The extracted (actual) surface shall be contained between two parallel planes 0,4 mm apart, which are parallel to datum plane A




To be reported:
The distance between nearest and furthest measuring point normal to reference plane (Datum A).

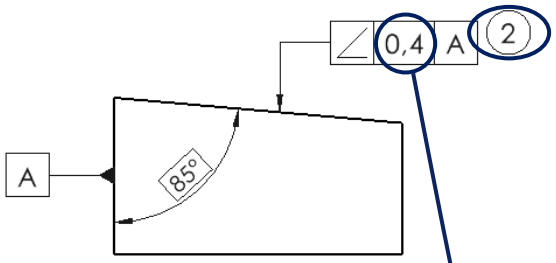



Tolerance zone: (0,4 mm)
Two planes parallel to reference plane.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | | |
| **Drawing Rev:** | | | | | | | | | |
| **Cavity number:** | | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production bat | |
| DIM ID # | Ongoing insp/Cpk Study, dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 2 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,2530 | |
| 3 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | |

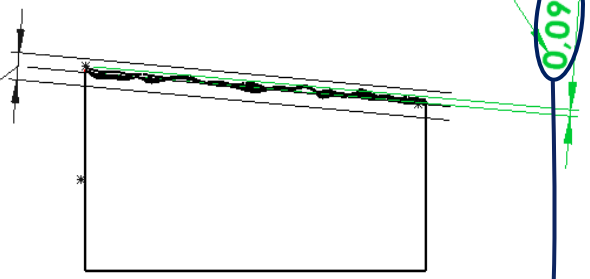
# Angularity

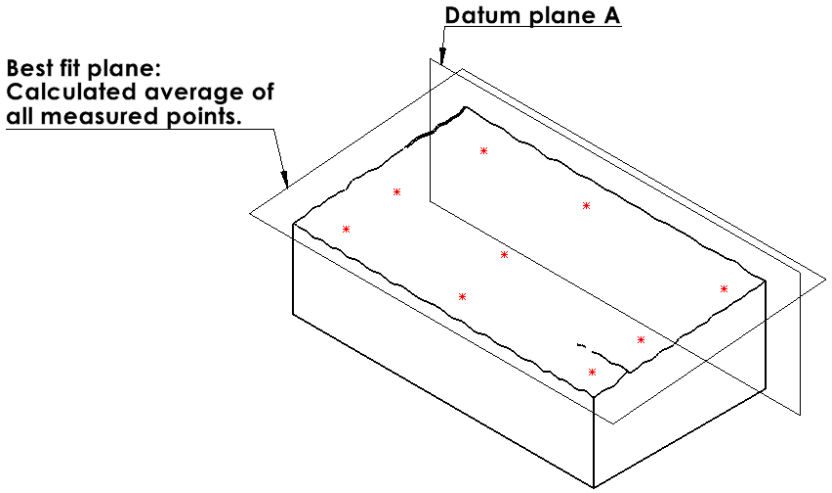
- The tolerance zone is limited by two parallel planes a distance 0,4 mm apart and inclined at the specified angle to the datum A.
- The extracted (actual) surface shall be contained between two parallel planes 0,4 mm apart that are inclined at a theoretically exact angle of 85º to datum plane A.




To be reported:
The largest distance between the measured points, measured in the angle 85 ° to the reference (best fit) plane.

Tolerance zone: (0,4 mm)
Two parallel planes, in the angle 85 ° to reference plane A.

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| **Alternate ID:** | | | | | | | | |
| **Drawing Rev:** | | | | | | | | |
| **Cavity number:** | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production batch |
| DIM ID # | Ongoing insp/Cpk Study, dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 2 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,0930 |
| 3 | No | 0,000 | 0,000 | | | | 0,0000 | |

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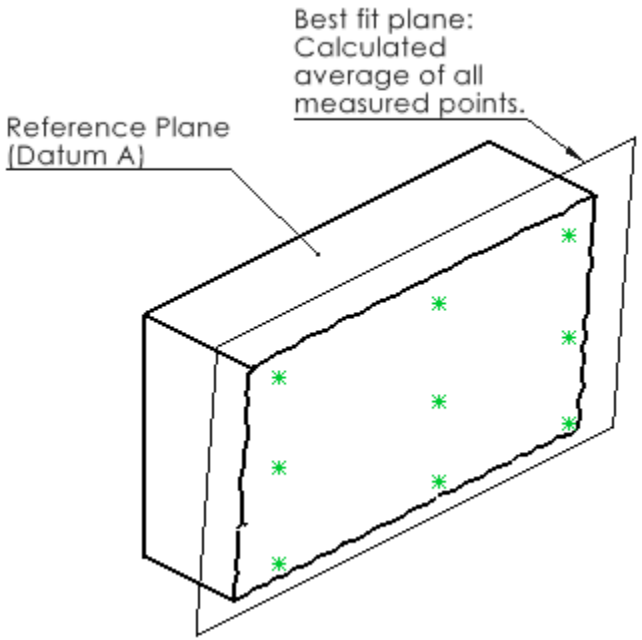
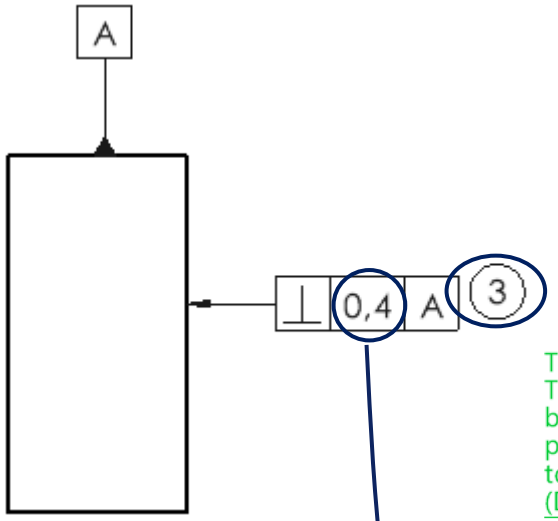
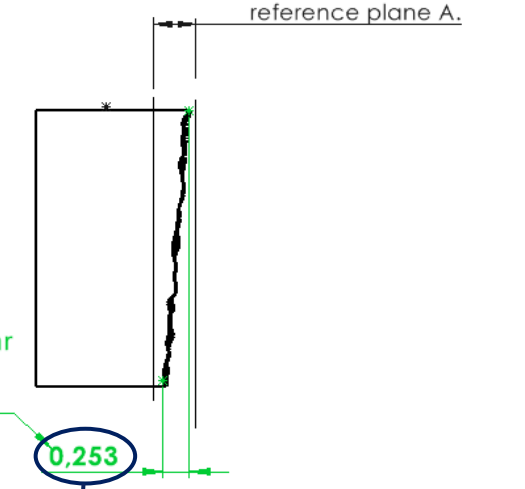
# Perpendicularity

- The tolerance zone is limited by two parallel planes a distance 0,4 mm apart and perpendicular to the datum A.
- The extracted (actual) surface shall be contained between two parallel planes 0,4 mm apart, which are perpendicular to datum plane A.




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | | |
| **Drawing Rev:** | | | | | | | | | |
| **Cavity number:** | | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production bat | |
| DIM ID # | Ongoing insp/Cpk Study. dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 3 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,2530 | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | |

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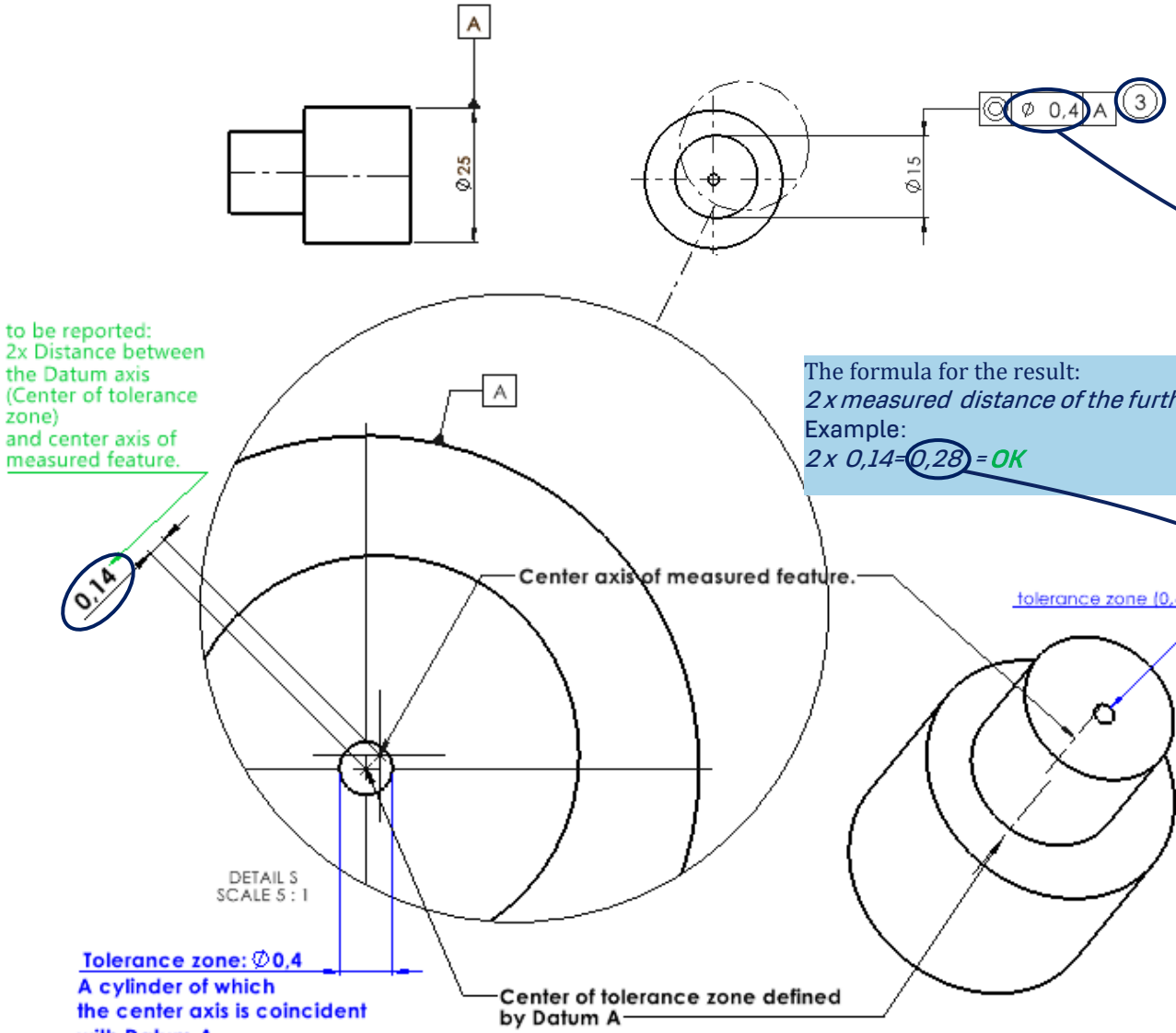
# Coaxiality

- The extracted (actual) median line of the toleranced cylinder shall be within a cylindrical zone of diameter 0,4 mm, the axis of which is datum axis A.




The formula for the result:
*2 x measured distance of the furthest point*
Example:
*2 x 0,14=0,28 = OK*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | |
| **Drawing Rev:** | | | | | | | | |
| **Cavity number:** | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production bat |
| DIM ID # | Ongoing insp/Cpk Study dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 3 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,2800 |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 5 | No | 0,000 | 0,000 | | | | 0,0000 | |

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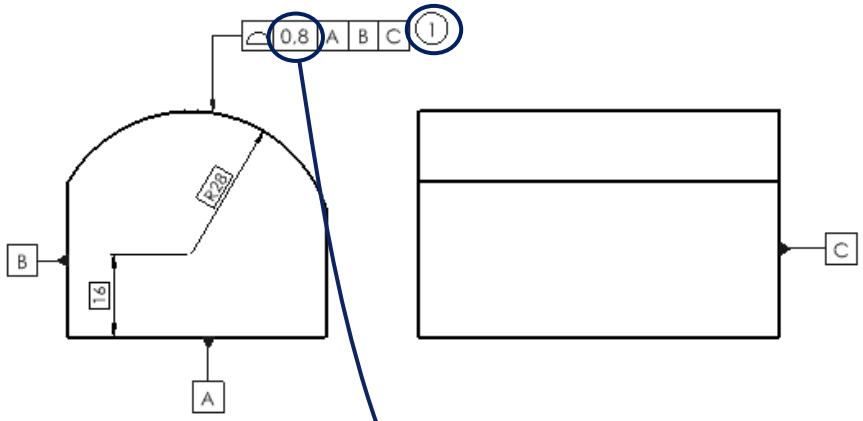
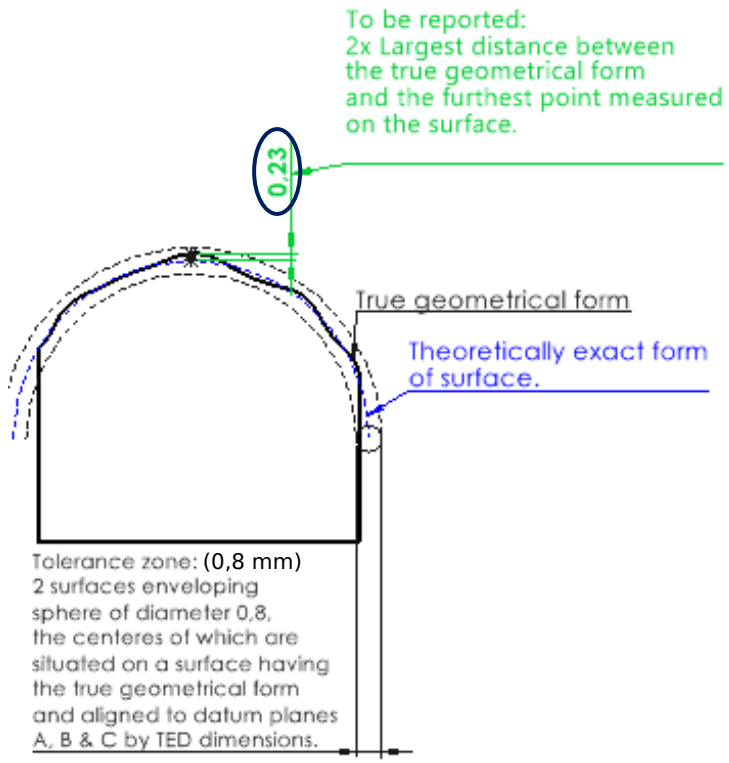
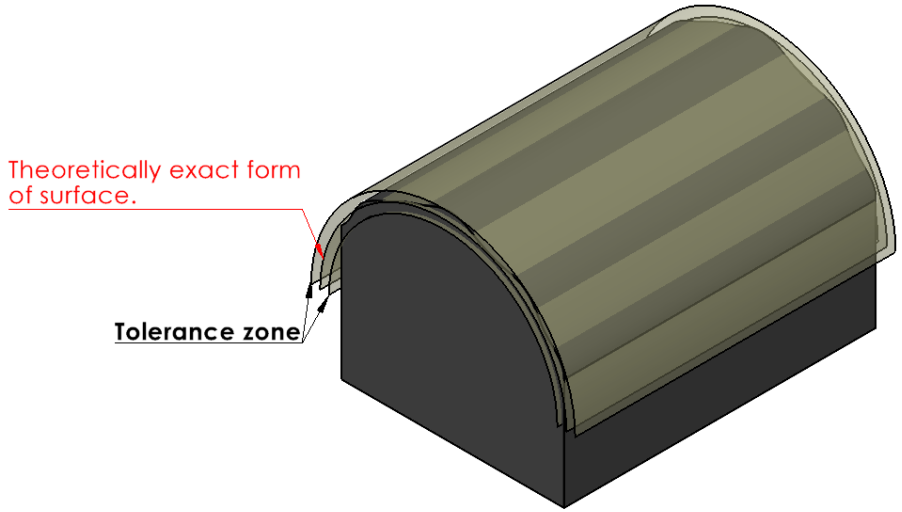
# Surface profile

- 3–Dimensional tolerance zone existing of 2 parallel surface curves that follow the contour of the surface profile across the entire length of the surface. This tolerance zone may or may not be referenced by a datum. Tolerance zone may or may not be referenced by a datum.
- Profile is usually measured using a CMM due to the complexity of some of the surfaces that are called out. The CMM would compare the 3D scan of the profile to the dimensions called out on the drawing to see if it was in spec.



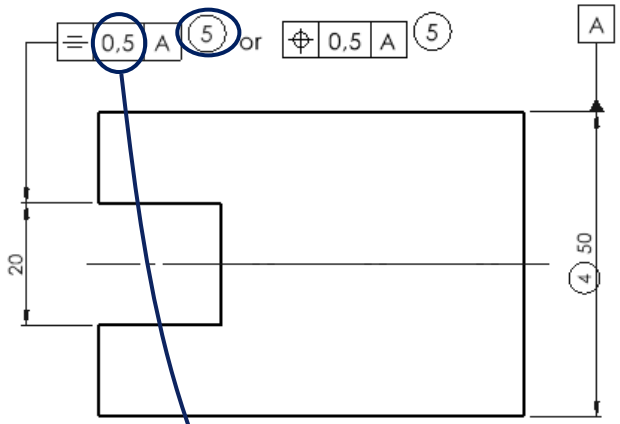



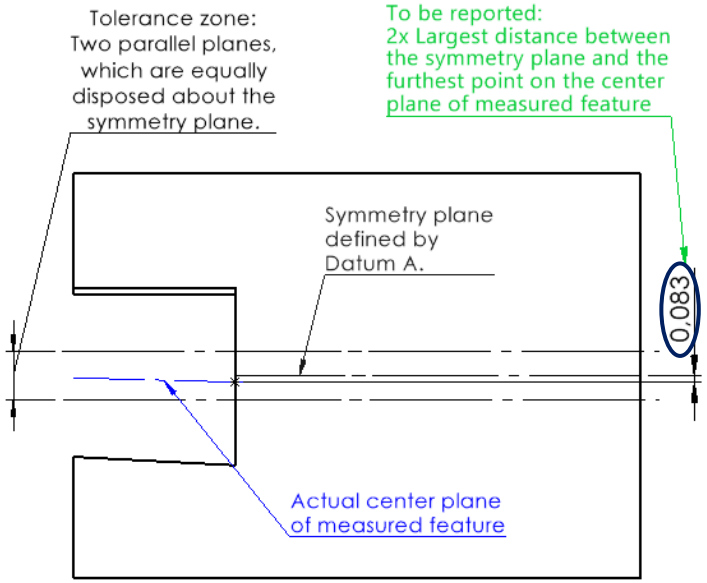

The formula for the result:
*2 x measured distance of the furthest point*
Example:
*2 x 0,23=0,46 = OK*

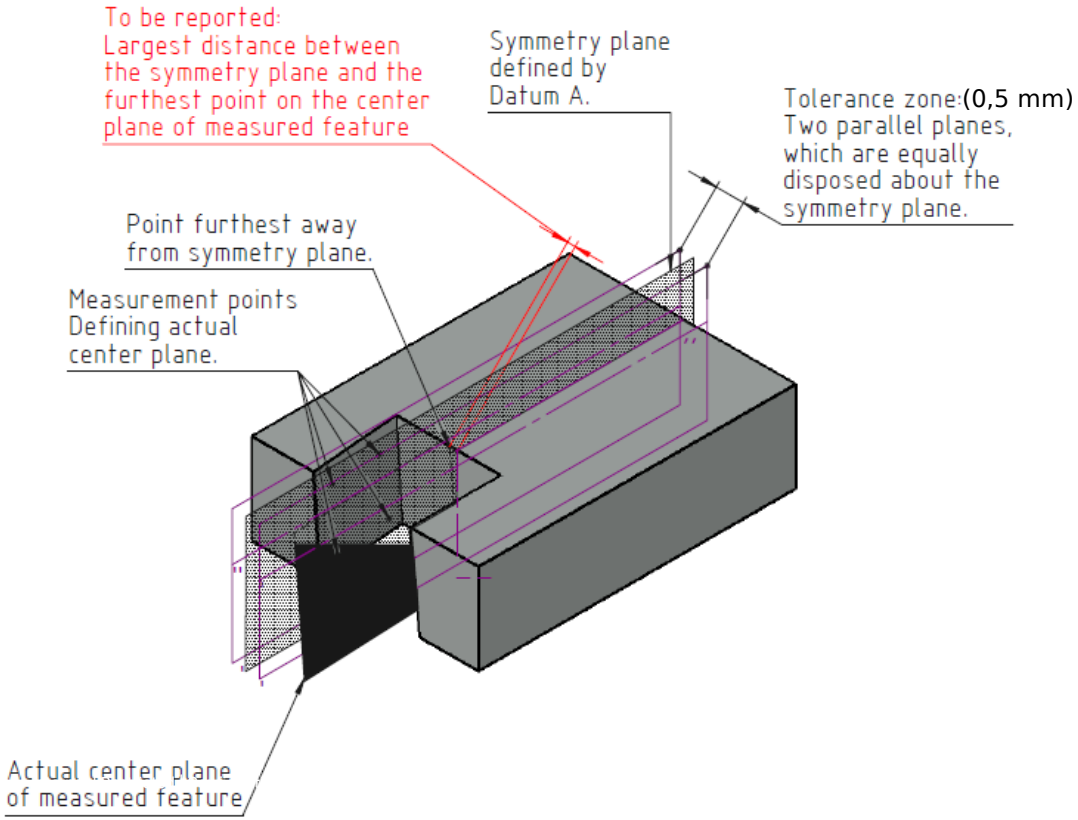
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | |
| **Drawing Rev:** | | | | | | | | |
| **Cavity number:** | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production batc |
| DIM ID # | Ongoing insp/Cpk Study dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 |
| 1 | No | 0,000 | 0,600 | 0,0000 | 0,000 | 0,800 | 0,0000 | 0,4600 |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 3 | No | 0,000 | 0,000 | | | | 0,0000 | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | |

# Symmetry (or position)

- The extracted (actual) median surface shall be contained between two parallel planes 0,5 mm apart, which are symmetrically disposed about datum plane A.




The formula for the result:
*2 x measured distance of the furthest point*
Example:
*2 x 0,083 = 0,166 = OK*

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| **Alternate ID:** | | | | | | | | | |
| **Drawing Rev:** | | | | | | | | | |
| **Cavity number:** | | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production batch | |
| DIM ID # | Ongoing insp/Cpk Study , dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 3 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 5 | No | 0,000 | 0,375 | 0,0000 | 0,000 | 0,500 | 0,0000 | 0,1660 | |
| 6 | No | 0,000 | 0,000 | | | | 0,0000 | | |

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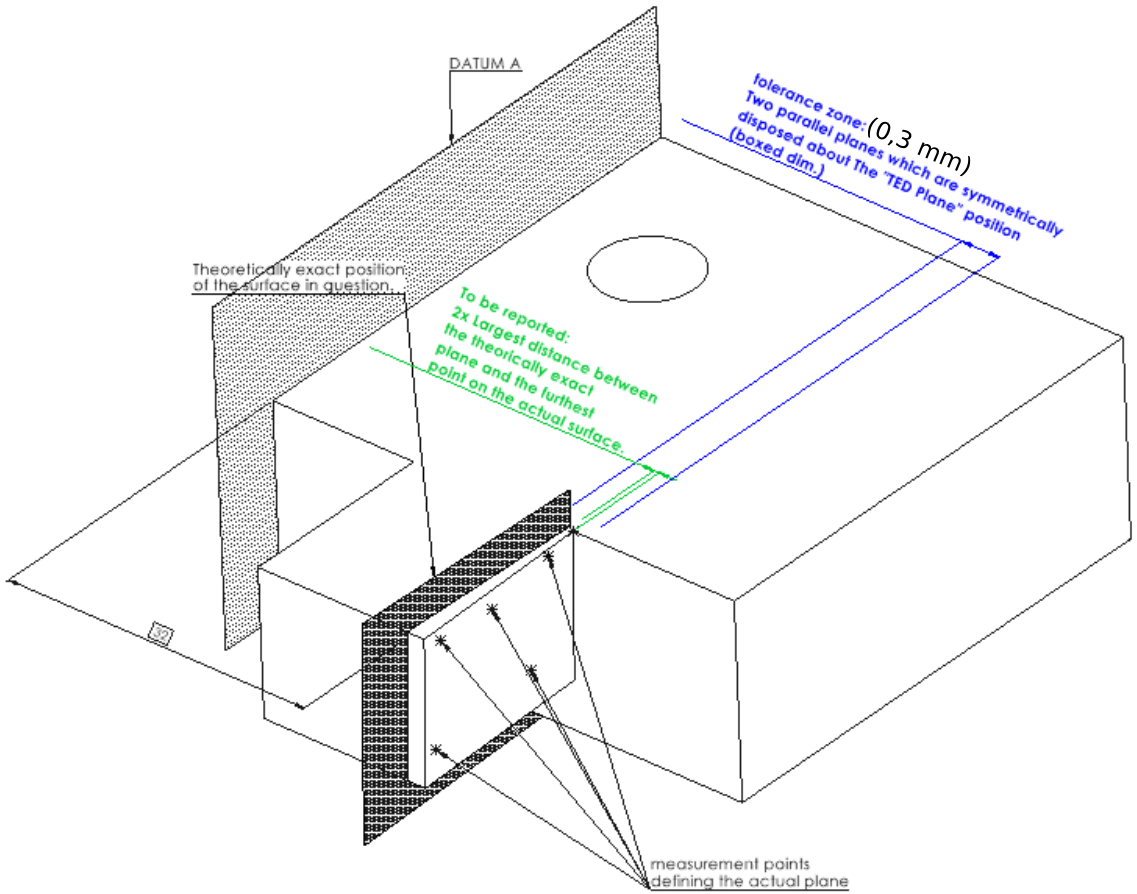
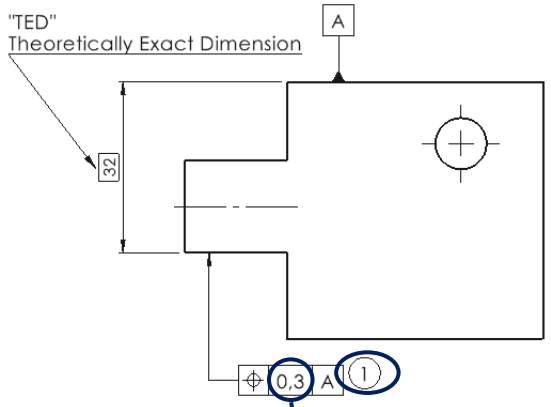
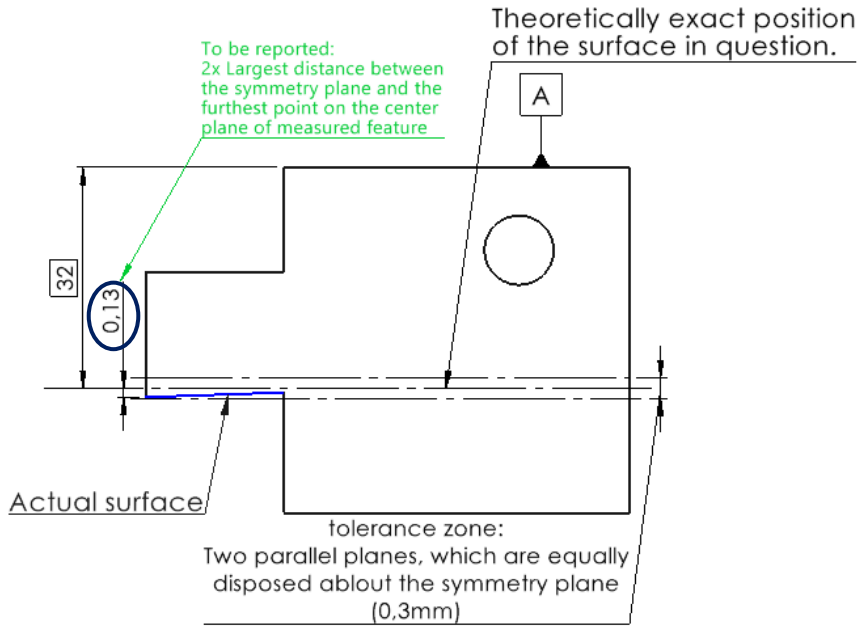
# Position

- Tolerance zone is defined by two parallel planes which are oriented at the specified distance in relation to a datum. All points on the referenced surface must fall into this tolerance zone.




The formula for the result:
*2 x measured distance of the furthest point*
Example:
*2 x 0,13 = 0,26 = OK*

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| **Document ID:** | | | | | | | | Email: | |
| **Alternate ID:** | | | | | | | | | |
| **Drawing Rev:** | | | | | | | | | |
| **Cavity number:** | | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production batch | |
| DIM ID # | Ongoing insp/Cpk Study . dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | |
| 1 | No | 0,000 | 0,225 | 0,0000 | 0,000 | 0,300 | 0,0000 | 0,2600 | |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 3 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 5 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 6 | No | 0,000 | 0,000 | | | | 0,0000 | | |

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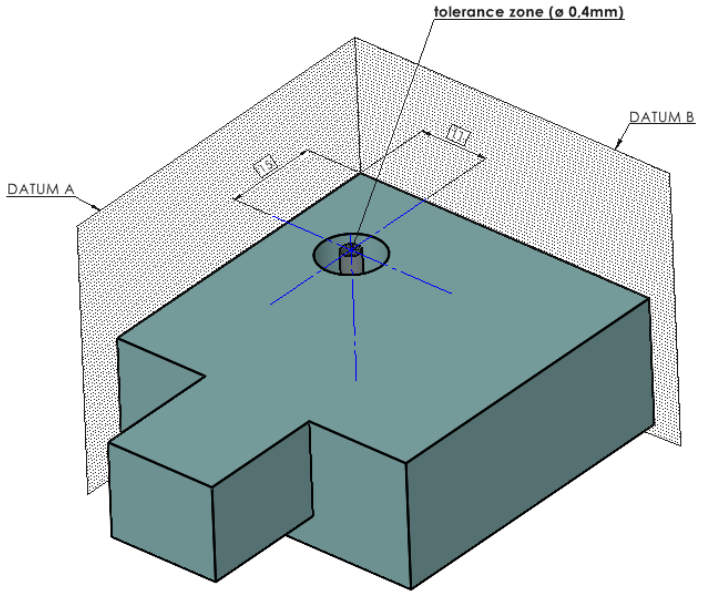
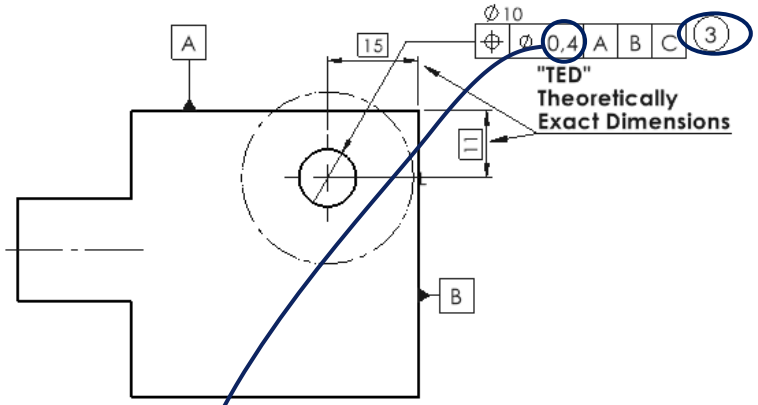
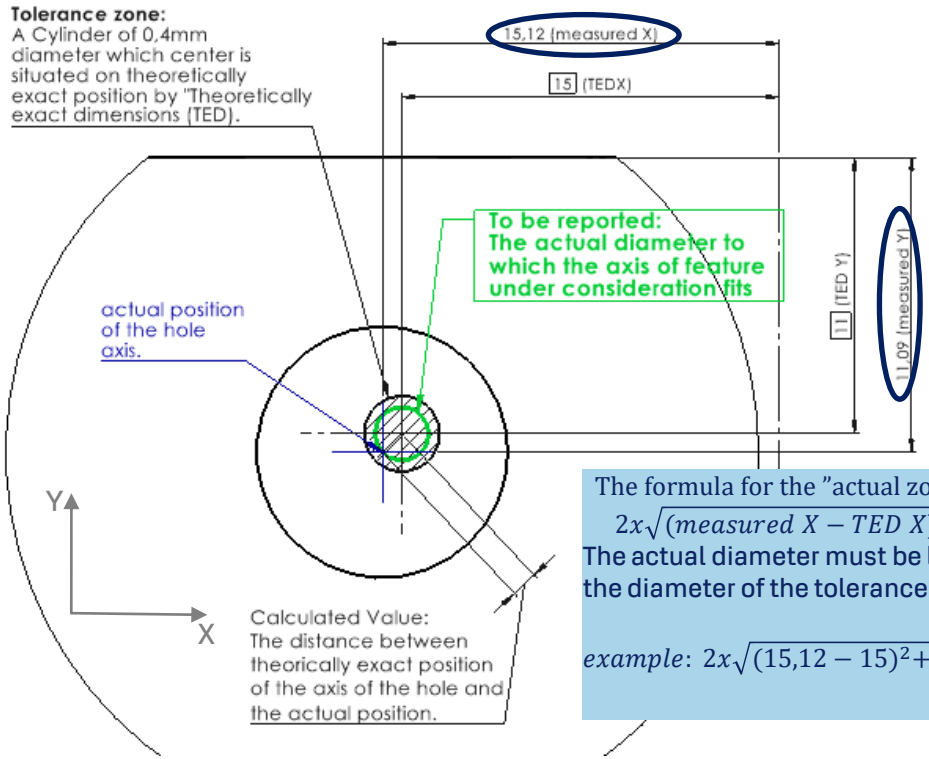
# Position with circular tolerance zone

- Position in terms of the axis, point or plane defines how much variation a feature can have from a specified exact true location.
- The tolerance is a 2 or 3-Dimensional tolerance zone that surrounds the true location where a feature must lie.




The formula for the "actual zone diameter":

$$2x\sqrt{(measured\ X - TED\ X)^2+(measured\ Y - TED\ Y)^2}$$

The actual diameter must be less than the diameter of the tolerance zone

$$example:\ 2x\sqrt{(15{,}12 - 15)^2+(11{,}09 - 11)^2} = 0{,}3$$ = OK

| | |
|---|---|
| **Alternate ID:** | |
| **Drawing Rev:** | |
| **Cavity number:** | |
| **Tool ID:** | Date of measurement: (dd.mm.yyyy) |
| | Production batch ID or Date: (dd.mm.yyy) |

| DIM ID # | Ongoing insp/Cpk Study. dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |
| 3 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,3000 | | | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |
| 5 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |
| 6 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |
| 7 | No | 0,000 | 0,000 | | | | 0,0000 | | | | |

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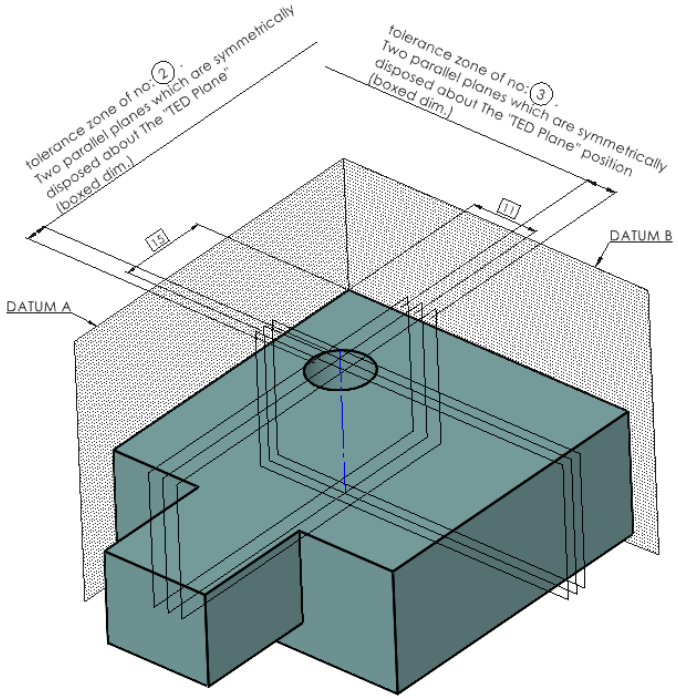
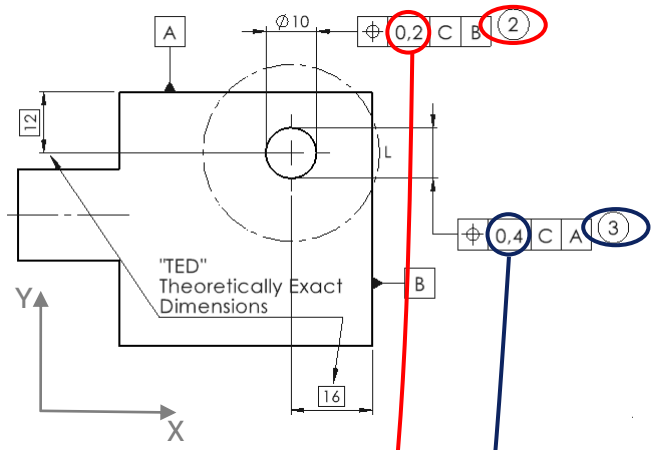
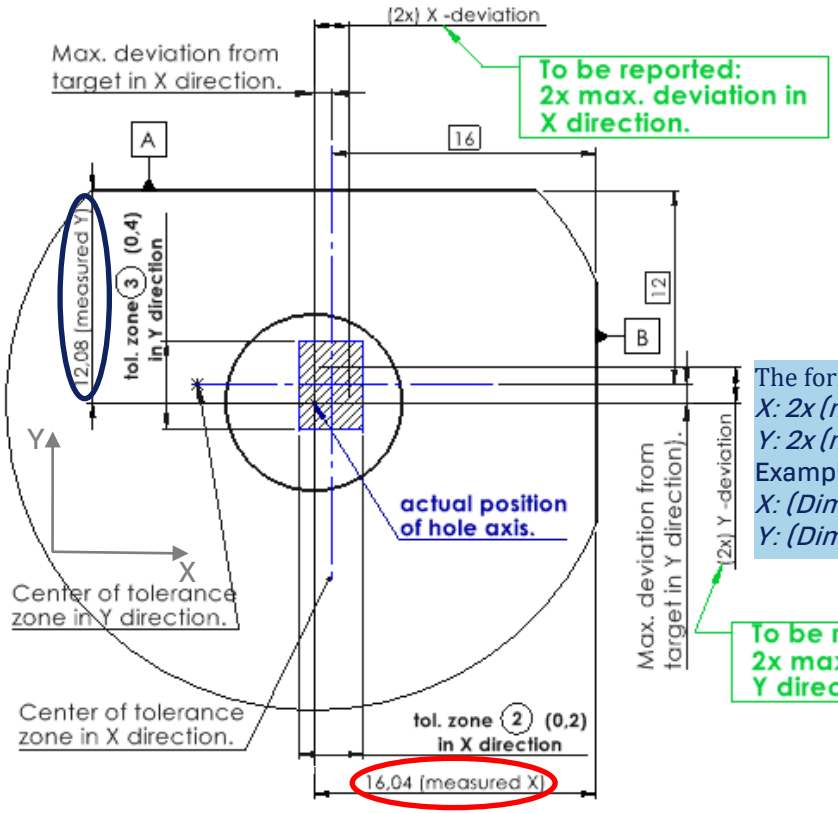
# Position plane (2 axis)

- Position in terms of the axis, point or plane defines how much variation a feature can have from a specified exact true location.
- The tolerance is a 2 or 3-Dimensional tolerance zone that surrounds the true location where a feature must lie.




The formula for the result:
*X: 2x (measured X – TED X)*
*Y: 2x (measured Y – TED Y)*
Example:
*X: (Dim2)= 2x (16,04-16) = 0,08 = OK*
*Y: (Dim3)= 2x (12,08-12) = 0,16 = OK*

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| **Alternate ID:** | | | | | | | | | |
| **Drawing Rev:** | | | | | | | | | |
| **Cavity number:** | | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production batch ID | |
| DIM ID # | Ongoing insp/Cpk Study. dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 | 2 |
| 1 | No | 0,000 | 0,000 | | | | 0,0000 | | |
| 2 | No | 0,000 | 0,150 | 0,0000 | 0,000 | 0,200 | 0,0000 | 0,0800 | |
| 3 | No | 0,000 | 0,300 | 0,0000 | 0,000 | 0,400 | 0,0000 | 0,1600 | |
| 4 | No | 0,000 | 0,000 | | | | 0,0000 | | |

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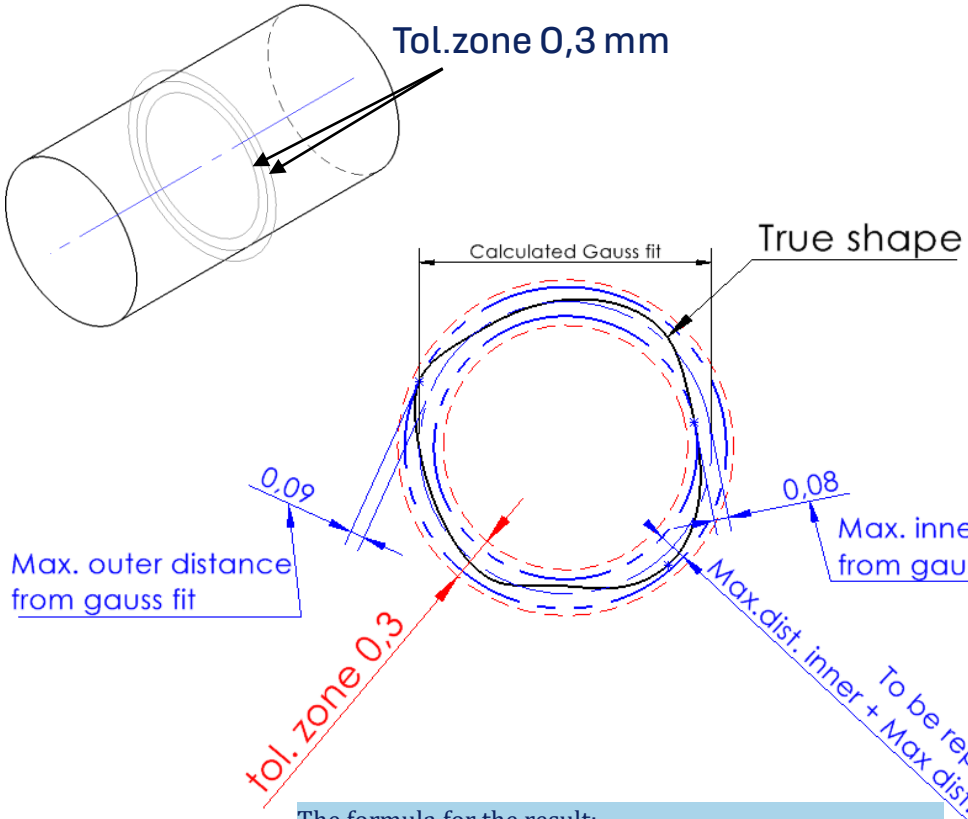
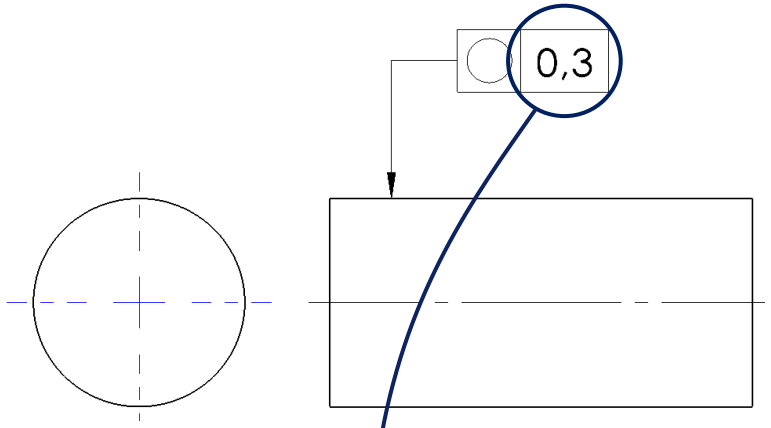
# Circularity

- For the cylindrical (or conical) surfaces, the extracted ( actual) circumferential line, in any cross. Section of the surfaces, shall be contained between two coplanar concentric circles, with a different in radii of 0,3 mm.




The formula for the result:
*Roundness = max. Outer + max. Inner*
Example:
*Roundness = 0,09 + 0,08 = 0,017 = OK*




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alternate ID:** | | | | | | | | |
| **Drawing Rev:** | | | | | | | | |
| **Cavity number:** | | | | | | | | |
| **Tool ID:** | | | | Date of measurement: (dd.mm.yyyy) | | | | Production bat |
| DIM ID # | Ongoing insp/Cpk Study. dim? (Y/N) | Tightened Lower limit -25,0 % | Tightened Upper limit -25,0 % | Nominal | Lower tol. | Upper tol. | Target | 1 |
| 1 | No | 0,000 | 0,225 | 0,0000 | 0,000 | 0,300 | 0,0000 | 0,1700 |
| 2 | No | 0,000 | 0,000 | | | | 0,0000 | |

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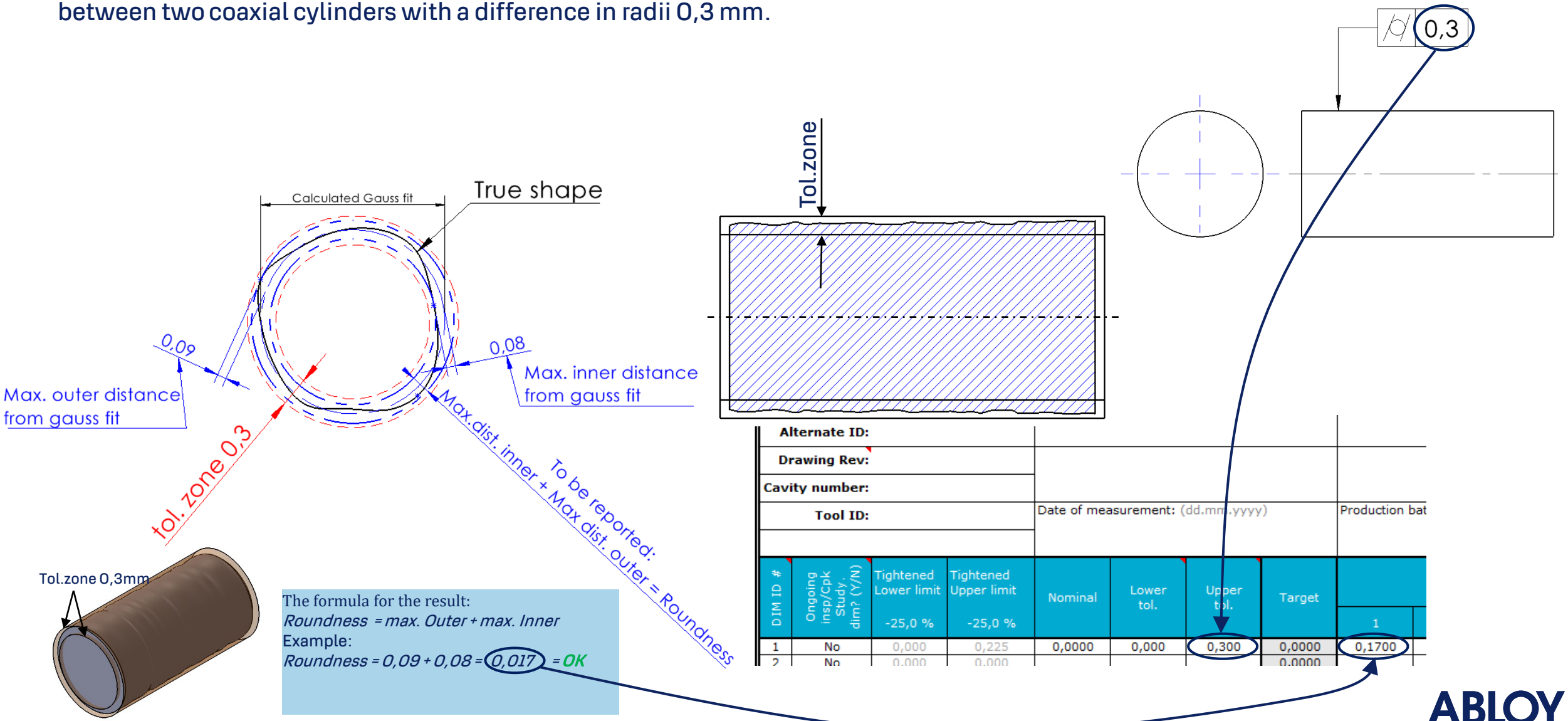
# Cylindricity

- The extracted (true shape) cylindrical surface shall be contained between two coaxial cylinders with a difference in radii 0,3 mm.

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