



# Geometrical Product Specifications (GPS) – Consequences on the Tolerancing of Features of Size

## Preface

The first three articles of this series offered an overview of fundamental standards of the GPS concept required to describe geometrical characteristics. These three articles are:

- [Geometrical Product Specifications \(GPS\) – an incomplete survey](#)
- [Geometrical Product Specifications \(GPS\) – ISO 8015 basic GPS standard](#)
- [Geometrical Product Specifications \(GPS\) - ISO 14405-1, the general GPS standard for dimensional tolerancing of linear sizes](#)

After the GPS standard for dimensional tolerancing of linear sizes (ISO 14405-1) such as circle, cylinder, ball, pair of parallel lines and pair of parallel opposite surfaces had been published in April 2011, the German Institute for Standardisation withdrew DIN 7167 “Relationship between tolerances of size, form, and parallelism; envelope requirement without individual indication on the drawing” in November of the same year. The envelope requirement in drawings based on authorised DIN standards was thus no longer universally valid. People being less acquainted with this topic, however, were hardly able to identify the consequences. There is still the risk of agreeing on an entire GPS system (principle 1 according to ISO 8015) by applying the invocation principle and quoting a standard of the system. You thus accept the independency principle (principle 5 according to ISO 8015), which becomes binding, and the envelope requirement becomes invalid. This article informs you about the associated relationships and the predictable consequences.

## Former drawing specifications

It was common practice in many German companies to tolerate the envelope requirement for linear sizes of the geometric elements cylinder, circle, ball, parallel lines and parallel opposite surfaces without any drawing indication referring to DIN 7167.

Chapter 2 of this standard says that the envelope requirement without individual indication on the drawing applies to all single geometric elements on drawings based on DIN standards about tolerances and fits that do not include any contrary specifications. A single feature of size must not push or even tear the perfect (geometrically ideal) envelope with the maximum material size of the dimensional tolerance interval.

In order to prove that this construction requirement is met at the part, companies used to apply the Taylor Principle (go plug gauge, go snap gauge, go ring gauge). Negative effects of form and location deviations on mating parts can thus be excluded; especially those effects that cannot be identified in a two-point measurement, such as triangular cylinders, curved cylinders or curved surfaces.

The drawing below (Figure 1) shows a flange bushing as published in May 2001. This drawing does not have any individual indication, so it applies the envelope requirement since characteristics 2 and 6 are fits referring to standards about tolerances and fits (ISO 286:1990).

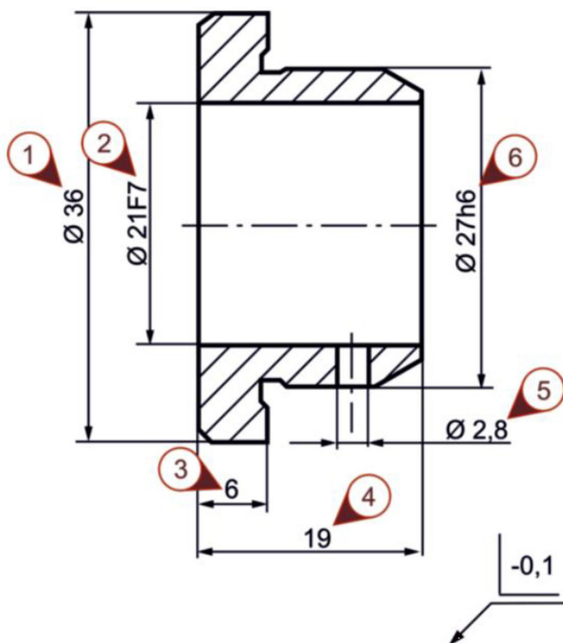


Figure 1

Note: For a better overview, the dimensioning and tolerancing in the following drawings are not complete. They only show the information relevant to this topic.

Since all the other numbered characteristics are also cylinders or parallel planes, a strict interpretation of DIN 7167 required that these sizes are mating sizes at the maximum material limit. Only the third characteristic does not meet this requirement since you are unable to check the flange width with mating parts.

We can assume that this principle was often not applied in industrial practice out of ignorance or due to a lack of suitable test equipment and that the respective operator took a two-point measurement for all characteristics except for the second and sixth one. Mating problems in the assembly, however, caused critical situations resulting from negligence, especially when the assembly operation obtained these non-mating parts from a supplier. In these cases, the assembly operation was able to refer to a violation of DIN 7167 in the complaints management, even if the mating characteristics were not associated with tolerance classes of the system of fits!

## Consequences of a formal application of former drawing specifications

If the flange bushing with the same design was constructed eleven years later, namely in May 2012, and the drawing was published while the persons involved knew that the envelope requirement still applies, even without any individual drawing indication, the situation would be as follows.

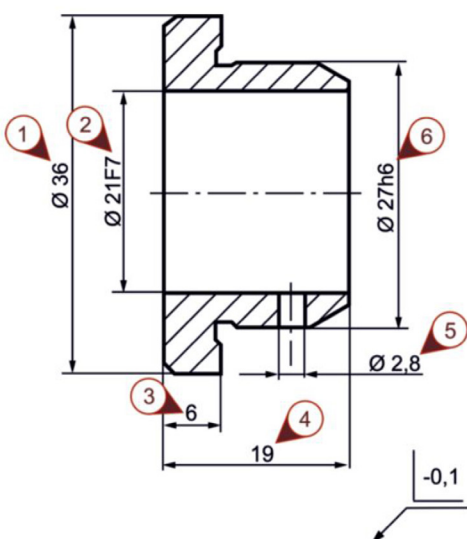


Figure 2

The drawing and all its details in Figure 2 is the same as Figure 1; the only difference is that the date of publication is May 2012. This date is of utmost importance for the interpretation of the indicated sizes.

Since the drawing of Figure 2 was released on 10 May 2012, **ISO 8015:2011** Geometrical product specifications (GPS) – Fundamentals – Concepts, principles and rules applies.

This global standard of the GPS system specifies in its first principle that once a portion of the ISO GPS system is “invoked” in the product documentation, the entire ISO GPS system is invoked. This drawing invokes ISO 1302 for tolerancing the surface texture and ISO 13715 for considering the state of edges especially with respect to burrs. Both standards are

general standards of the GPS system. Additionally, the fifth principle of this standard prefers the independency principle as a tolerancing principle rather than the envelope requirement.

The indication of fits (characteristics 2 and 6) on the drawing invokes GPS standard

## ISO 286-1:2010

Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits.

Since the drawing indicates all other linear sizes, you have to apply

## ISO 14405-1:2010

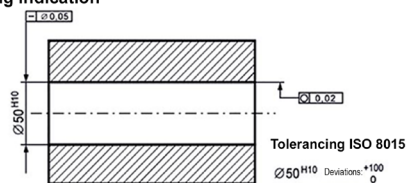
Geometrical product specifications (GPS) — Dimensional tolerancing — Part 1: Linear sizes for the interpretation of size characteristics.

Since the ISO 286 version of November 2010 and ISO 14405-1 both specify the local two-point size for controlling the function of the linear sizes “cylinder” and “two parallel opposite surfaces”, it is no longer required to ensure the function fit at characteristics 2 and 6. According to the independency principle, form deviations, such as a triangular cross section and a curved axis of a cylinder might even reach their maximum value when the two-point size is close to the maximum material limit. You thus do no longer have to ensure that the virtual size (formerly referred to as mating size) does not push or even tear the perfect (geometrically ideal) envelope with the maximum material size (see Figure 3).

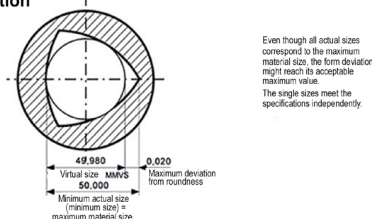
Based on the given example in Figure 2, this might lead to the following situation. Characteristic 2 is a fit  $\varnothing 21$  F7 (+ 41  $\mu\text{m}$  / + 20  $\mu\text{m}$ ), has a tolerance of size of 21  $\mu\text{m}$  and its maximum material limit (minimum size) amounts to 21.020 mm. By referring to ISO 2768, the cylinder's deviation from roundness may equal the tolerance of size, i.e. 21  $\mu\text{m}$ . In the worst case, the virtual size (mating size) thus amounts to 20.999 mm (21.020 mm – 0.021 mm) (see Figure 4).

The expected application of the envelope requirement due to the formal adoption of former drawing specifications is thus no longer compatible with other rules much less than it can be guaranteed.

Drawing indication



Interpretation of the independency principle in a radial section



Interpretation of the independency principle in an axial section

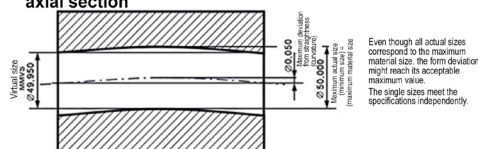


Figure 3

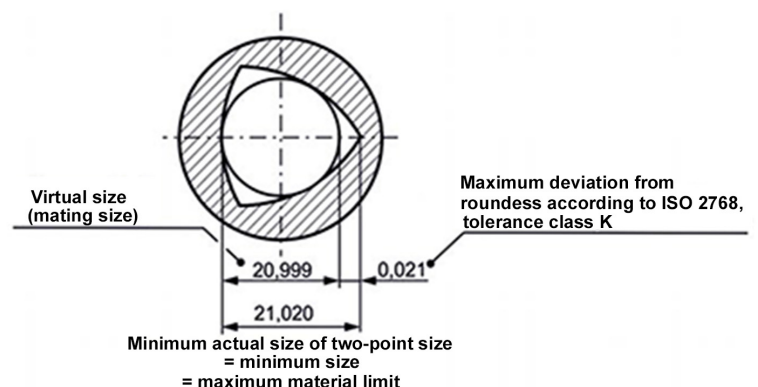


Figure 4

Here are some of the resulting consequences:

- The quality inspection is not what the application of the envelope requirement expects it to be. The “early assembly” based on gauges remains undone.
- Problems in the assembly process are quite likely to occur.
- It is important to clarify assembly problems with internal shop floor areas (acknowledged internal complaints) in case of in-house production.
- When parts are produced by external suppliers, the supplier might refuse the complaint because the parts produced are conforming to the drawing. This aspect may cause high non-conformity costs due to subsequent deliveries against charge and, of course, supply difficulties because of the resulting delay.

## Consequences for the creation of construction documents

The GPS system now provides two different options to incorporate the envelope requirement in a drawing.

- Option 1: assigning the envelope requirement to single features of size
- Option 2: assigning the envelope requirement to all features of size on a drawing

### Option 1 - envelope requirement applied to a single characteristic

In 1986, the modifier **E** (E...envelope) was introduced to indicate the envelope requirement and it has been applied to single features of size since then. ISO 14405-1 also recommends this modifier. Figure 5 shows what the flange bushing example would look like in this case.

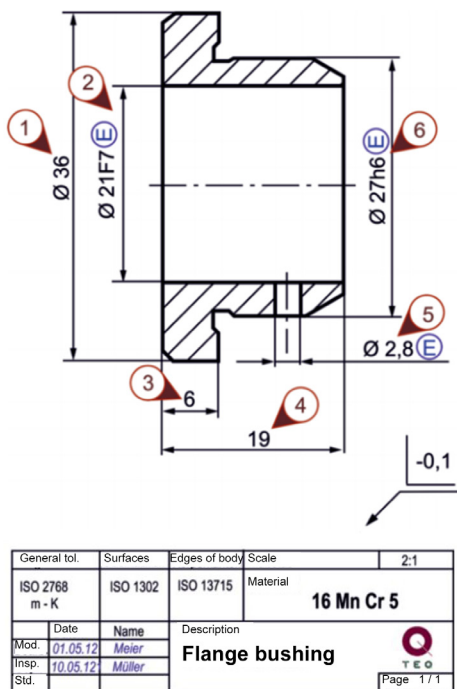


Figure 5

The second and sixth fit as well as characteristic 5 are mating-relevant characteristics.

You will have the following benefits by applying the first option.

- By carefully working through the drawing, you will only indicate functional, mating-relevant features of size. Now you only need to check whether these characteristics meet the criteria of the envelope requirement; you do not have to consider any other features.
- This fact certainly reduces the inspection effort and maybe even the inspection costs.
- The modifier **E** provides important information to the appraiser, e.g. important notes on the function of the part and the need to inspect it.
- You may now apply the envelope requirement even to a feature of size subject to a general tolerance (characteristic 5).

Mainly design engineers might find some disadvantages in this tolerancing option.

- You might overlook features of size to be mated when tolerancing a characteristic with respect to mating aspects. In this case, the universal validity of the envelope requirement is not able to solve this problem.
- More effort and a careful working method are assumed and expected when you work through the drawing.

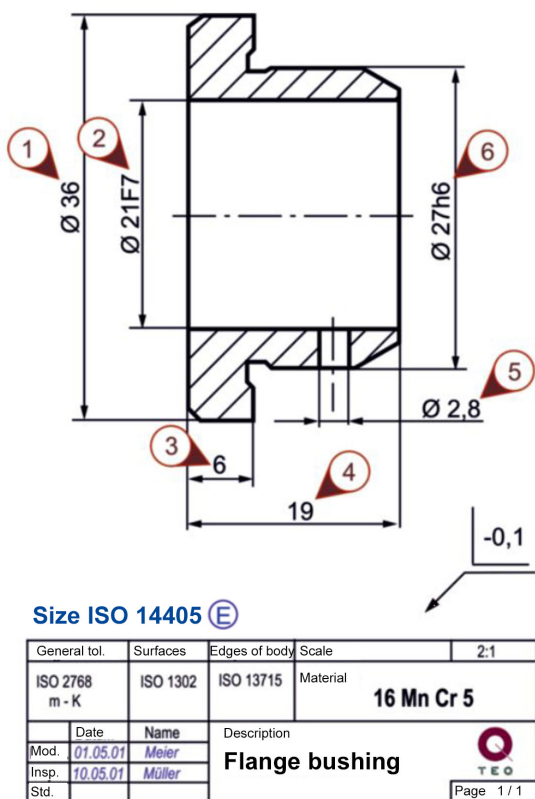


The design engineers are right to raise these concerns. In the end, the 1986 edition of ISO 8015 “Fundamental tolerancing principle – independency principle” was kind of dismissed by issuing the alternative draft of DIN 7167 “Relationship between tolerances of size, form, and parallelism; envelope requirement without individual indication on the drawing” in 1987. And indeed, the indication “Tolerancing ISO 8015:1986” was only invoked on few drawings.

## Option 2 - envelope requirement applied to all features of size on a drawing

Principle 7 of ISO 8015 introduces a drawing-specific specification operator that needs to be indicated near or in the title block (see Figure 6 or [“Geometrical product specification – part 2”](#)).

The envelope requirement applies to all features of size except for characteristic 3.



The advantages are as follows.

- The application of common drawing specifications does not change.
- There is no risk of overlooking features of size to be mated when tolerancing a characteristic with respect to mating aspects.
- Products whose sizes are indicated as fits and that cannot be mated in the assembly process may still be complained about when they do not meet the envelope requirement. However, complaints are only possible when the reason for the problems you might have assembling the parts are caused by pushing or even tearing the perfect (geometrically ideal) envelope with the maximum material size of the dimensional tolerance interval.
- By indicating “Size ISO 14405” the GPS system for geometric tolerancing is clearly invoked.

Figure 6

Mainly quality managers might find some disadvantages in this tolerancing option.

- Many sizes are overtolerated due to the global application of the envelope requirement. Examples are characteristics 1 and 4.
- Quality inspections require more effort and lead to high inspection costs when you really check whether all size characteristics fulfil the envelope requirement.
- The logical consequence is that quality inspectors will always make an individual decision whether they use gauges or take a two-point measurement. You might overlook crucial mating inspections.
- When you apply the envelope requirement globally to a drawing, technically speaking, it also applies to the features of size tolerated based on general geometrical tolerances. This requirement will be too excessive in many cases.

Moreover, it is worth mentioning that, based on the American standards ASME Y14.5 published in 1994 and its current version published in 2009, the envelope requirement generally applies to all drawings without any individual drawing indication.

## ● Needs and opportunities for action

The following statement applies to all (German) drawings created and released prior to the publication of ISO 8015:2011:


When “**Tolerancing ISO 8015**” is **not indicated** on a drawing, the independency principle does not apply to all features of size (cylinder, ball, pair of parallel opposite surfaces); the envelope requirement applies instead. The same applies when “**Tolerancing DIN 7167**” is indicated in or near the title block.

Since April 2011, ISO 14405-1 **applies** and since September 2011 also ISO 8015, so DIN 7167 becomes invalid for (German) drawings that have been released since October 2011.

When you invoke the entire GPS system by referring to a fundamental or general standard of the GPS system, you define the **two-point size** for features of size, such as cylinder (circle), ball and pair of parallel opposite surfaces (pair of parallel lines). In order to apply the envelope requirement, you may use option 1 or option 2 as described in this document.

The following recommendation concerns drawings created before October 2011 but updated due to changes after October 2011.


When you use **older** drawings (i.e. created before October 2011) that were based on the envelope requirement according to DIN 7167 and you still want to use them after they have been subject to changes, indicate

“**Sizes ISO 14405**  “

on the drawing as describes for option 2. The former indication “Tolerancing DIN 7167” serves the same purpose.

Where economically feasible, you should revise newly created drawings based on the independency principle and reissue them. Indicate

“**Sizes ISO 14405**”

in or near the title block or invoke the GPS system by referring to a different GPS standard. In case you still want to apply the envelope requirement, put the modifier  right next to the respective dimensional tolerance.

## ● Conclusion

It might seem hard to follow all these rules and to make the right decision – whether you keep the global envelope requirement or apply the envelope requirement to single features of size. However, especially companies with a huge output of drawings need to compare both options by making a benefit-cost analysis.

Since the GPS system will –without any doubt – become accepted on an international level, it is important to put such a decision, if it has not been made yet, on the agenda. You also have to decide on a preferred general rule you want to apply in product development; it is not reasonable to switch between option 1 and option 2 within a company only because the different people involved have a different state of knowledge.

Finally, we want to strike a blow for the previously common but nowadays rarely applied method to check technical drawings for compliance with standards. When qualified experts check drawings for compliance with standards, these inspections will lead to a documented release of a drawing. As an example, the “Standard” authorization field of the respective drawing examples is signed and there is thus nothing to discuss about these drawings. Critical situations affecting customer-supplier



relationships due to misinterpretations of tolerances of size, form and location are avoided right from the start.



TEQ Training & Consulting GmbH  
Eisleber Str. 2  
69469 Weinheim / Germany  
+ 49 6201 3941-15

Interested in this topic?  
[www.teq.de](http://www.teq.de)  
Contact the author  
[gunter.effenberger@teq.de](mailto:gunter.effenberger@teq.de)