IS 8000-2 (1992): Technical drawings - Geometrical tolerancing, Part 2: Maximum material principles [PGD 24: Drawings]

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IS 8000 (Part 2) : 1992
ISO 2692 : 1988

(Reaffirmed 2003)

भारतीय मानक

तकनीकी ड्राइंगें – ज्यामितीय छूटें

भाग 2 अधिकतम सामग्री सिद्धान्त

(पहला पुनरीक्षण)

Indian Standard

TECHNICAL DRAWINGS — GEOMETRICAL TOLERANCING

PART 2 MAXIMUM MATERIAL PRINCIPLES

(First Revision)

First Reprint MARCH 1996

UDC 744-4 : 621·753·1

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

November **1992** **Price Group 9**

Drawing Sectional Committee, LMD 02

NATIONAL FOREWORD

This Indian Standard, which is identical with ISO 2692 : 1988 'Technical drawings — Geometrical tolerancing — Maximum material principles' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendations of the Drawing Sectional Committee (LMD 02) and approval of the Light Mechanical Engineering Division Council.

The original version of this standard, IS 8000 (Part 2) : 1976 'Geometrical tolerancing on technical drawings : Part 2 Maximum material principle' was based on ISO 1101/11-1974 'Technical drawings — Tolerancing of form and of position — Part 11 : Maximum material principle' issued by ISO. ISO has published a separate standard ISO 2692 : 1988 'Technical drawings — Geometrical tolerancing — Maximum material principle'. Harmonization of this standard with International Standard has been made by the adoption of ISO 2692 : 1988.

In the adopted standard, certain terminology and conventions are not identical with those used in Indian Standards; attention is especially drawn to the following:

a) Comma (,) has been used as a decimal marker while in Indian Standards the current practice is to use point (.) as the decimal marker.

b) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 1101 : 1983	IS 8000 (Part 1) : 1985 Geometrical tolerancing on technical drawings : Part 1 Tolerances of form, orientation, location and run-out and appropriate geometrical definitions (*first revision*)	Identical
ISO 5458 : 1987	IS 13099 : 1991 Technical drawings — Geometrical tolerancing — Positional tolerancing	Identical
ISO 5459 : 1981	IS 10721 : 1983 Datum and datum systems for geometrical tolerancing on technical drawings	Identical
ISO 7083 : 1983	IS 11158 : 1984 Proportions and dimensions of symbols for geometrical tolerancing in technical drawings	Identical
ISO 8015 : 1985	IS 12160 : 1987 Technical drawings — Fundamental tolerancing principles	Identical

The concerned technical committee has reviewed the provisions of ISO/TR 5460 referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard.

This Indian Standard is one of a series of Indian Standards on geometrical tolerancing on technical drawings. The other standards in this series are:

IS 8000 (Part 1) : 1985 Geometrical tolerancing on technical drawings : Part 1 Tolerances of form, orientation, location and run-out and appropriate geometrical definitions (*first revision*) (Identical with ISO 1101)

IS 8000 (Part 3) : 1992 technical drawings — Geometrical tolerancing : Part 3 Dimensioning and tolerancing of profiles (*second revision*) (identical with ISO 1660)

IS 8000 (Part 4) : 1976 Geometrical tolerancing on technical drawings : Part 4 Practical examples of indication on drawings (Identical with ISO/R 1661)

Indian Standard

TECHNICAL DRAWINGS — GEOMETRICAL TOLERANCING

PART 2 MAXIMUM MATERIAL PRINCIPLES

(First Revision)

0 Introduction

0.1 The assembly of parts depends on the relationship between the actual size and actual geometrical deviation of the features being fitted together, such as the bolt holes in two flanges and the bolts securing them.

The minimum assembly clearance occurs when each of the mating features is at its maximum material size (e.g. largest bolt and smallest hole) and when their geometrical deviations (e.g. positional deviation) are also at their maximum.

Assembly clearance increases to a maximum when the actual sizes of the assembled features are furthest from their maximum material sizes (e.g. smallest shaft and largest hole) and when the geometrical deviations (e.g. positional deviations) are zero.

From the above, it follows that if the actual sizes of a mating part do not reach their maximum material size, the indicated geometrical tolerance may be increased without endangering the assembly of the other part.

This is called the "maximum material principle" and is indicated on drawings by the symbol Ⓜ .

The figures in this International Standard are intended only as illustrations to aid the user in understanding the maximum material principle. In some instances, figures show added details for emphasis; in other instances, figures have deliberately been left incomplete. Numerical values of dimensions and tolerances have been given for illustrative purposes only.

For simplicity, the examples are limited to cylinders and planes.

0.2 For uniformity all figures in this International Standard are in first angle projection.

It should be understood that the third angle projection could equally well have been used without prejudice to the principles established.

For the definitive presentation (proportions and dimensions) of symbols for geometrical tolerancing, see ISO 7083.

1 Scope and field of application

This International Standard defines and describes the maximum material principle and specifies its application.

The use of the maximum material principle facilitates manufacture without disturbing the free assembly of parts where there is a mutual dependence of size and geometry.

NOTE — The envelope requirement (see 5.2.2) for a single feature may be indicated by the symbol Ⓔ (see ISO 8015) or by reference to an appropriate national standard invoking this requirement.

2 References

ISO 1101, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings.*

ISO 5458, *Technical drawings — Geometrical tolerancing — Positional tolerancing.*

ISO 5459, *Technical drawings — Geometrical tolerancing — Datums and datum-systems for geometrical tolerances.*

ISO/TR 5460, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Verification principles and methods — Guidelines.*

ISO 7083, *Technical drawings — Symbols for geometrical tolerancing — Proportions and dimensions.*

ISO 8015, *Technical drawings — Fundamental tolerancing principle.*

3 Definitions

3.1 actual local size: Any individual distance at any cross-section of a feature, i.e. any size measured between any two opposite points [examples: see figures 1, 12 b) and 13 b)].

3.2 Mating size

3.2.1 mating size for an external feature: The dimension of the smallest perfect feature which can be circumscribed about the feature so that it just contacts the surface at the highest points.

NOTE — For example, the size of the smallest cylinder of perfect form or the smallest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface(s) (see figure 1).

3.2.2 mating size for an internal feature: The dimension of the largest perfect feature which can be inscribed within the feature so that it just contacts the surface at the highest points.

NOTE — For example, the size of the largest cylinder of perfect form or the largest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface(s).

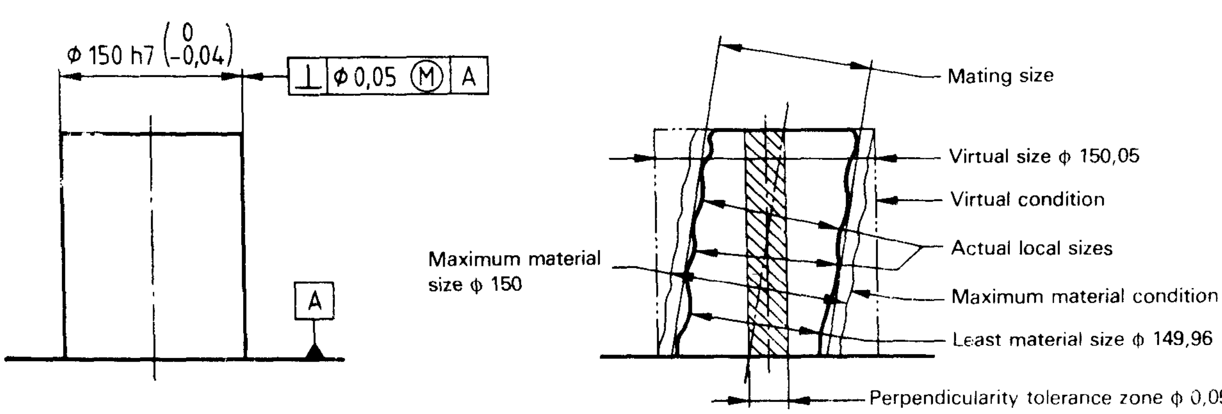
3.3 maximum material condition (MMC): The state of the considered feature in which the feature is everywhere at that limit of size where the material of the feature is at its maximum, e.g. minimum hole diameter and maximum shaft diameter (see figure 1).

NOTE — The axis of the feature need not be straight.

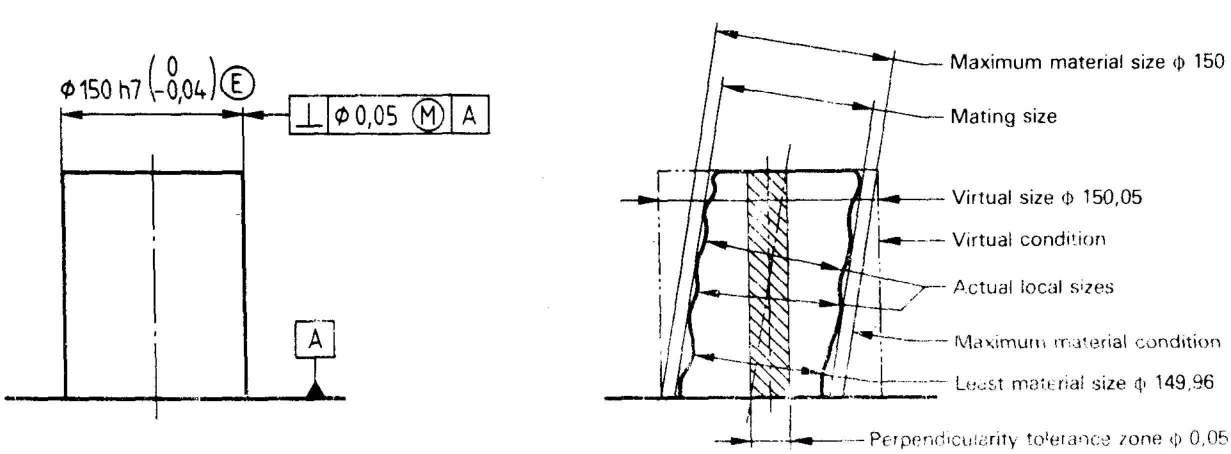
3.4 maximum material size (MMS): The dimension defining the maximum material condition of a feature (see figure 1).

3.5 least material condition (LMC): The state of the considered feature in which the feature is everywhere at that limit of size where the material of the feature is at its minimum, e.g. maximum hole diameter and minimum shaft diameter.

Indication on the drawing **Interpretation**



a) Dimensioning in accordance with the independance principle



b) Dimensioning in accordance with the envelope principle

Figure 1

3.6 least material size (LMS): The dimension defining the least material condition of a feature (see figure 1).

3.7 virtual condition: The limiting boundary of perfect form permitted by the drawing data for the feature; the condition is generated by the collective effect of the maximum material size and the geometrical tolerances.

When the maximum material principle is applied, only those geometrical tolerances followed by the symbol Ⓜ shall be taken into account when determining the virtual condition (see figure 1).

NOTE — The virtual condition represents the design dimension of the functional gauge.

3.8 virtual size: The dimension defining the virtual condition of a feature.

4 Maximum material principle

4.1 General

The maximum material principle is a tolerancing principle which requires that the virtual condition for the toleranced feature(s) and, if indicated, the maximum material condition of perfect form for datum feature(s), shall not be violated.

This principle applies to axes or median planes and takes into account the mutual relationship of size and the geometrical tolerance concerned. The application of this principle shall be indicated by the symbol Ⓜ.

4.2 Maximum material principle applied to the toleranced feature(s)

When applied to the toleranced feature(s), the maximum material principle permits an increase in the stated geometrical tolerance when the toleranced feature concerned departs from its maximum material condition provided that the feature does not violate the virtual condition.

4.3 Maximum material principle applied to the datum feature(s)

When the maximum material principle is applied to the datum feature(s), the datum axis or median plane may float in relation to the toleranced feature if there is a departure from the maximum material condition of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size [see figures 27 b) and 27 c)].

NOTE — The departure of the datum feature from its maximum material size does not increase the tolerance of the toleranced features in relation to each other.

5 Application of the maximum material principle

In all cases, the designer has to decide whether the application of the maximum material principle may be permitted on the tolerances concerned.

NOTE — The maximum material principle should not be used in such applications as kinematic linkages, gear centres, threaded holes, interference fit holes, etc., where the function may be endangered by an increase in the tolerance.

5.1 Positional tolerance for a group of holes

The maximum material principle is most commonly used with positional tolerances, and therefore positional tolerancing has been used for the illustrations in this sub-clause.

NOTE — In the calculations of virtual size, it has been assumed that the pins and holes are at their maximum material size and are of perfect form.

5.1.1 The indication on the drawing of the positional tolerance for a group of four holes is shown in figure 2.

The indication on the drawing of the positional tolerance for a group of four fixed pins which fit into the group of holes is shown in figure 4.

The minimum size of the holes is ϕ 8,1 — this is the maximum material size.

The maximum size of the pins is ϕ 7,9 — this is the maximum material size.

5.1.2 The difference between the maximum material size of the holes and the pins is

8,1 − 7,9 = 0,2

The sum of the positional tolerances for the holes and pins shall not exceed this difference (0,2). In this example, this tolerance is equally distributed between holes and pins, i.e. the positional tolerance for the holes is ϕ 0,1 (see figure 2) and the positional tolerance for the pins is also ϕ 0,1 (see figure 4).

The tolerance zones of ϕ 0,1 are located at their theoretically exact positions (see figures 3 and 5).

Depending on the actual size of each feature, the increase in the positional tolerance may be different for each feature.

Indication on the drawing

Interpretation

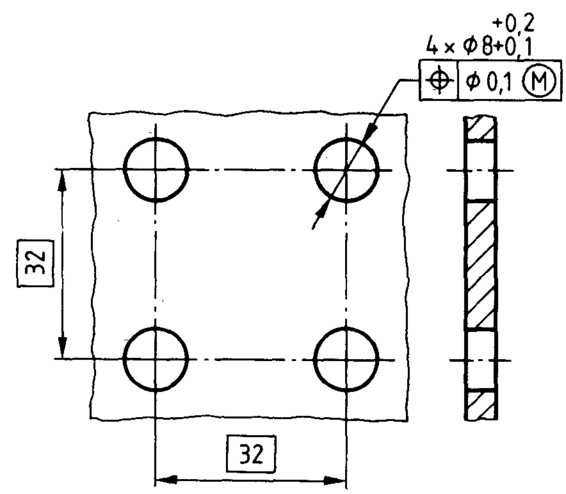


Figure 2

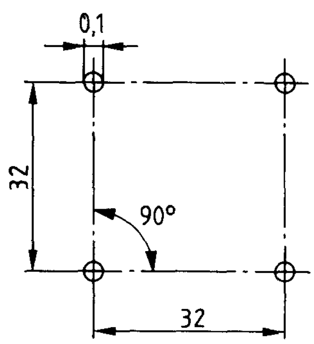


Figure 3

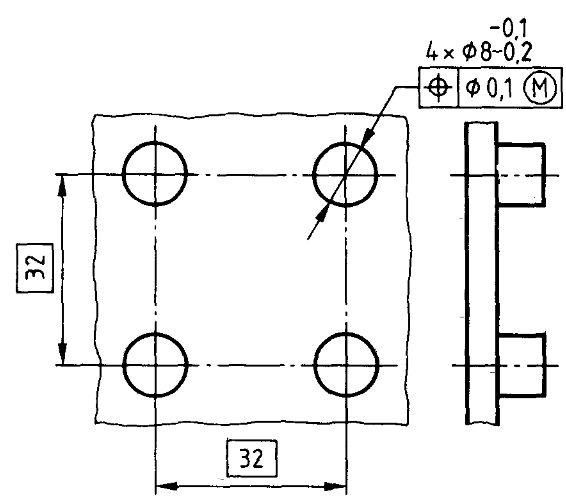


Figure 4

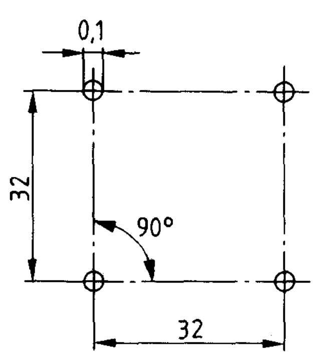


Figure 5

5.1.3 Figure 6 shows four cylindrical surfaces for each of the four holes all being at their maximum material size and of perfect form. The axes are located at extreme positions within the tolerance zone.

Figure 8 shows the corresponding pins at their maximum material size. It can be seen from figures 6 to 9 that assembly of the parts is still possible under the most unfavourable conditions.

5.1.3.1 *One of the holes in figure 6 is shown to a larger scale in figure 7.* The tolerance zone for the axis is ϕ 0,1. The maximum material size of the hole is ϕ 8,1. All ϕ 8,1 circles, the axes of which are located at the extreme limit of the ϕ 0,1 tolerance zone, form an inscribed enveloping cylinder of ϕ 8. This ϕ 8 enveloping cylinder is located at the theoretically exact position and forms the functional boundary for the surface of the hole.

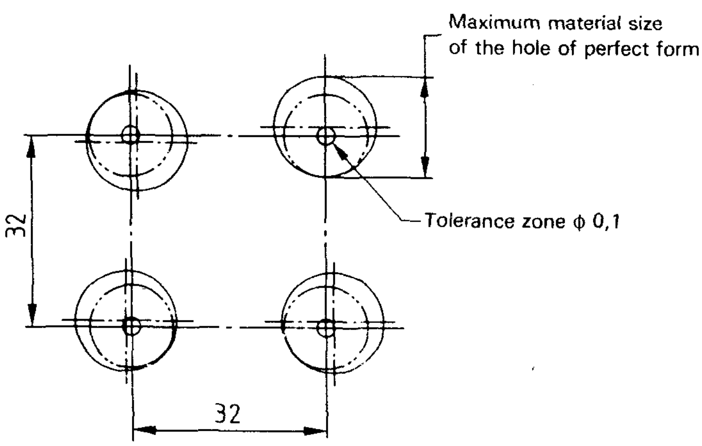


Figure 6

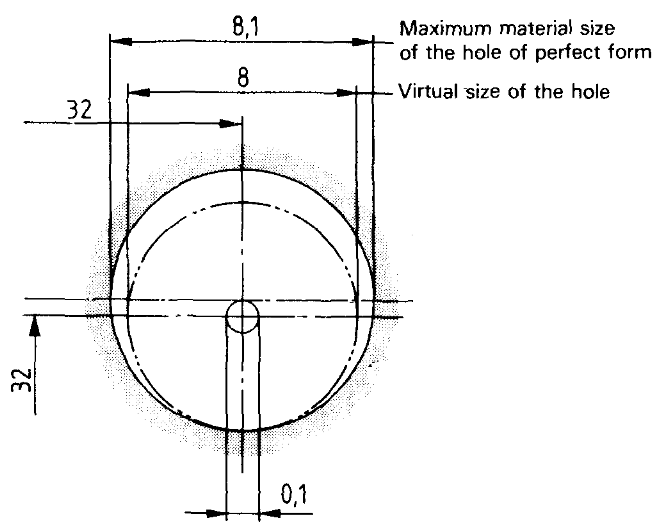


Figure 7

5.1.3.2 One of the pins in figure 8 is shown to a larger scale in figure 9. The tolerance zone for the axis is ϕ 0,1. The maximum material size of the pin is ϕ 7,9. All ϕ 7,9 circles, the axes of which are located at the extreme limit of the ϕ 0,1 tolerance zone, form a circumscribed enveloping cylinder of ϕ 8, which is the virtual condition of the pin.

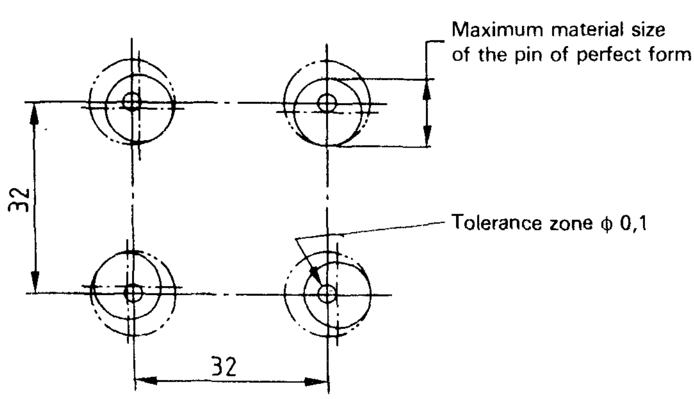


Figure 8

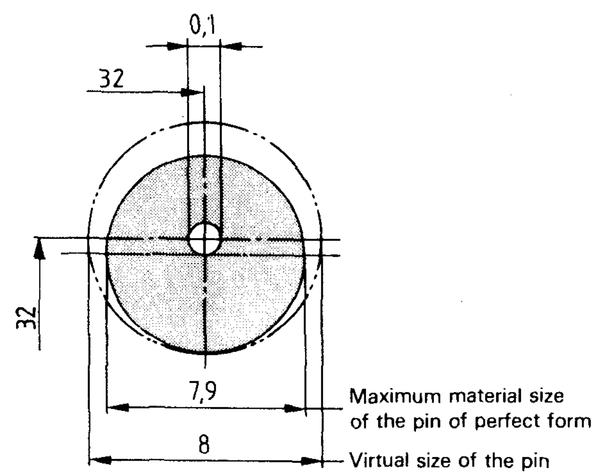


Figure 9

5.1.4 When the size of the hole is larger than its maximum material size and/or when the size of the pin is smaller than its maximum material size, there is an increased clearance between the pin and hole which can be used to increase the positional tolerances of the pin and/or the hole. Depending on the actual size of each feature, the increase in the positional tolerance may be different for each feature.

The extreme case is when the hole is at the least material size, i.e. ϕ 8,2. Figure 10 shows that the axis of the hole may lie anywhere within a tolerance zone of ϕ 0,2 without the surface of the hole violating the cylinder of virtual size.

Figure 11 shows a similar situation with regard to the pins. When the pin is at the least material size, i.e. ϕ 7,8, the diameter of the tolerance zone for position is ϕ 0,2.

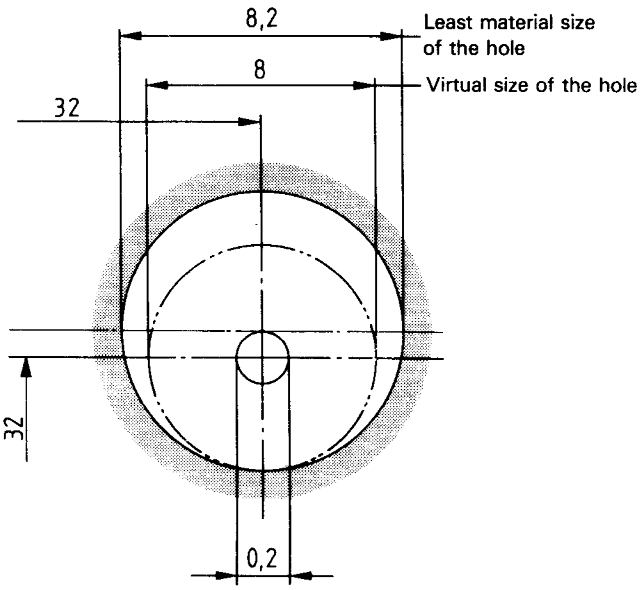


Figure 10

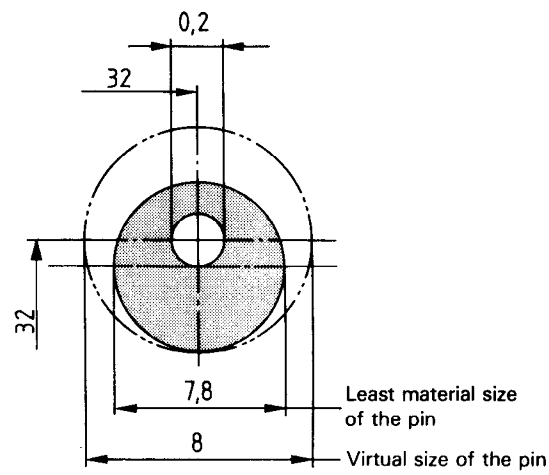


Figure 11

5.1.5 The increase in geometrical tolerance is applied to one part of the assembly without reference to the mating part. Assembly will always be possible even when the mating part is manufactured on the extreme limits of the tolerance in the direction most unfavourable for the assembly, because the combined deviation of size and geometry on neither part is exceeded, i.e. their virtual conditions are not violated.

5.2 Perpendicularity tolerance of a shaft related to a datum plane

5.2.1 The toleranced feature in figure 12 a) has to meet the conditions shown in figure 12 b), i.e. the feature shall not violate the virtual condition, i.e. ϕ 20,2 (ϕ 20 + 0,2), and as all actual local sizes shall remain between ϕ 19,9 and ϕ 20, the straightness deviations of the generator lines or of the axis cannot exceed 0,2 ... 0,3 depending on the actual local sizes, e.g. 0,2 if all actual local sizes are ϕ 20 [see figure 12 c)] and 0,3 if all actual local sizes are ϕ 19,9 [see figure 12 d)].

Indication on the drawing

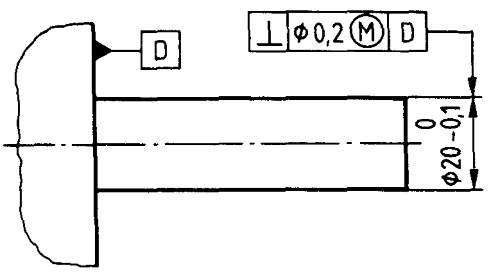
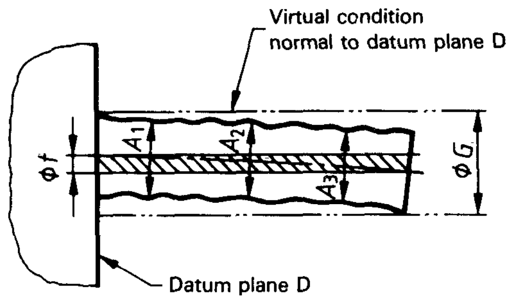


Figure 12 a)

Interpretation



A_1 to A_3 = actual local sizes = 19,9 ... 20
(maximum material size = ϕ 20)

G = virtual size = ϕ 20,2

ϕt = orientational tolerance zone = 0,2 ... 0,3

Figure 12 b)

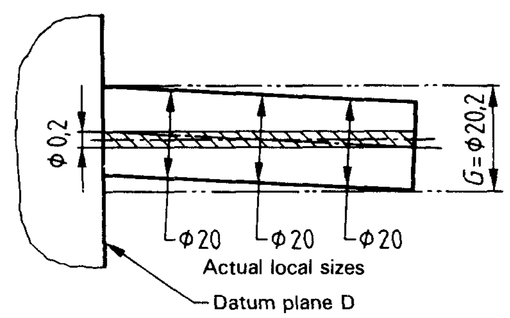


Figure 12 c)

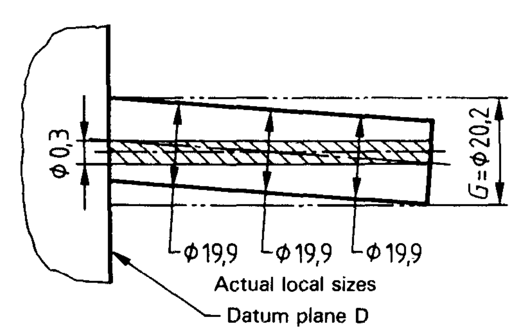


Figure 12 d)

5.2.2 In figure 13 a) the additional requirement Ⓔ (see ISO 8015) together with Ⓜ further restricts the feature to lie within the envelope of perfect form at maximum material size ϕ 20 [see figure 13 b)]. In this example, the actual local sizes shall remain within ϕ 19,9 and ϕ 20 and the combined effect of the straightness and roundness deviations shall not cause the feature to violate the envelope requirement. For example, the straightness deviation of the generator lines or of the axis cannot exceed 0 ... 0,1 depending on the actual local sizes; however, the perpendicularity deviation, because of the Ⓜ-indication, may be increased to 0,3 (virtual size = ϕ 20,2) when the actual local sizes of the feature are ϕ 19,9 [see figure 13 b)].

Indication on the drawing

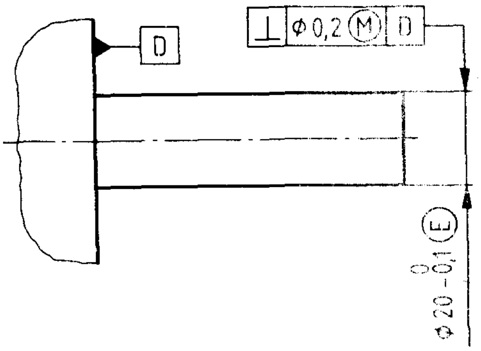
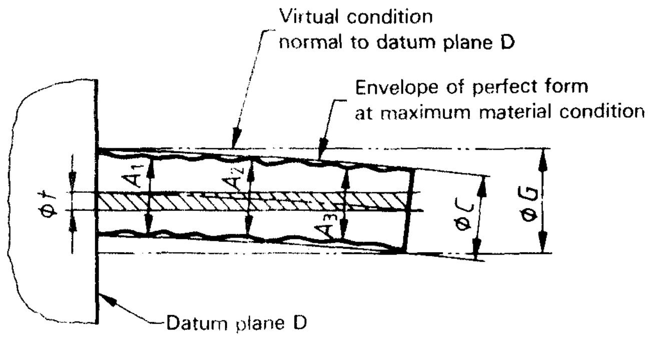


Figure 13 a)

Interpretation



A_1 to A_3 = actual local sizes = 19,9 ... 20
C = maximum material size = ϕ 20
G = virtual size = ϕ 20,2
ϕt = orientational tolerance zone = 0,2 ... 0,3

Figure 13 b)

6 Examples of application where Ⓜ applies to the toleranced feature(s)

6.1 Straightness tolerance of an axis

a) Indication on the drawing

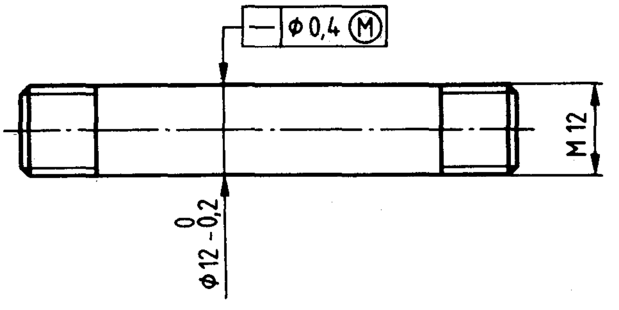


Figure 14 a)

b) Functional requirements

The toleranced feature shall meet the following requirements:

— each actual local size of the feature shall remain within the size tolerance of 0,2 and therefore may vary between ϕ 12 and ϕ 11,8;

— the toleranced feature shall comply with the virtual condition, i.e. the enveloping cylinder of perfect form of ϕ 12,4 (= ϕ 12 + 0,4) [see figures 14 b) and 14 c)].

The axis shall, therefore, remain within the straightness tolerance zone of ϕ 0,4 when all diameters of the feature are at their maximum material size of ϕ 12 [see figure 14 b)] and may vary within a tolerance zone of up to ϕ 0,6 when all diameters of the feature are at their least material size of ϕ 11,8 [see figure 14 c)].

NOTES

1 The two figures 14 b) and 14 c) illustrate the extreme cases of the size of the feature. In practice, the feature would be somewhere between the extreme conditions with different actual local sizes.

2 This indication [see figure 14 a)] may be appropriate when the indication of a greater diameter tolerance associated with the envelope requirement cannot be applied, e.g. in the case of a threaded bolt.

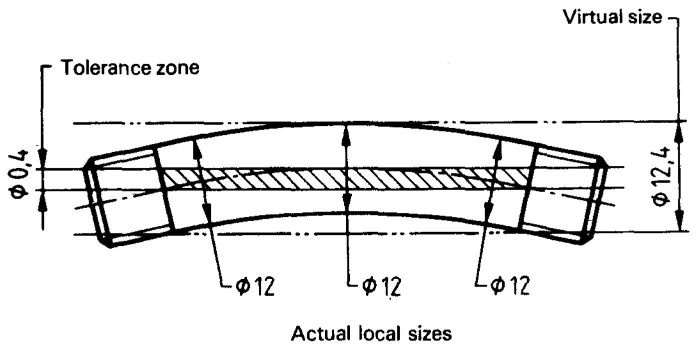


Figure 14 b)

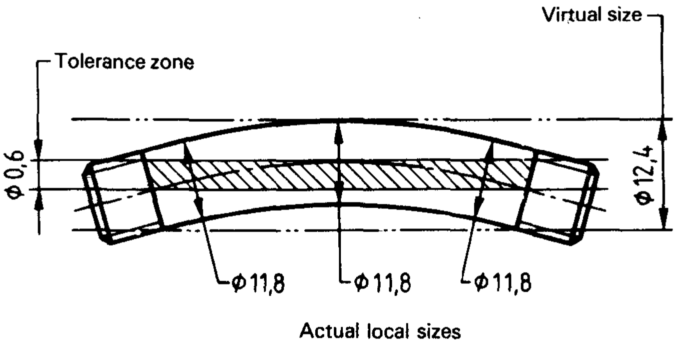


Figure 14 c)

6.2 Parallelism tolerance of a shaft related to a datum plane

a) Indication on the drawing

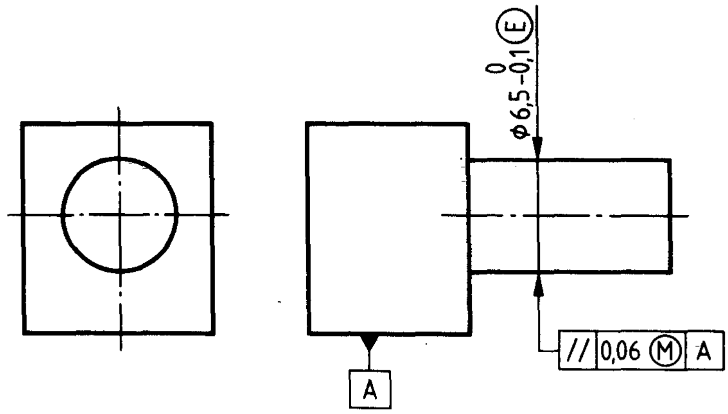


Figure 15 a)

b) Functional requirements

The toleranced feature shall meet the following requirements:

— each actual local size of the feature shall remain within the size tolerance of 0,1 and therefore may vary between ϕ 6,5 and ϕ 6,4;

— the entire feature shall remain within the boundary of the enveloping cylinder of perfect form of ϕ 6,5;

— the toleranced feature shall comply with the virtual condition established by two parallel planes 6,56 (= 6,5 + 0,06) apart and parallel to the datum plane A [see figures 15 b) and 15 c)].

The axis shall, therefore, remain between two parallel planes 0,06 apart and parallel to the datum plane A when all diameters of the feature are at their maximum material size of ϕ 6,5 [see figure 15 b)] and may vary within a tolerance zone (distance between two parallel planes) of up to 0,16 when all diameters of the feature are at their least material size of ϕ 6,4 [see figure 15 c)].

NOTES

1 In the case of a parallelism tolerance of an axis to a datum plane, the tolerance zone has to be a zone between two parallel planes and cannot be a cylindrical tolerance zone.

2 As the parallelism tolerance zone is a zone between parallel planes, the virtual condition is a zone between two parallel planes. The distance between them is the maximum material size 6,5 plus the parallelism tolerance of 0,06, i.e. 6,56.

The condition of the perfect cylinder at maximum material size, as indicated by E, has to be checked separately.

3 The two figures 15 b) and 15 c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local sizes.

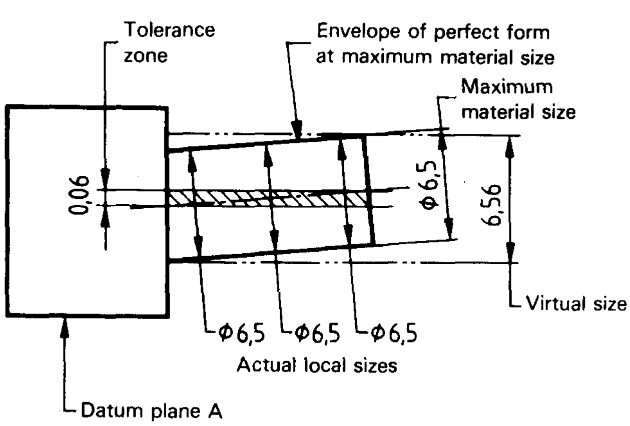


Figure 15 b)

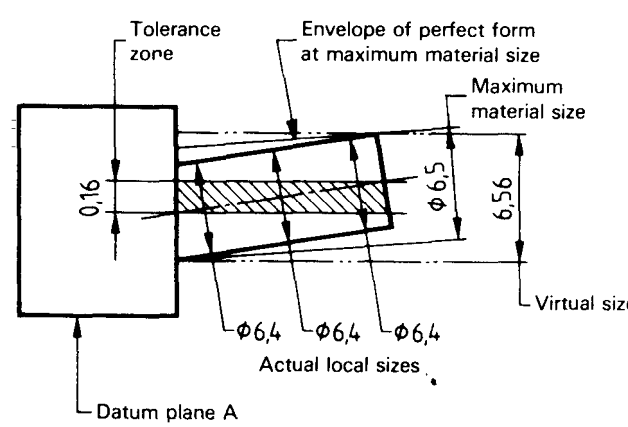


Figure 15 c)

6.3 Perpendicularity tolerance of a hole related to a datum plane

a) Indication on the drawing

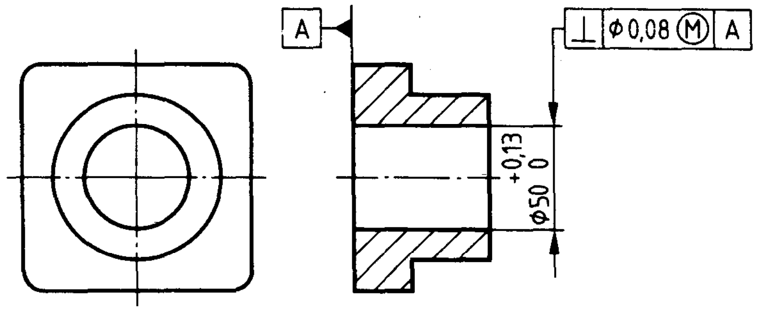


Figure 16 a)

b) Functional requirements

The toleranced feature shall meet the following requirements:

— each actual local size of the feature shall remain within the size tolerance of 0,13 and therefore may vary between ϕ 50 and ϕ 50,13;

— the toleranced feature shall comply with the virtual condition boundary, i.e. the inscribed cylinder of perfect form of ϕ 49,92 (= ϕ 50 − 0,08) and perpendicular to the datum plane A [see figures 16 b) and 16 c)].

The axis shall, therefore, remain within the tolerance zone of ϕ 0,08 perpendicular to the datum plane A when all diameters of the feature are at their maximum material size of ϕ 50 [see figure 16 b)] and may vary within a tolerance zone of up to ϕ 0,21 when all diameters of the feature are at their least material size of ϕ 50,13 [see figure 16 c)].

NOTE — The two figures 16 b) and 16 c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local sizes.

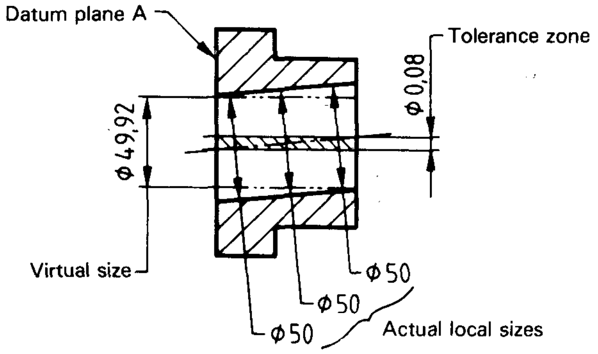


Figure 16 b)

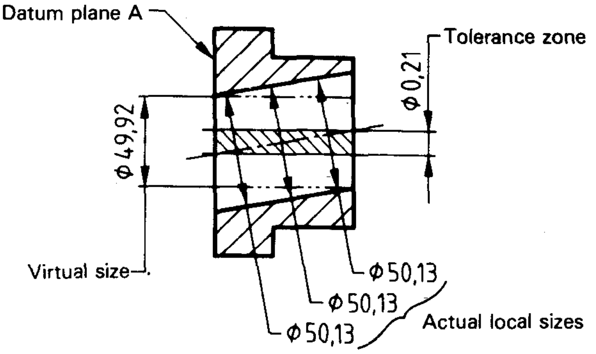


Figure 16 c)

6.4 Angularity tolerance of a slot related to a datum plane

a) Indication on the drawing

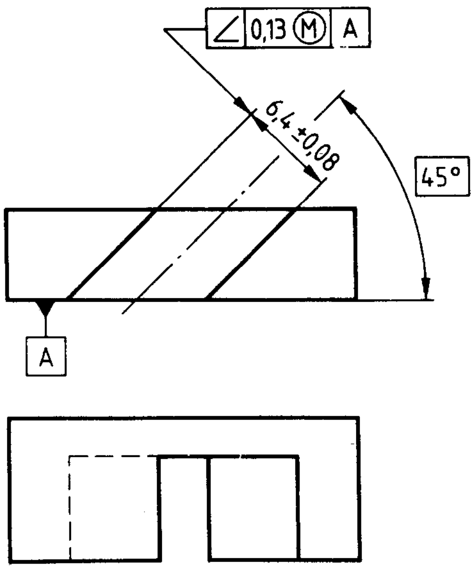


Figure 17 a)

b) Functional requirements

The toleranced feature shall meet the following requirements:

— each actual local size of the feature shall remain within the size tolerance of 0,16 and therefore may vary between 6,32 an 6,48;

— the toleranced feature shall comply with the virtual condition boundary established by two parallel planes 6,19 (= 6,32 - 0,13) apart and at the specified angle of 45° to the datum plane A [see figure 17 a)].

The median plane of the feature shall, therefore, remain between two parallel planes 0,13 apart, inclined at the specified angle c 45° to the datum plane A, when all widths of the feature are at their maximum material size of 6,32 [see figure 17 b)]. The media plane of the feature may vary within a tolerance zone of up to 0,29 when all widths of the feature are at their least material size c 6,48 [see figure 17 c)].

NOTE — The two figures 17 b) and 17 c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature wou be somewhere between the extreme conditions with different actual local sizes.

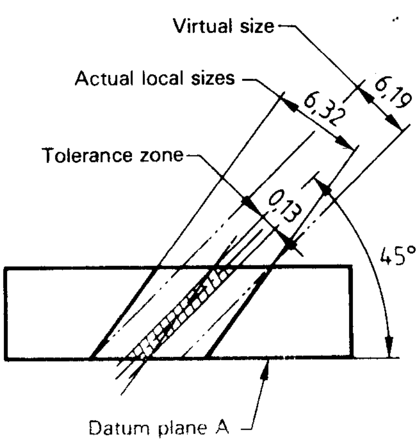


Figure 17 b)

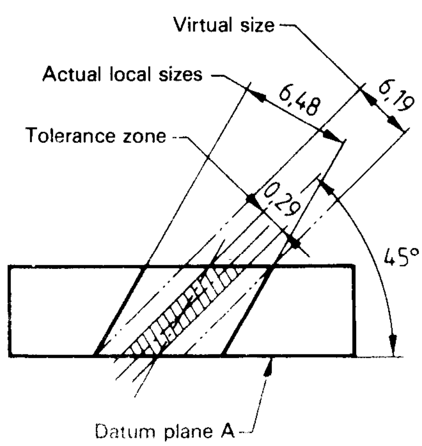


Figure 17 c)

6.5 Positional tolerance of four holes related to each other

a) Indication on the drawing

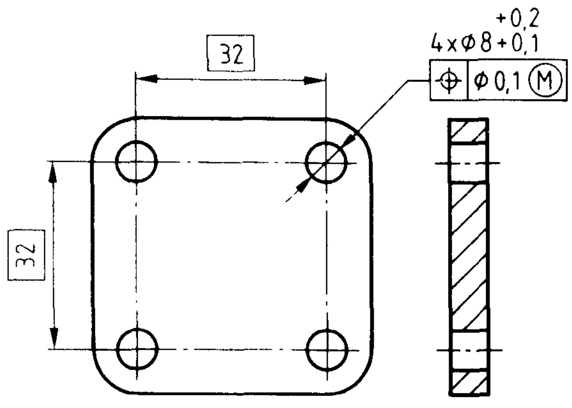


Figure 18 a)

b) Functional requirements

The toleranced features shall meet the following requirements:

— each actual local size of each feature shall remain within the size tolerance of 0,1 and each may vary between ϕ 8,1 and ϕ 8,2;

— all toleranced features shall comply with the virtual condition boundary, i.e. the inscribed cylinder of perfect form of ϕ 8 (= ϕ 8,1 − 0,1), where each of these cylinders is located in its theoretically exact position in relation to the other cylinders (dimension 32 in an exact 90° pattern) [see figure 18 a)].

The axis of each feature shall, therefore, remain within the positional tolerance zone of ϕ 0,1 when each diameter of the feature is at its maximum material size of ϕ 8,1 [see figure 18 b)] and may vary within a tolerance zone of ϕ 0,2 when each diameter of the feature is at its least material size of ϕ 8,2 [see figure 18 c)].

NOTE — The two figures 18 b) and 18 c) illustrate the extreme cases where the features are of theoretically exact form. In practice, the features would be somewhere between the extreme conditions with different actual local sizes.

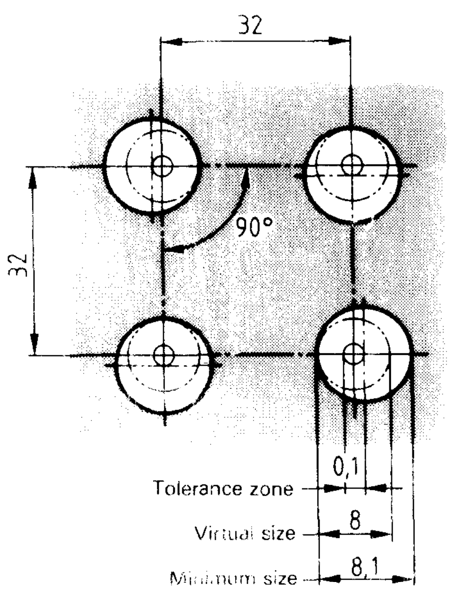


Figure 18 b)

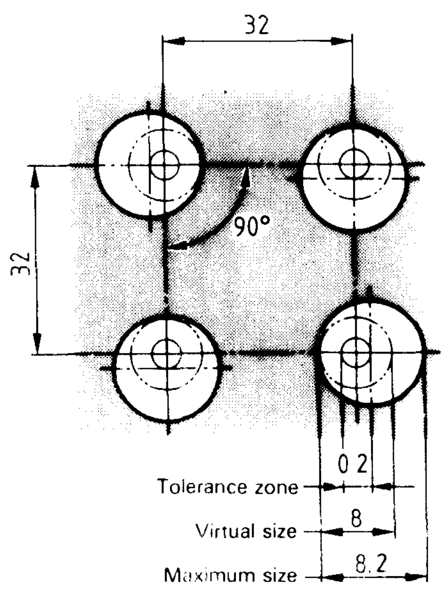


Figure 18 c)

The dynamic tolerance diagram (see figure 19) illustrates the interrelation between the feature size and the permissible deviation from theoretically exact position according to table 1.

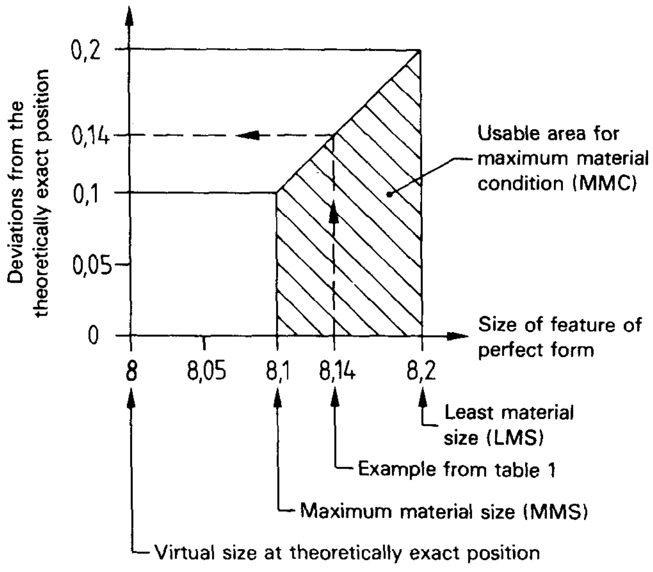


Figure 19

Table 1

Diameter of hole of perfect form	Positional tolerance
8,1 MMS	0,1
8,12	0,12
8,14	0,14
8,16	0,16
8,18	0,18
8,2 LMS	0,2

The functional gauge (see figure 20) represents the virtual condition.

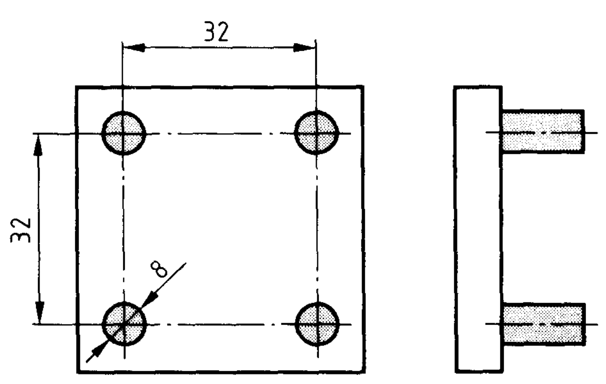


Figure 20

7 Zero geometrical tolerancing

7.1 General

In the examples given in 5.1 and 6.5, the tolerance is distributed between size and position. The extreme case is to allocate the total tolerance to the size and to indicate a zero positional tolerance. In this case, the size tolerance is increased and becomes the sum of the size and positional tolerance indicated previously.

The indication on the drawing for the holes in figure 2, therefore, becomes as illustrated in figure 21 a) and the indication on the drawing for the pins in figure 4 therefore becomes as illustrated in figure 21 b).

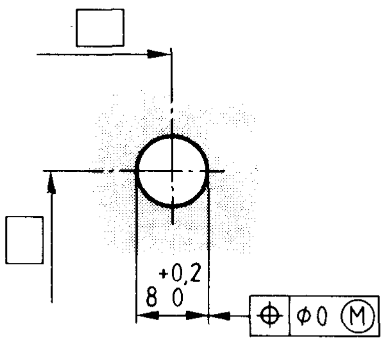


Figure 21 a)

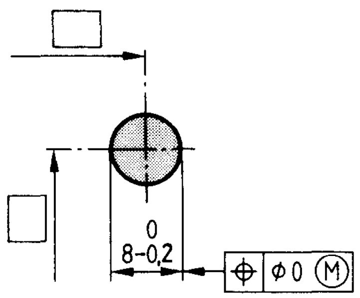


Figure 21 b)

According to the indications on the drawings in figures 21 a) and 21 b), the positional tolerances may vary between ϕ 0 and ϕ 0,2 as the actual sizes vary between maximum and minimum.

The indication "0Ⓜ" may also be used with other geometrical characteristics.

7.2 Examples

7.2.1 Four holes related to each other

a) Indication on the drawing

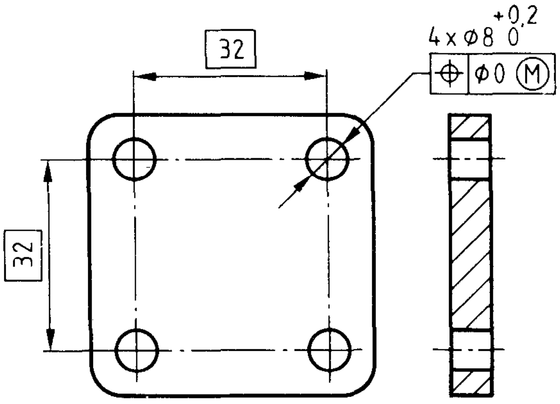


Figure 22

b) Interpretation

According to the indication on the drawing in figure 22, the virtual size is the maximum material size (minimum hole diameter) minus the given positional tolerance, i.e. $\phi\,8 - \phi\,0 = \phi\,8$.

The dynamic tolerance diagram (see figure 23) illustrates the interrelation between the feature size and the permissible deviation from the theoretically exact position according to table 2.

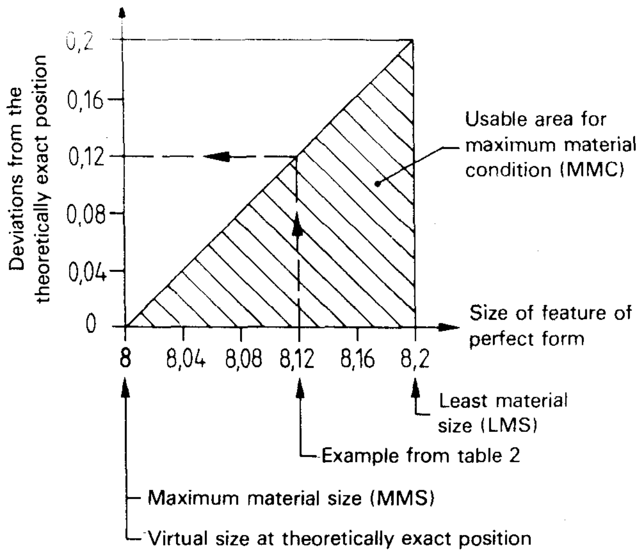


Figure 23

Table 2

Diameter of hole of perfect form	Positional tolerance
8 MMS	0
8,04	0,04
8,08	0,08
8,12	0,12
8,16	0,16
8,2	0,2

The functional gauge in accordance with figure 20 also represents the virtual condition of the part illustrated in figure 22. In both cases, the feature diameters shall be checked separately according to their different size tolerances.

7.2.2 Four pins related to each other

a) Indication on the drawing

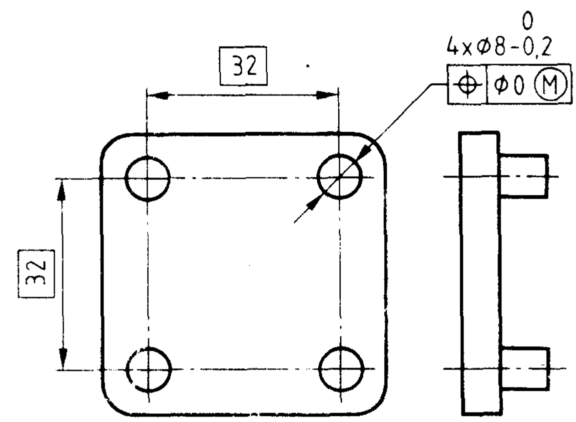


Figure 24

b) Interpretation

According to the indication on the drawing in figure 24, the virtual size is the maximum material size (maximum pin diameter) plus the given positional tolerance, i.e. $\phi\, 8 + \phi\, 0 = \phi\, 8$.

The dynamic tolerance diagram (see figure 25) illustrates the interrelation between the feature size and the permissible deviation from the theoretically exact position according to table 3.

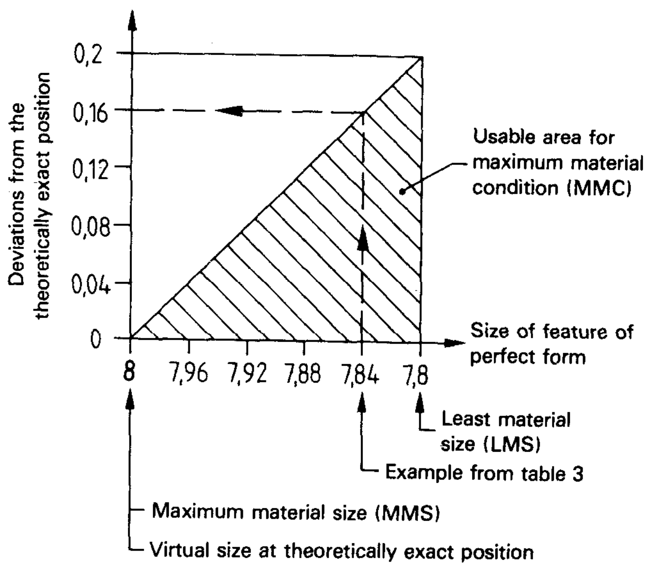


Figure 25

Table 3

Diameter of pin of perfect form	Positional tolerance
8 MMS	0
7,96	0,04
7,92	0,08
7,88	0,12
7,84	0,16
7,8	0,2

The functional gauge (see figure 26) represents the virtual condition.

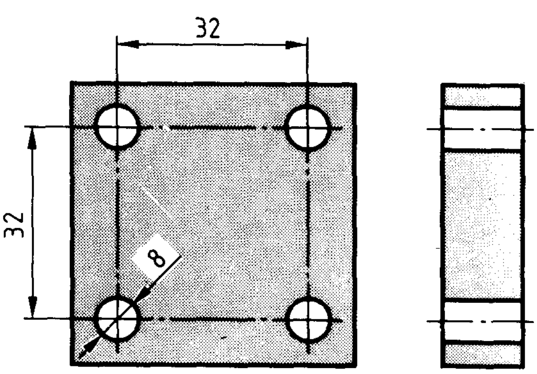


Figure 26

8 Examples of application where Ⓜ applies to the toleranced feature(s) and the datum feature

8.1 Positional tolerance of four holes related to a datum hole

a) Indication on the drawing

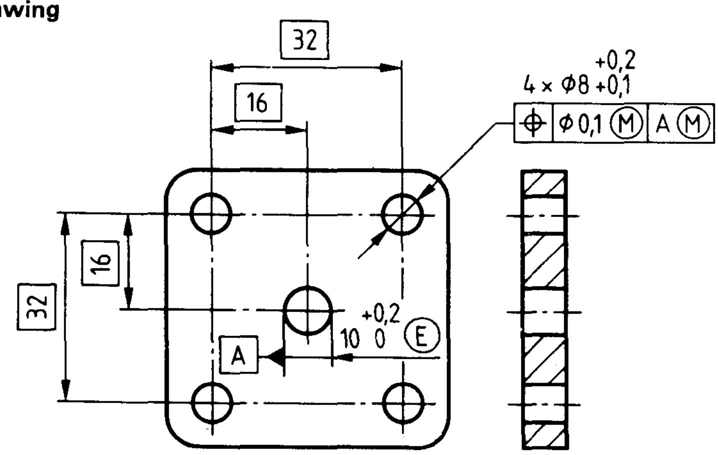


Figure 27 a)

b) Functional requirements

The toleranced feature shall meet the following requirements:

— Each actual local size of each feature shall remain within the size tolerance of 0,1 and therefore may vary between ϕ 8,1 and 8,2 [see figures 27 b) and 27 c)].

— All toleranced features shall comply with the virtual condition boundary, i.e. the inscribed cylinder of perfect form of ϕ 8 (= ϕ 8,1 − 0,1), where each of these cylinders is located in its theoretically exact position in relation to the other cylinders [dimension 32 in an exact 90° pattern, see figures 27 b) and 27 c)] and also in its theoretically exact position in relation to the datum axis when the mating size of the datum feature A is at the maximum material size of ϕ 10 [see figure 27 b)].

In the extreme case, the axis of each feature shall, therefore, remain within the positional tolerance zone of ϕ 0,1 when each feature diameter is at its maximum material size of ϕ 8,1 [see figure 27 b)] and may vary within a tolerance zone of ϕ 0,2 when each feature diameter is at its least material size of ϕ 8,2 [see figure 27 c)].

— The actual axis of the datum feature A may float in relation to the virtual conditions of the position of the four features if there is a departure from the maximum material size of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size [see figures 27 b) and 27 c)].

In the extreme case, the actual axis of the datum feature A may, therefore, float within a zone of ϕ 0,2 when the datum feature A is of perfect form and of least material size φ 10,2 [see figure 27 c)].

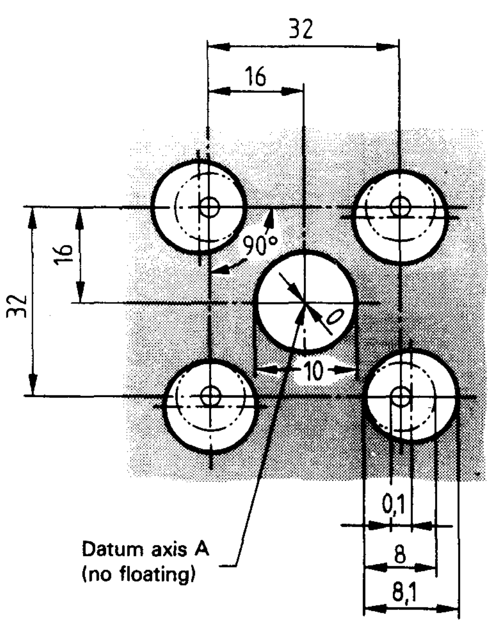


Figure 27 b)

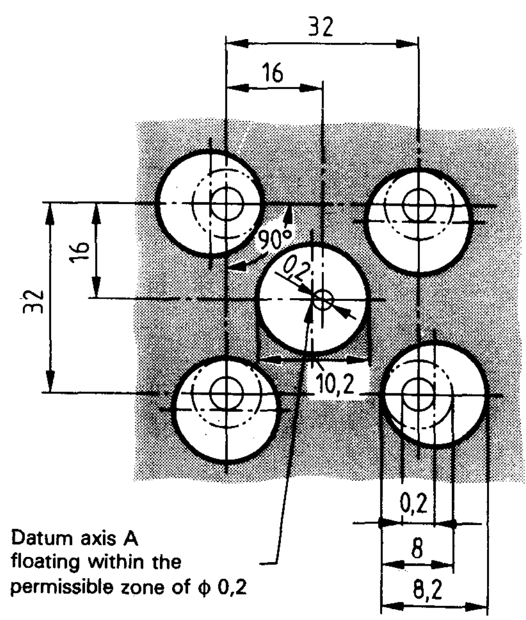


Figure 27 c)

The positional tolerance applies to the four toleranced features in relation to each other as well as in relation to the datum feature. The given value is increased by an amount equal to the departure given in table 4 (second column).

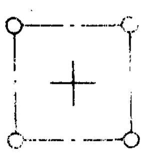
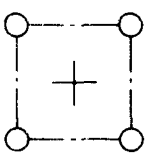
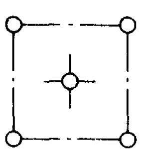
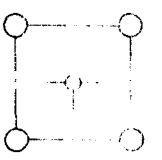
The additional positional tolerance which depends on the size of the datum feature (due to the maximum material condition on the datum) applies only to the toleranced features as a group tolerance in relation to the datum feature, but does not apply to the toleranced features in relation to each other, i.e. the datum may float in relation to the toleranced feature (for the values, see table 4).

Table 4

Toleranced hole diameter	Positional tolerance of each toleranced feature	Datum hole diameter	Floating zone for datum feature
8,1 MMS	0,1	10 MMS	0
8,12	0,12	10,05	0,05
8,14	0,14	10,1	0,1
8,16	0,16	10,15	0,15
8,18	0,18	10,2 LMS	0,2
8,2 LMS	0,2		

Any combination of the values in the second and fourth columns of table 4 may occur. The values in the second and fourth columns cannot simply be added because they have different interpretations. Some examples of extreme combinations are given in table 5.

Table 5

Tolerance zone for toleranced feature	0,1	0,2	0,1	0,2
Tolerance zone for datum feature	0	0	0,2	0,2
Tolerance diagram				

The functional gauge (see figure 28) represents the virtual condition.

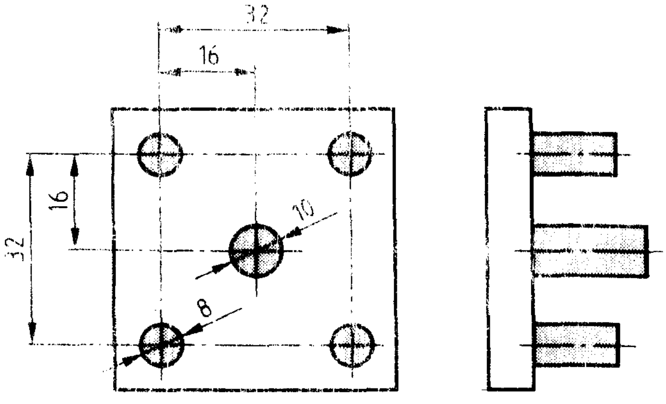


Figure 28

8.2 Coaxiality tolerance

a) Indication on the drawing

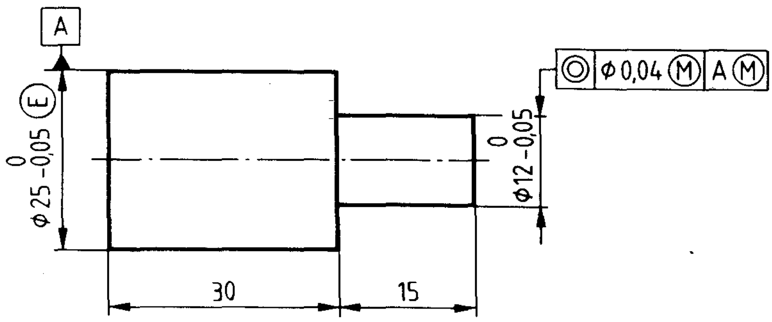


Figure 29 a)

b) Functional requirements

The actual toleranced feature shall meet the following requirements:

— Each actual local size of the feature shall remain within the size tolerance of 0,05 and therefore may vary between ϕ 12 and ϕ 11,95 [see figures 29 b) and 29 c)].

— The whole feature shall remain within the virtual condition boundary, i.e. the enveloping cylinder of perfect form of ϕ 12,04 (= ϕ 12 + 0,04) and coaxial to the datum axis A when the mating size of the datum feature A is at its maximum material size [see figures 29 b) and 29 c)].

— The actual axis of the datum feature A may float in relation to the virtual condition if there is a departure from the maximum material size of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size [see figure 29 d)].

The axis of the feature shall, therefore, remain within the coaxiality tolerance zone of ϕ 0,04 when all diameters of the feature are at their maximum material size of ϕ 12 [see figure 29 b)] and may vary within a tolerance zone of up to ϕ 0,09 when all diameters of the toleranced feature are at their least material size of ϕ 11,95 and the mating size of the datum feature is at the maximum material size of ϕ 25 [see figure 29 c)]. The actual axis of the datum feature A may float within a zone of ϕ 0,05 when the mating size of the datum feature A is at the least material size of ϕ 24,95 [see figure 29 d)]. As in this case only one feature is related to the datum, the float of the datum has the effect of an increase in the coaxiality tolerance as illustrated in figure 29 e).

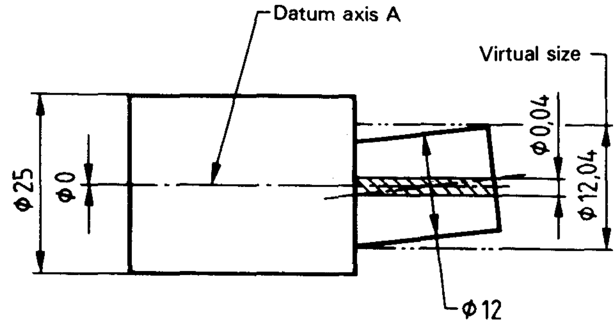


Figure 29 b)

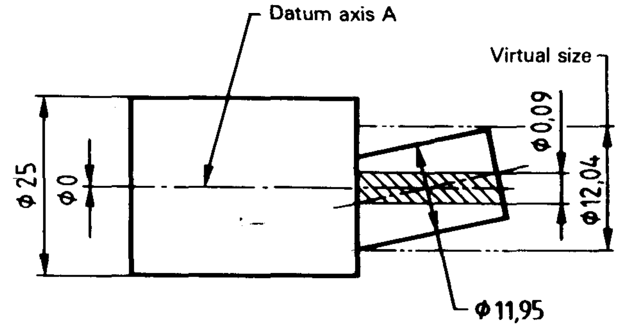


Figure 29 c)

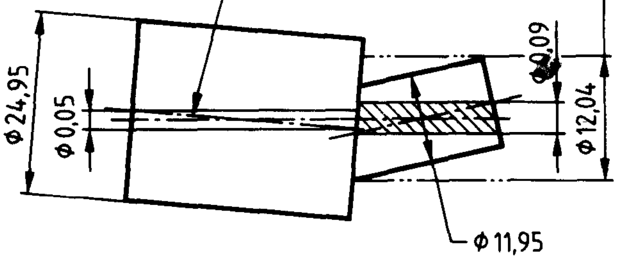
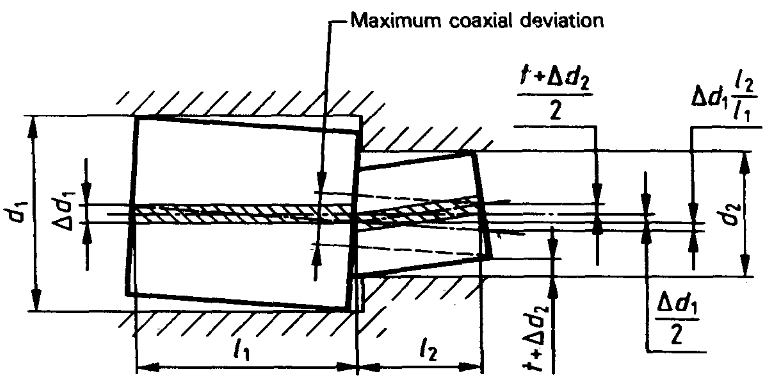


Figure 29 d)



where

d_1 is the maximum material size MMS of the datum feature

d_2 is the virtual size of the toleranced feature

t is the geometrical tolerance

Δd_1 = d_1 minus the mating size of the datum feature

$t + \Delta d_2$ = d_2 minus the mating size of the toleranced feature

Maximum coaxial deviation: $\approx 2 \left(\frac{t + \Delta d_2}{2} + \frac{\Delta d_1}{2} + \Delta d_1 \frac{l_2}{l_1} \right)$

$$\approx 2 \left(\frac{0{,}04 + 0{,}05}{2} + 0{,}025 + 0{,}05 \frac{15}{30} \right)$$

$$\approx 0{,}19$$

Figure 29 e)

The functional gauge (see figure 30) represents the virtual condition.

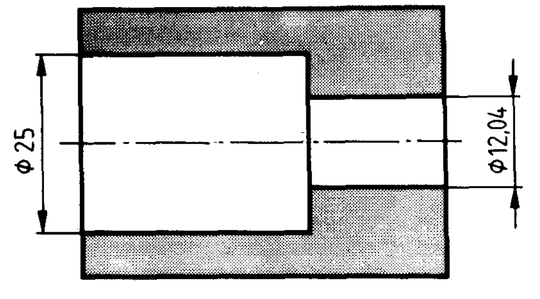


Figure 30

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This Indian Standard has been developed from Doc : No. **LMD 02 (0076)**

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Printed at Dee Kay Printers, New Delhi, India