Application and Explanation of General Geometrical Tolerances According to ISO 22081

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Abstract. This article is based on new general geometrical tolerances and general size tolerances according to ISO 22081 from year 2021 used in ISO GPS standards. This standard canceled and replaced ISO 2768-2 from year 1989. The main changes are rules for application of general geometrical specification and general size specification have been clarified. This article shall be explaining the principle of creating a drawing or 3D model according to the rules for using general tolerances. All rules are ISO 22081 shall respect all principles defined into ISO 8015 from year 2011. This article explains application of general geometric tolerances or specifications to specific components with detailed descriptions.

Keywords: ISO 22081, General Geometric Tolerances, Profile tolerances, Theoretical Exact Dimensions, ISO GPS, 3D annotation model.

1 Introduction

The ISO GPS (Geometrical Product Specifications) defines an internationally uniform description language, that allows expressing unambiguously and completely all requirements for the micro and macro geometry of a product with the corresponding requirements for the inspection process in technical drawings, considering current possibilities of measurement and testing technology [5].

Engineering drawings without tolerances (size, roughness and geometrical) are in most cases incomplete, ambiguous, and therefore not unambiguously interpretable [6]. ISO default specification operators and number of fundamental principles that apply to all GPS standards and technical product documentation are indicate in fundamental ISO GPS standards [2] [7].

In this article shall be explains the issue of general tolerancing within ISO GPS according to the newly introduced ISO 22081 standard [1], which is valid from year 2021. On the same year, ISO 2768-2, i.e., the part that related to geometric tolerances, was repealed (now it is no longer possible to prescribe accuracy classes for geometrical tolerances – "H", "K" or "L") – see **Error! Reference source not found.**.

In the new standard (ISO 22081), rules for the application of general geometrical and size specifications have been added and clarified.

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The aim of this study shall be explaining the reason for the deletion and therefore the reasons why ISO 22081 was introduced, which in some ways changes the approach to tolerancing and general dimensioning of drawings/parts. I would also outline some examples of the application of ISO 22081 and explain the basic rules.

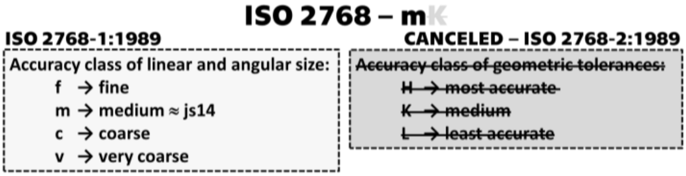

Fig. 1. Not tolerated dimensions – General tolerances according to ISO 2768-1:1989 is still valid, but ISO 2768-2:1989 (part 2: Geometrical tolerances for features without individual tolerance indications) was canceled and replaced by ISO 22081:2021.

2 Materials and Methods

If we look at the history of ISO 2768-1(2), I will venture to write that there has been no major revision of the standard since it was first published in 1989. However, if we look at the many other standards, they have started to change with regard to the way they are produced and, more importantly, the way they are controlled, i.e. metrology. I dare to write that this process of changes/adjustments started around 2010.

The fundamental change came with the update of ISO 8015:2011, and therefore the introduction of the whole ISO GPS system into the creation of the Technical Product Documentation (TPD).

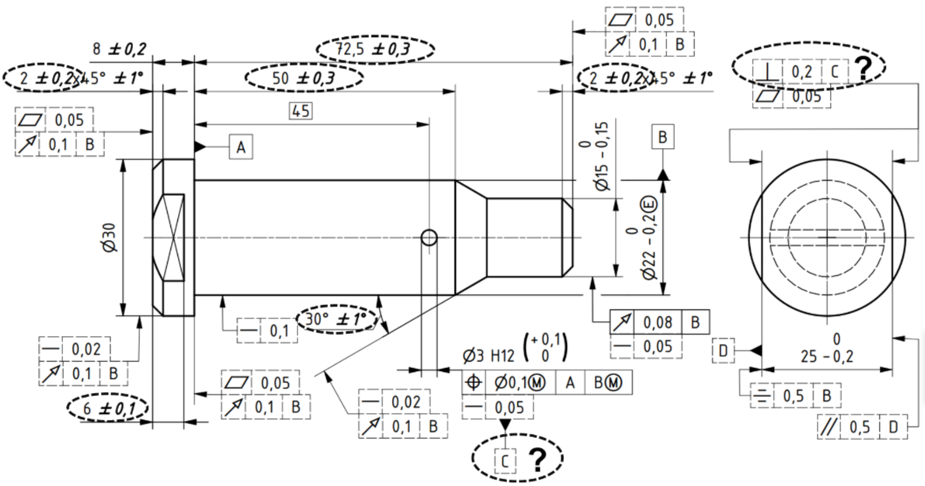

Fig. 2. Example drawing from general tolerances ISO 2768-2 (replaced by ISO 22081:2021).

Fig. 2 shows the workpiece with the tolerances of ISO 2768-1 and ISO 2768-2. The following tolerances are shown on the part:

- Individual tolerances (linear sizes, geometric tolerances, TEDs) – all indicated by solid lines.
- General linear and angular size tolerances according to ISO 2768-1 – indicated and added to the drawing using italic type and bold.
- General geometrical tolerances according to ISO 2768-2 – tolerances are indicated by a dashed box.

In Fig. 2, the dashed circles indicate the "DISTANCE" to which the general dimensional tolerance is added. However, this is inconsistent with the ISO GPS concept because the tolerances are only for "SIZE" [6]. It follows that in practice there is a wrong application of ISO 2768-1. This is one of the reasons why there is a change in the tolerancing of general tolerances and all functional tolerances.

Furthermore, ambiguous geometric specifications are indicated in Fig. 2 by the dashed circles with a question mark. Why is the datum "C" chosen on hole „∅12 H7"? Some tolerances are ambiguously chosen, and various ambiguous applications can occur.

2.1 Reasons for Introducing ISO 22081 Instead of ISO 2768

There may be a few reasons, but it shall be highlight at least three that seem to me to be crucial. I may have mentioned some of them above.

The Main Reasons for The Abolition of ISO 2768-2 Incompliance with ISO 8015.

Incompliance with ISO 8015 (ISO GPS), maybe I can specifically mention "DISTANCE" vs. "SIZE". Maybe I can write that distance should never be tolerated, i.e., it should not carry limit deviations. A typical example might be a distance of "20 ±0.1", which represents an example of an inappropriately specified distance (see Fig. 3). Regarding measurements, this distance should be specified using geometric tolerancing (in accordance with ISO GPS) [4].

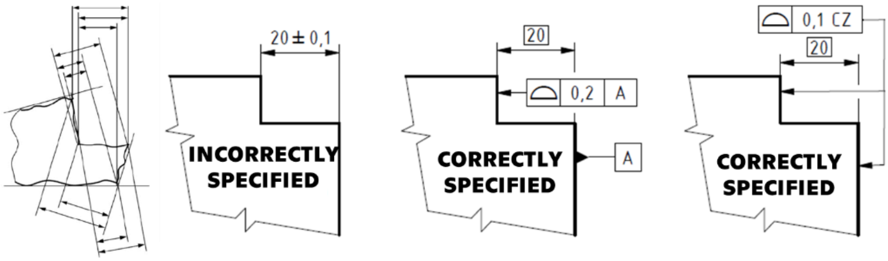

Fig. 3. Example of improperly specified distance and its correct specification (marking) using geometric tolerancing (in accordance with ISO GPS) – planar workpiece.

The variant with position tolerance and base is shown in the middle and the variant with position tolerance and the symbol “CZ” (Combined Zone) is shown on the right. It can be noted that this method of tolerancing is mainly related to the following reason (metrology).

A Different Approach to Component Inspection, Especially with Respect to CMM and Scanner Inspection (Metrology)

The distance shown in **Fig. 4**. is not correctly measurable and evaluated on CMMs or scanners. For these measurement/inspection approaches, this distance (dimension) needs to be tolerated using geometric tolerances and preferably those that need TED (theoretically accurate surface profile, line profile or position/) to function – see following reason (3D Annotation Models).

Now the question is, if I don't use this method of measurement (CMMs or scanners) do I need to change anything? And we can answer that in principle I don't have to. The ISO GPS tolerancing and quotation approach implies more automation, reducing the human factor and thus achieving higher productivity and uniformity of quality of the same products across plants (my opinion on future developments).

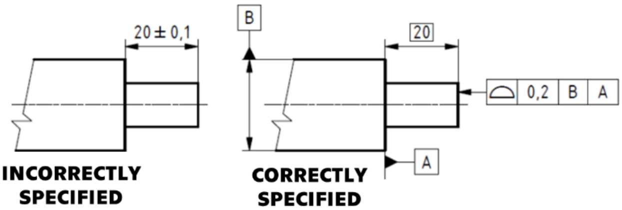

Fig. 4. Example of improperly specified distance and its correct specification (marking) using geometric tolerancing (in accordance with ISO GPS) – rotating workpiece.

Slow Emergence of Drawing-less Documentation – 3D Annotation Models

With the onset of drawing-less documentation (3D Annotation Models) [3], and therefore the placement of functional specifications (functional dimensions, tolerances, etc.) in the 3D model, the approach to quotation needs to change.

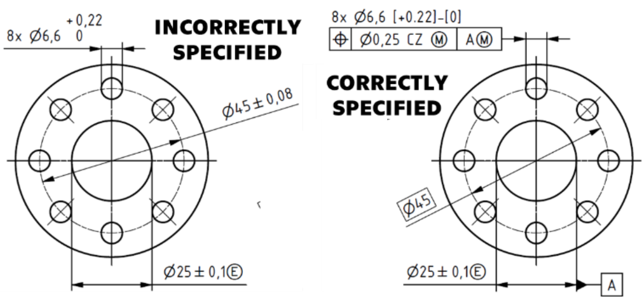

Fig. 5. Example of improperly specified distance and its correct specification (marking) using geometric tolerancing (in accordance with ISO GPS) – pattern of holes.

Such defined 3D models can then be used in manufacturing (CAM) and measurement (metrology) software. The main advantage is that there is no need to transcribe anything into a 2D drawing and then from the 2D drawing into e.g., measurement software - elimination of errors, speeding up the process of creating drawing/technical documentation.

2.2 Basic Rules for The Application of ISO 22081

By using a general geometrical specification and a general size specification, we can minimize the number of entries in the TPD (Technical Product Documentation) – which is of course the designer's goal.

First, solve all functional requirements (tolerance everything – size, geometrical /form, orientation, location and run-out/) and then go to general specification (size and geometrical). and check that everything is defined correctly. The following points are important for ISO 22081:

- The standard gives general geometrical and size (linear or angular) specifications/tolerances.
- The standard gives clear rules for the application of general specifications – (Rules A - H).
- The standard follows the principles of ISO 8015 (independence, uniqueness, element, ...).
- General specifications (geometrical and size) may only be used for integral features including features of size.
- General tolerances (geometrical and size) cannot be used for derived features or integral lines (ISO 17450-1).
- Dimensions other than linear or angular are not defined in ISO 22081 (see ISO 14405-2).

In Table 1, rules A-H are displayed and categorized as is shown.

Table 1. Rules – overview

Basic	Indication in TPD	General geometric specifications	Datum systems	General size specifications
Rule A – what is possible defined.	Rule B – to apply general geometrical/size specifications.	Rule C – indication of general geometrical specification. Rule D – applicability of the general geometrical specification.	Rule E – definition of datum systems. Rule F – datum systems locked all degrees of freedom.	Rule G – indication of general size specification. Rule H – applicability of the general size specification.

2.3 Indication of General Geometrical Specifications and General size specifications

The following figures show the options for indicating general specifications according to ISO 22081.

Fig. 6 shown general geometrical specification according to ISO 22081 with indication of TEDs according CAD model (the best option). In this case there are no size specifications (linear and angular) on the drawing.

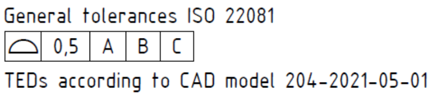

Fig. 6. General geometrical specification according to ISO 22081 with indication of TEDs according CAD model (the best option).

Fig. 7 shown general geometrical and size (linear and angular) specification according to ISO 22081 with indication of TEDs according CAD model. In this case there are all specifications (geometrical, linear and angular) indicated with a specific value.

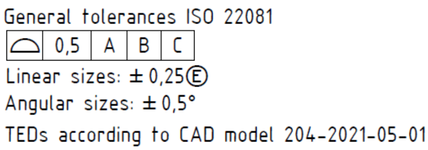

Fig. 7. General geometrical and size specification according to ISO 22081 with indication of TEDs according CAD model.

Fig. 8 shown general geometrical and size (linear and angular) specification according to ISO 22081 with indication of TEDs according CAD model. In this case there are all specifications (geometrical, linear and angular) indicated in external table or standards.

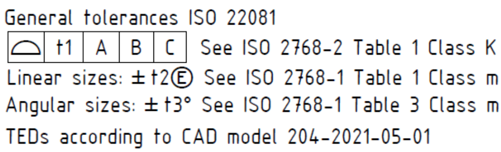

Fig. 8. General geometrical and size specification according to ISO 22081 with indication of TEDs according CAD model. Values of specifications are according external table/standards.

3 Results and Discussion

Now I will come back to the change of approach in drawing (3D Annotation Models). If I don't enter all dimensions/distances into the 3D model (PMI dimensions) and write that I shall measure them, I can't use the standard ± tolerancing. Why? Because everyone might measure different dimensions, so I shall use TED dimensions (write something to the effect of "take the unlisted dimensions as TED according to CAD model no. ... "). And I can apply tolerances to the TED dimensions used in this way using geometric tolerances (surface profile, line profile and position). This is how ISO 22081 is set up.

Based on the data mentioned above, it is fair to say that ISO 22081 tolerance has a future in the context of digitalization and flows within Industry 4.0. Now it is just a question of how to put this into practice.

However, we must also not forget smaller companies that can get by with simpler drawings and do not have to make the full transition to the ISO GPS concept.

Below are two examples that illustrate the application of ISO 22081.

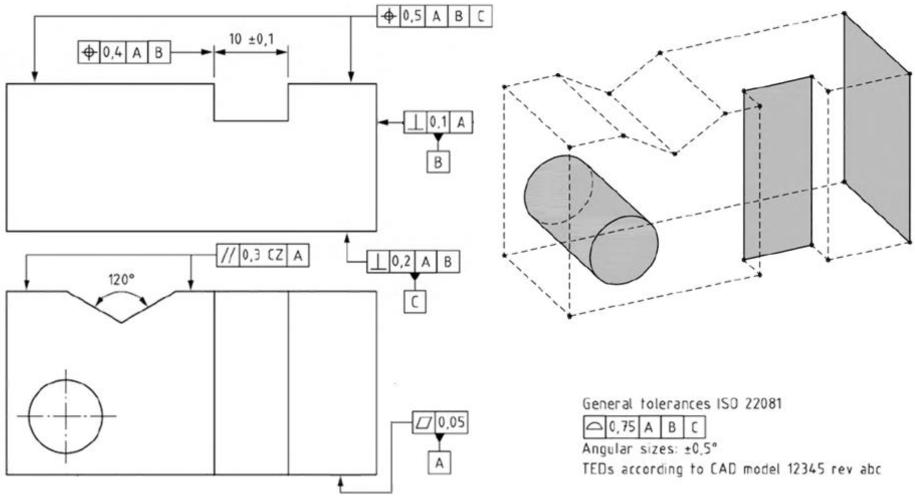

Fig. 9. Example of application of general geometrical specification. The general geometrical specification applies to the integral features with shading (3D view on right side of figure).

3.1 Application of ISO 22081 on Workpiece – Example 1

The general geometrical specification applies to grey elements and does not apply to:

- two planes at 120° as they are specified by the general size specification (**Fig. 9**);
- the two parallel planes with 10 mm distance because they are specified by an individual size specification (see **Fig. 9**);
- the two parallel planes with 10 mm distance because the derived feature is specified by an individual geometrical specification (see **Fig. 9**);

- datum feature 'A' (or 'B' or 'C') because the integral element is specified by an individual geometric specification (see **Fig. 9**);
- datum feature ‚A' (or 'B' or 'C') because datum ‚A' (or 'B' or 'C') is used in the datum section of the general geometrical specification (see **Fig. 9**);
- the two planes opposed to datum feature ‚C' (and ‚A') because the integral features are specified by an individual geometrical specification (see **Fig. 9**).

3.2 Application of ISO 22081 on Workpiece from ISO 2768-2 – Example 2

Fig. 10 and **Fig. 11** compare the tolerancing according to ISO 2768-mK (**Fig. 10**) and ISO 22081 (**Fig. 11**). The main advantage of ISO 22081 is the possibility to refer to TEDs in the CAD model. Due to this, the number of data is reduced.

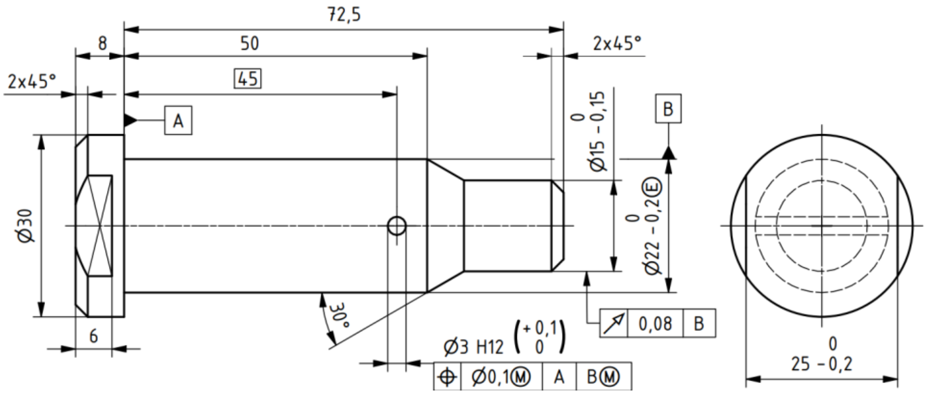

Fig. 10. Indication of ISO GPS according to ISO 2768-1 and 2 from year 1989. Incompliance with ISO 8015.

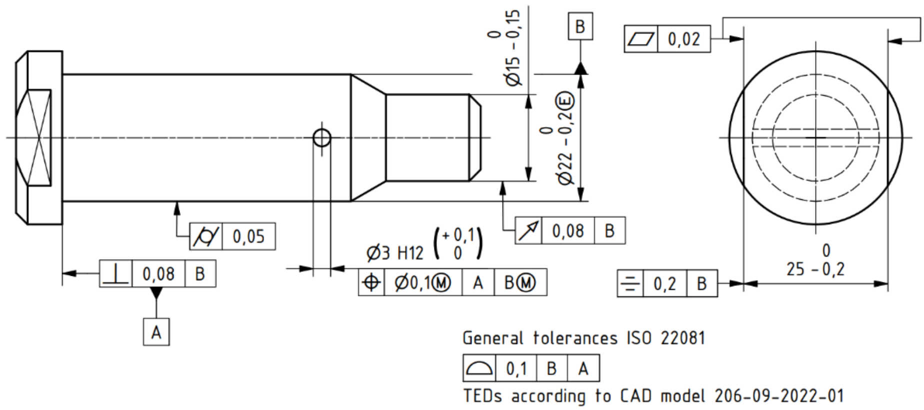

Fig. 11. Indication of ISO GPS according to ISO 22081 from year 2021. This definition is in according to ISO GPS and ISO 8015.

4 Conclusions

The article outlines the process of drawing creation with the application of general specifications according to ISO 22081. The basic rules and reasons that have resulted in its introduction and the abolition of ISO 2768-2 were also given.

This general specification method is not suitable for all types of components, as it involves more complex tolerancing for shaft components, for example. In contrast, for planar components, or better still for complex shaped components, the possibility of using the tolerance of the surface profile may be beneficial.

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