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Technical drawings — Tolerances of form and of position — Part II : Maximum material principle

Dessins techniques — Tolérances de forme et tolérances de position — Partie II : Principe du maximum de matière

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

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It has been approved by the Member Bodies of the following countries :

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This International Standard is a part of the following series under the general heading ISO 1101, *Technical drawings — Tolerances of form and of position* :

- *Part I : Generalities, symbols, indications on drawings* (at present ISO/R 1101).
- *Part II : Maximum material principle.*
- *Part III : Dimensioning and tolerancing of profiles* (at present ISO/R 1660).
- *Part IV : Practical examples of indications on drawings* (at present ISO/R 1661).

Technical drawings — Tolerances of form and of position — Part II : Maximum material principle

1 SCOPE AND FIELD OF APPLICATION

This International Standard describes the maximum material principle and specifies its application to different tolerances.

2 THE MAXIMUM MATERIAL PRINCIPLE

The free assembly of components depends on the combined effect of the actual finished sizes and the errors of form or position of the mating features. The minimum clearance for assembly occurs when the features are in their maximum material conditions of size and the most disadvantageous permissible errors of form or position are present.

However, more clearance of assembly will be present if the actual sizes of the mating features are away from the maximum material limits of size, and if the actual errors of form or position are less than the maximum.

It follows, therefore, that if the actual sizes of the mating features are away from the maximum material limits of size, the specified tolerance of form or position can be exceeded without endangering the possibility of assembly.

This increase of tolerance, according to the maximum material principle, which is applicable to size tolerances (see figure 9) as well as to tolerances of position and to certain tolerances of form, is advantageous for manufacture, but may not always be permissible from the functional point of view. For instance, in positional tolerancing the increase of tolerance can generally be permitted on the centre distances of such features as bolt holes, studs, etc., but it may not be permissible in kinematic linkages, gear centres, etc. In all cases the designer shall decide whether or not the application of the maximum material principle may be permitted and, if it can be, the symbol Ⓜ shall be added to the tolerance in question (see 4.8 of part I).

This symbol indicates that the tolerance with which it is associated has been specified in relation to the maximum material limits of size of the feature or features concerned, and that if the actual size of the feature is away from its maximum material limit of size, the specified tolerance of form or position may be increased as permitted by the difference between the actual size of the feature and its maximum material limit of size. Obviously the amount of this increase can never exceed the amount of the size tolerance on the feature.

It is important to note that the increase of form or position tolerance referred to above can be applied to one part of an assembly without reference to the mating part. Assembly will always be possible, even if the mating part is finished on the extreme limits of the tolerances in the directions most unfavourable for assembly, because the combined total of errors of size and of form or position specified for the one part is not exceeded.

When a tolerance of form or of position is applied to a feature which is related to a datum feature having limits of size, it may be possible to apply the maximum material principle to the datum feature as well as to the feature which is toleranced, and thereby to obtain full advantage (see figures 11 and 12). In such cases the symbol Ⓜ shall also be added to the datum letter (see 4.8 and figures 24 and 25 of part I).

The indication of "maximum material condition" is therefore shown by the symbol Ⓜ placed after

- the tolerance value (figure 1),
- the datum letter (figure 2),
- or both (figure 3).

according to whether the maximum material condition is to be applied to the toleranced feature, the datum, or both.

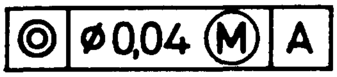

FIGURE 1

FIGURE 2

FIGURE 3

The frame is connected to the toleranced feature as illustrated in 4.2 and 4.3 of part I.

NOTE — It must be clearly understood that if the maximum material principle is not (or cannot be) applied to tolerances of form or of position, these tolerances must be observed regardless of the actual finished sizes of the features concerned. This means that the errors of form or of position must be checked independently.

If the maximum material principle is applied then the errors of form or position can be checked by appropriately designed gauges.

3 APPLICATION OF THE MAXIMUM MATERIAL PRINCIPLE

3.1 Perpendicularity

The application of the maximum material principle to perpendicularity is illustrated in figures 4 a) to 4 d).

The axis of the spigot should be contained in a cylindrical tolerance zone, perpendicular to the datum plane A; the diameter of this zone varies from 0,04 to 0,06 as the actual spigot diameter varies from 16 (maximum material) to 15,98 (minimum material).

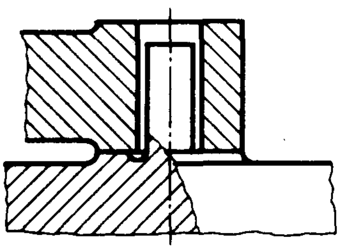

FIGURE 4 a) — **Assembly**

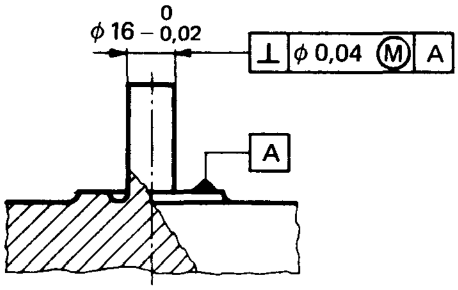

FIGURE 4 b) — **Detail drawing**

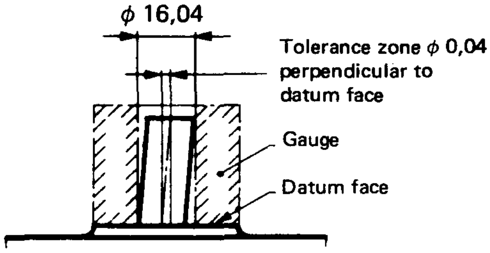

FIGURE 4 c) — **Material of the maximum diameter (16,00) shown in gauge — Effective perpendicularity tolerance : ϕ 0,04**

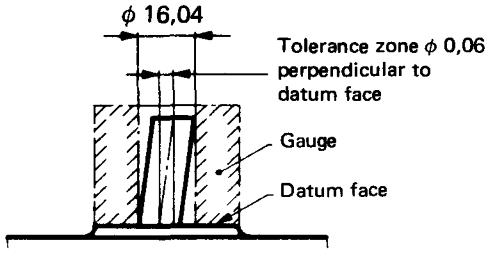

FIGURE 4 d) — **Material of the minimum diameter (15,98) shown in gauge — Effective perpendicularity tolerance : ϕ 0,06**

Note that the gauge shown in figures 4 c) and 4 d) checks the combined effect of perpendicularity and size.

The size of the spigot must be checked independently to ensure that the limits of size are not exceeded.

Note also that in this example the positional accuracy (i.e. its relationship to another feature) is not in question.

3.2 Straightness

The application of the maximum material principle to straightness is illustrated in figures 5 a) to 5 d).

The axis of the pin should be contained in a cylindrical tolerance zone of diameter varying from 0,01 to 0,03 as the actual pin diameter varies from 10,0 (maximum material) to 9,98 (minimum material).

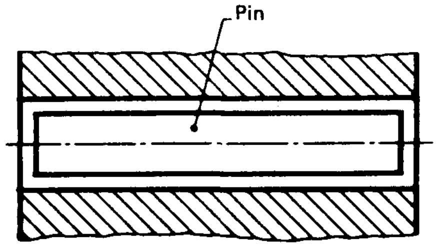

FIGURE 5 a) – **Assembly**

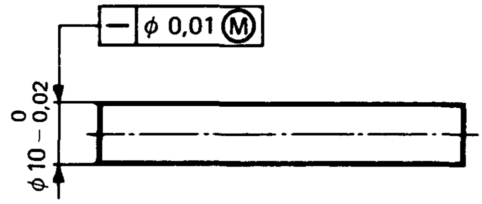

FIGURE 5 b) – **Detail drawing of pin**

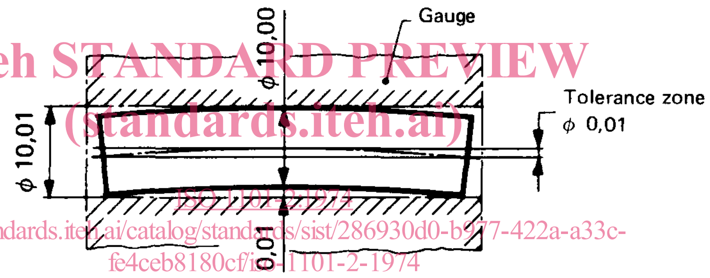

FIGURE 5 c) – **Maximum material pin (φ 10) shown in gauge – Effective straightness tolerance φ 0,01**

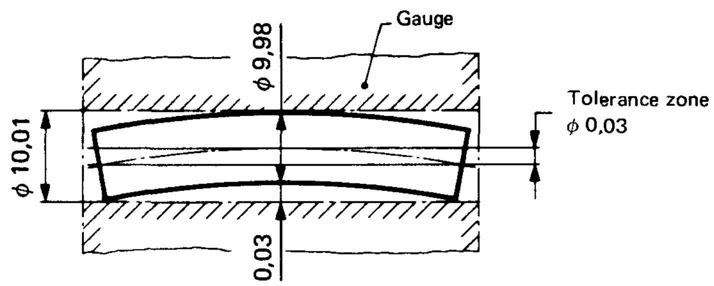

FIGURE 5 d) – **Minimum material pin (φ 9,98) shown in gauge – Effective straightness tolerance φ 0,03**

Note that the gauge shown in figures 5) c) and 5 d) checks the combined effect of straightness and size. The size of the pin must be checked independently to ensure that the limits of size are not exceeded.

If it is necessary that the pin remains on the whole length within the imaginary cylinder of the maximum diameter permitted by the diameter tolerance (Taylor principle), the straightness tolerance has to be indicated on the generating line instead of the axis (see 4.2 in part I).

3.3 Perpendicularity with zero form tolerance

Where it is necessary to specify that any errors of orientation are to be contained within the maximum material limits of a feature, this shall be indicated as shown in figure 6. This indication means that if the feature is finished everywhere on its maximum limits of size it must be perfect in form. Errors of form are permissible if the feature is finished away from the maximum material limits of size in the direction of minimum material, provided that the minimum limits of size are everywhere observed.

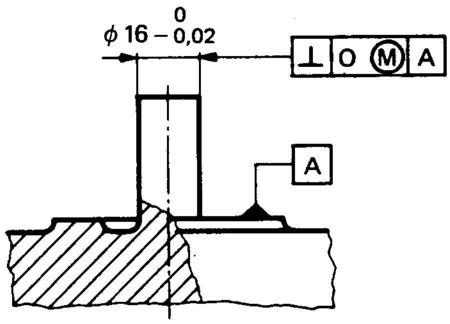

FIGURE 6

It should be noted that zero form tolerances can only be associated with the maximum material condition as to do otherwise would be to demand perfection.

3.4 Centre distance

Figure 7 illustrates a simple case of linear tolerancing of centre distance, and shows two components which will assemble even under the worst possible conditions permitted by the centre distance tolerances and size tolerances, i.e.

- upper component : centre distance and diameter of pins at maximum;
- lower component : centre distance and diameter of holes at minimum;

or

- upper component : centre distance at minimum diameter of pins at maximum;
- lower component : centre distance at maximum diameter of holes at minimum.

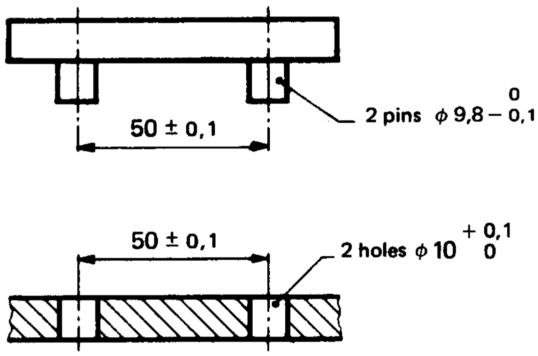

FIGURE 7

Figure 8 illustrates the extreme cases of the lower component shown in figure 7.

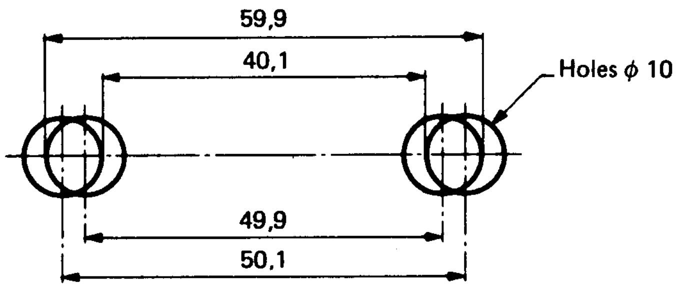

FIGURE 8

Assembly will be possible provided that the two following conditions are fulfilled :

1) distance between the outer sides of the pins in the upper component does not exceed 59,9;

2) distance between the inner sides of the pins is not less than 40,1.

Hence, if the pin diameters are at their minimum material condition, i.e. 9,7, their centre distance could vary between :

$$59{,}9 - 9{,}7 = 50{,}2 \quad \text{and} \quad 40{,}1 + 9{,}7 = 49{,}8$$

which is equivalent to a tolerance of ± 0,2, as compared to the drawing requirement of ± 0,1.

Advantage may be taken of this increase in manufacturing freedom by specifying that the maximum material concept applies to the centre distance of the pins of the upper component.

The maximum material principle could also be specified for the lower component of figure 7, with corresponding advantage.

When the maximum material principle is used, it can be specified

– according to figure 9, which shows the lower component; the symbol Ⓜ follows the centre distance tolerance;

– according to figure 10, which illustrates the same component; the symbol Ⓜ follows the hole position tolerance, signifying that the tolerance zones are circular for the hole centres.

The only difference between the requirement of figures 9 and 10 is that figure 10 specifies circular tolerance zones for the hole centres.

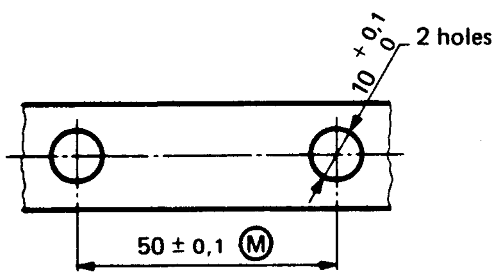

FIGURE 9

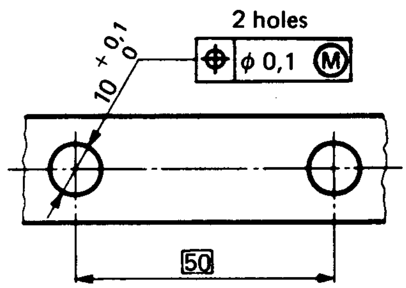

FIGURE 10

3.5 Positional tolerances

Figure 11 illustrates a further example of position tolerancing, and shows a case where the maximum material principle is applied both to the holes which are toleranced and to the datum feature. When the holes and the datum cylinder are in the maximum material condition, the axes of the holes should be contained in cylindrical tolerance zones of 0,2 diameter, the axes of which are in the true position. Variations from the maximum material size of the eight holes and of the datum cylinder will allow additional tolerance of position on the holes.

The actual hole diameters as compared with their maximum material size will determine the additional tolerance on the positions of the holes in relation to one another. The variation of the datum cylinder from its maximum material size allows a further increase of the position tolerance for all the holes relative to the datum cylinder but not in relation to each other.

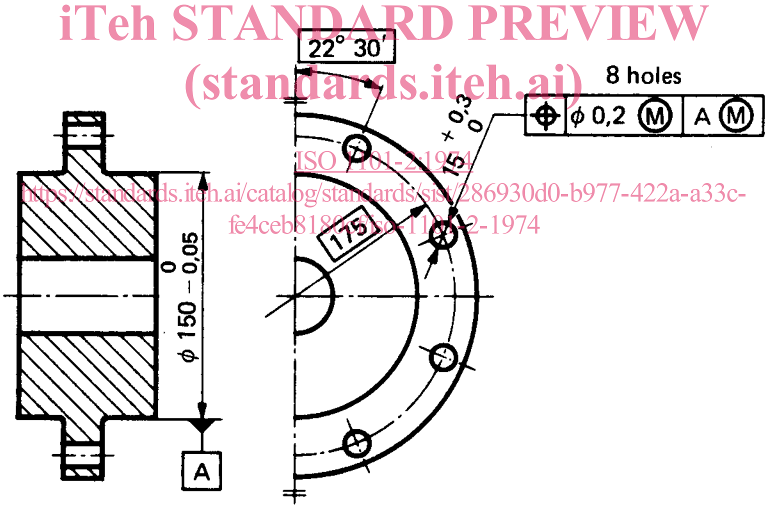

FIGURE 11

3.6 Coaxiality

The application of the maximum material principle to coaxiality is illustrated in figure 12. The axis of the head of the pin should be contained in a cylindrical tolerance zone, the axis of which coincides with that of the shank of the pin and the diameter of which varies from 0,05 to 0,165 as the actual diameters of the head and the shank vary from the maximum to the minimum material limits of size (figures 13 and 14 respectively).

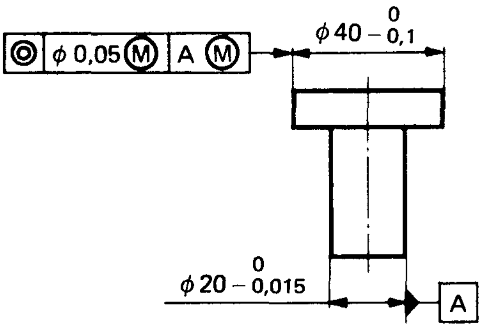

FIGURE 12

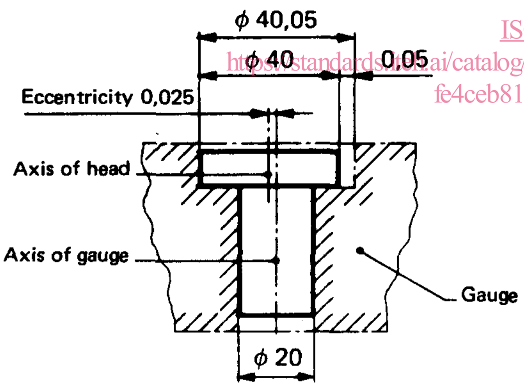

FIGURE 13

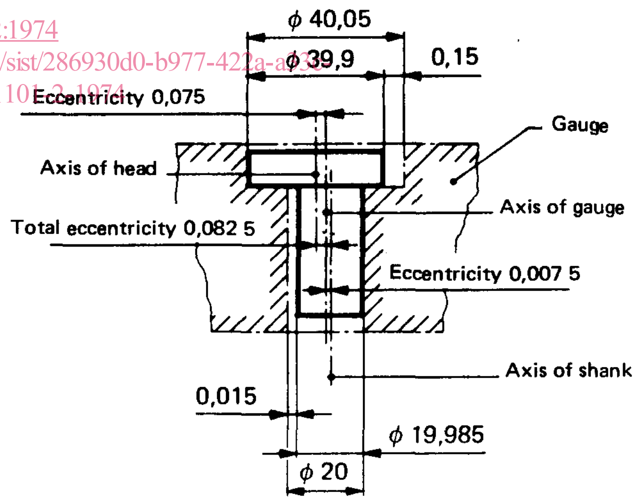

FIGURE 14