



BSI Standards Publication

**Limits and fits – Guidance
for system of cone (taper)
fits and tolerances for cones
from $C = 1:3$ to $1:500$, lengths
from 6 mm to 630 mm and
diameters up to 500 mm**

Publishing and copyright information

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 30 September 2009. It was prepared by Technical Committee TDW/4, *Technical product realization*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 4500-4:1985 and BS 4500-5:1988, which are withdrawn.

Relationship with other publications

This British Standard is derived from the ISO 286 (BS EN 20286) series, which establishes the ISO code-system for tolerances of linear sizes and is published in the following parts:

- ISO 286-1 (BS EN 20286-1), *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*;
- ISO 286-2 (BS EN 20286-2), *ISO system of limits and fits – Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*.

The ISO 286 series covers the metric system of limits and fits and replaced the original national limits and fits standard BS 4500-1:1969.

The BS 1916 series provides guidance and recommendations on the equivalent inch system (imperial) of limits and fits and is published in the following parts:

- BS 1916-1, *Limits and fits for engineering – Part 1: Guide to limits and tolerances*;
- BS 1916-2, *Limits and fits for engineering – Part 2: Guide to the selection of fits in BS 1916-1*;
- BS 1916-3, *Limits and fits for engineering – Part 3: Guide to tolerances, limits and fits for large diameters*.

This British Standard complements BS EN ISO 1119, *Geometrical product specifications (GPS) – Series of conical tapers and taper angles*.

Information about this document

In view of the time elapsed since the publication of BS 4500-4 in 1985 and BS 4500-5 in 1988, these British Standards were reviewed in detail in 2009 and amalgamated into one Standard. It was decided that the technical provisions of the previous editions were still generally applicable but the figures have been redrawn for ease of use, the wording of some guidance updated for clarity, and the opportunity was taken to update references to other standards.

Use of this document

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This British Standard gives guidance on a system of cone fits and tolerances for cones from $C = 1:3$ to $1:500$ and lengths from 6 mm to 630 mm.

The appropriate tolerances of this British Standard can also be used for prismatic workpieces, for example wedges.

This British Standard applies to cones which are dimensioned and toleranced according to BS ISO 3040, Method 1, Basic Taper method. This means that the tolerances limit the variation of penetration of mating surfaces, each surface being within two limiting profiles of the same taper corresponding to the maximum material condition (MMC) and the least material condition (LMC).

This British Standard is derived from BS EN 20286, and is a complement to BS EN ISO 1119.

NOTE For dimensioning and tolerancing cones on drawings, see BS ISO 3040.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 20286-1, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions used for cylindrical fits given in BS EN 20286-1 and the following apply.

3.1 cones

3.1.1 actual cone

cone, the conical surface of which has been found by measurement

NOTE See Figure 1.

3.1.2 basic cone

geometrically ideal conical surface which is given by its geometrical dimensions

NOTE These dimensions are either: a basic cone diameter, the basic cone length and the basic rate of taper or the basic cone angle; or two basic cone diameters and the basic cone length. See Figure 2.

3.1.3 cone

conical surface or conical workpiece, defined by its geometrical dimensions

NOTE See Figure 3. In the absence of any indication concerning the geometrical form, "cone" is understood to mean a straight circular cone or truncated cone.

3.1.4 conical surface

surface of revolution formed by rotating a straight line (generator) around an axis with the straight line intersecting this axis at the apex

NOTE See Figure 3. The parts of this infinite conical surface are also known as conical surfaces or cones. Similarly, "cone" is also the abbreviated designation of a truncated cone.

3.1.5 conical workpiece

workpiece or portion of a workpiece the main part of which is a conical surface

NOTE See Figure 4 and Figure 5.

3.1.6 external cone

cone which limits the outside form of a conical feature of a workpiece

NOTE See Figure 4 and Figure 6.

3.1.7 generator

line of intersection of the conical surface with a section in the axial plane

NOTE See Figure 3 and Figure 6.

3.1.8 internal cone

cone which limits the inside form of a conical feature of a workpiece

NOTE See Figure 5 and Figure 6.

3.1.9 limit cones

geometrically ideal coaxial surfaces, having the same basic cone angle, which result from the basic cone and the cone diameter tolerances

NOTE 1 The difference between the largest and the smallest cone diameters is the same in all sections normal to the cone axis. See Figure 7.

NOTE 2 The surfaces of the limit cones can be made to coincide by axial displacement.

3.2 sizes on cones**3.2.1 actual cone diameter (d_a)**

distance between two parallel tangents to the intersection line of the surface of the actual cone with a defined plane normal to the cone axis

NOTE See Figure 1.

3.2.2 basic cone angle (α)

angle formed by the two generators of the basic cone in a section in the axial plane

NOTE See Figure 8.

3.2.3 basic cone diameters

- a) largest cone diameter D ; or
- b) smallest cone diameter d ; or
- c) cone diameter d_x at a place determined by its position in the axial direction

NOTE See Figure 2.

3.2.4 basic cone length (L)

distance in the axial direction between two limiting ends of a cone

NOTE See Figure 2 and Figure 6.

3.2.5 cone diameter

distance between two parallel lines tangent to the intersection of the circular conical surface with a plane normal to the cone axis

3.2.6 cone generating angle ($\alpha/2$)

angle contained between a generator and the cone axis

NOTE See Figure 8. The generating angle is equal to half the basic cone angle α .

3.2.7 limit cone angles

largest and smallest cone angles resulting from the basic cone angle α and the d position and magnitude of the cone angle tolerance

NOTE See Figure 9.

3.2.8 limit cone diameters

diameters of the limit cones in each section in a plane normal to the axis

NOTE See Figure 7.

3.2.9 rate of taper (C)

ratio of the difference between the cone diameters D and d to the cone length L

$$\text{NOTE } C = \frac{D-d}{L} = 2 \tan \frac{\alpha}{2}$$

The rate of taper is often indicated by the expressions 1:x or 1/x and "Cone 1:x" for short. For example, $C = 1:20$ means that a diameter difference $D - d$ of 1 mm occurs an axial distance L of 20 mm between the cone diameters D and d .

3.3 cone fit**3.3.1 character of a cone fit**

clearances or interferences measured normal to the cone axis

NOTE The clearances and interferences are effective normal to the conical surfaces, but are indicated and measured normal to the cone axis. The differences between the values shown normal to the cone surface and normal to the cone axis are negligible for cones with rates of taper up to 1:3 and can be ignored for practical purposes.

3.3.2 cone fit

relationship resulting from the difference in assembly between the cone diameters of conical workpieces (internal cone and external cone) having circular sections and the same basic cone angle α or the same rate of taper C

NOTE The definition for a cone fit with a circular section is also applicable for taper workpieces with other sections, for example, prismatic parts, wedges, etc.

3.4 axial displacement for single conical workpieces**3.4.1 axial displacement (EN)**

calculated axial distance of the cone with regard to the basic cone

NOTE See Figure 21a). This has importance only for the calculation of the axial displacement for cone assemblies (see 3.5.1).

3.4.2 maximum axial displacement ($EN_{\max}$)

displacement relative to the basic cone which is calculated from the fundamental deviation and the tolerance for the basic cone diameter

3.4.3 minimum axial displacement ($EN_{\min}$)

displacement relative to the basic cone which is calculated from the fundamental deviation for the basic cone diameter

3.5 constructional and dimensional location cone fits**3.5.1 axial displacement for cone assemblies (EP)**

axial displacement of the conical workpieces to be assembled with respect to each other

NOTE This is the algebraic sum of the calculated displacements EN_i of the internal cone and EN_e of the external cone (referred to the basic cone).

3.5.2 maximum axial displacement for cone assemblies ($EP_{\max}$)

displacement which is calculated from the sum $EN_{i\max}$ of the internal cone and $EN_{e\max}$ of the external cone

NOTE $EP_{\max} = EN_{i\max} + EN_{e\max}$

For the basic hole system, $EN_{i\max} = \frac{1}{C} \times IT$.

3.5.3 minimum axial displacement for cone assemblies ($EP_{\min}$)

displacement which is calculated from the sum of $EN_{i\min}$ of the internal cone and $EN_{e\min}$ of the external cone

NOTE $EP_{\min} = EN_{i\min} + EN_{e\min}$

For the basic hole system, $EN_{i\min} = 0$.

3.5.4 variation of cone diameter fit (T_{DP})

possible variation of the diametral clearance and/or interference between the conical workpieces to be assembled and the absolute value of the difference between the maximum and minimum clearances and interferences respectively

NOTE 1 See Figure 10, Figure 17, Figure 18, Figure 19, Figure 20 and Figure 21.

NOTE 2 $T_{DP} = S_{\max} - S_{\min}$ or $U_{\max} - U_{\min}$

where $S_{\max}$ and $S_{\min}$ are the maximum and minimum diametral clearances respectively and $U_{\max}$ and $U_{\min}$ are the maximum and minimum diametral interferences respectively.

The variation of cone diameter fit is equal to the sum of the cone diameter tolerances of the internal cone T_{Di} and the external cone T_{De} , i.e.:

$T_{DP} = T_{Di} + T_{De}$.

3.6 axial displacement type cone fits**3.6.1 assembly force (F_s)**

force to be applied axially in the assembly of the conical workpieces starting from the actual starting position (P_a) in order to reach a defined interference cone fit in the final position (P_f) of the cones

NOTE See Figure 20.

3.6.2 axial displacement for assembled cones (E_a)

algebraic difference measured axially between the separation of the reference planes of the internal and external cones respectively at the actual starting position (P_a), and the separation of the reference planes at the final position (P_f) required for the cone fit

NOTE Figure 19 gives an example of an interference cone fit. The amount of the axial displacement E_a depends on the rate of taper C of both conical workpieces to be assembled.

3.6.3 maximum axial displacement (E_{amax})

measured axial displacement giving the maximum clearance or the maximum interference respectively in the final position of the conical workpieces

NOTE Figure 10 gives an example of an interference cone fit.

3.6.4 minimum axial displacement (E_{amin})

axial displacement giving the minimum clearance and the minimum interference respectively in the final position of the conical workpieces

NOTE Figure 10 gives an example of an interference cone fit.

3.6.5 tolerance on the axial displacement (T_E)

difference between the minimum and maximum axial displacements

NOTE $T_E = E_{\text{amax}} - E_{\text{amin}}$. See Figure 10.

3.6.6 final position (P_f)

axial position prescribed for the conical workpieces with respect to each other in the final state in which the required clearances or interferences exist

3.6.7 starting positions**3.6.7.1 starting position (P)**

axial position of the conical workpieces with respect to each other at which the cones contact without force

3.6.7.2 actual starting position (P_a)

axial position of the actual cones (internal cone and external cone) relative to each other at which they contact without force

NOTE See Figure 19 and Figure 20. This parameter is important in the production of cone fits and should lie within the limit starting positions P_1 and P_2 (see Figure 11).

3.6.7.3 limit starting positions (P_1 and P_2)

extreme axial positions of the conical workpieces to be assembled with respect to each other which are calculated from the limit cones at contact without force

NOTE 1 The limit cones are those (extreme) cones having basic cone angle and cone diameter tolerances T_{Di} and T_{De} respectively.

NOTE 2 The limit starting positions are calculated from the assembly of the smallest possible internal cone with the largest possible external cone on the one hand, and the largest possible internal cone with the smallest possible external cone on the other hand (see Figure 11).

3.6.7.4 tolerance on the starting positions (T_p)

maximum axial distance between the reference planes of the internal cone and the external cone relative to each other, resulting from the calculated limit starting positions P_1 and P_2

NOTE See Figure 11. The tolerance T_p of the starting position is calculated from: $T_p = \frac{1}{C} \times (T_{Di} + T_{De})$

3.7 cone tolerances**3.7.1 cone angle tolerance (AT)**

difference between the largest and smallest permissible cone angles

NOTE See Figure 9 and Figure 12.

3.7.2 cone diameter tolerance (T_D)

difference between the largest and smallest permissible cone diameters in any section, i.e. between the limit cones

NOTE See Figure 7.

3.7.3 cone form tolerances (T_F)**3.7.3.1 tolerance on the roundness of the section**

distance between two coplanar concentric circles in a section normal to the axis between which the actual cone section is situated

NOTE See Figure 13. The actual value for the error on roundness is taken as the distance between two coplanar concentric circles which touch the actual line of any section normal to the axis.

3.7.3.2 tolerance on the straightness of the generator

distance between two parallel, straight lines between which the actual generator lies

NOTE See Figure 7. The actual value for the error on straightness is taken as the distance between two parallel straight lines touching the actual generator, and so placed that the distance between them is a minimum.

3.7.4 cone section diameter tolerance (T_{DS})

difference between the largest and smallest permissible cone diameters in a defined section

NOTE See Figure 14.

3.7.5 cone tolerance system

system containing the cone diameter tolerances, the cone angle tolerances and the tolerances on the cone form of the generator and the circumferential line of the section normal to the cone axis

3.7.6 cone tolerance space

space between the two limit cones, for the conical surface

NOTE Cone tolerance space includes all the tolerances referred to in 3.7. It can be represented by tolerance zones in two plane sections. See Figure 7 and Figure 13.

3.8 actual cone angles**3.8.1 actual cone angle**

in any axial plan section, the angle between the two pairs of parallel straight lines that enclose the form errors of the two generators in such a way that the maximum distance between them is the least possible value

NOTE See Figure 15. For a given cone, there is not only one actual cone angle; for cones having deviations of roundness, the actual cone angle will be in different axial planes (see α_1 and α_2 in Figure 15).

3.8.2 average actual cone angle

arithmetical average value of the actual cone angle in several equally distributed axial plane sections

NOTE Amongst the axial planes chosen, one at least should cover the greatest deviation of roundness from the circle line of the cone diameter.

3.9 cone tolerance zones

3.9.1 cone diameter tolerance zone (in a graphic representation)

zone, lying in the plane section of the cone axis, which is limited by the limit cones

NOTE The total tolerances zone is represented in Figure 7 and Figure 13 by the hatched portions, which also indicate the cone tolerance space. It includes the tolerances for the cone diameter, the cone angle, the roundness and the straightness which can occupy the whole cone tolerance zone. In general, each of these particular deviations occupies a part of the cone diameter tolerance zone only.

3.9.2 cone section diameter tolerance zone

tolerance zone for the cone diameter in a defined section

NOTE It applies where the cone diameter tolerance is indicated for a fixed diameter only.

3.9.3 tolerance zone for the cone angle

fan-shaped zone within the limit cone angles

NOTE The inclination of the limit cones can be indicated by plus, minus or plus/minus for the cone angle tolerances. See Figure 16. For the indication of plus/minus, the values can be different.

3.9.4 tolerance zone for the roundness of the section (in a graphic representation)

zone lying in a section normal to the cone axis and formed by concentric circles

NOTE See Figure 13. As this zone is narrower than that referred to in 3.9.1, it only applies if the tolerance for the roundness of the section is reduced with respect to the cone diameter tolerance zone. The contour is situated anywhere with a tolerance zone given by the tolerance for the roundness of the section.

3.9.5 tolerance zone for the straightness of the generator (in a graphic representation)

zone (band), situated in any axial plane section and disposed on each side of the cone axis, which is determined by the form tolerance of the generators

NOTE See Figure 7. As this zone is smaller than that referred to in 3.9.1, it only applies if the tolerance on the straightness of the generator is reduced with respect to the cone diameter tolerance zone. The actual generator is situated anywhere with a tolerance zone given by the tolerance for the straightness.

Figure 1 Actual cone

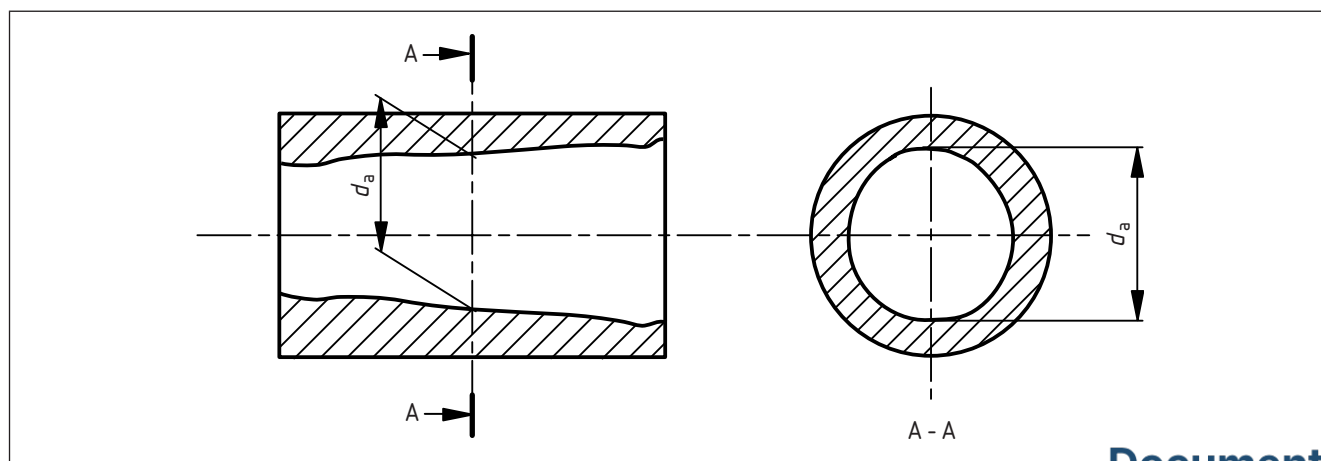


Figure 2 Basic cone

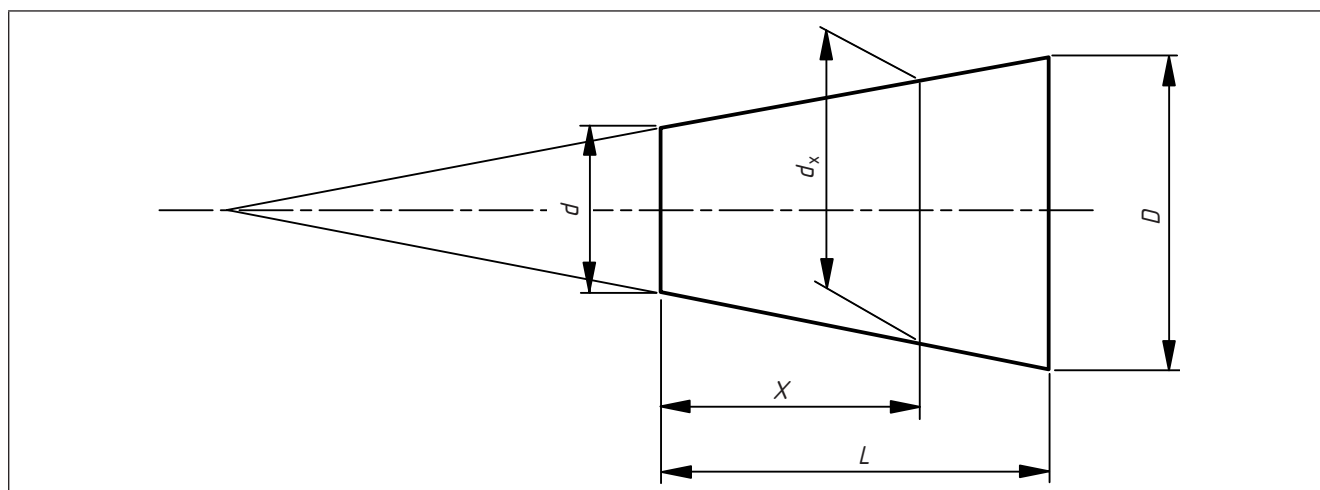


Figure 3 Cone

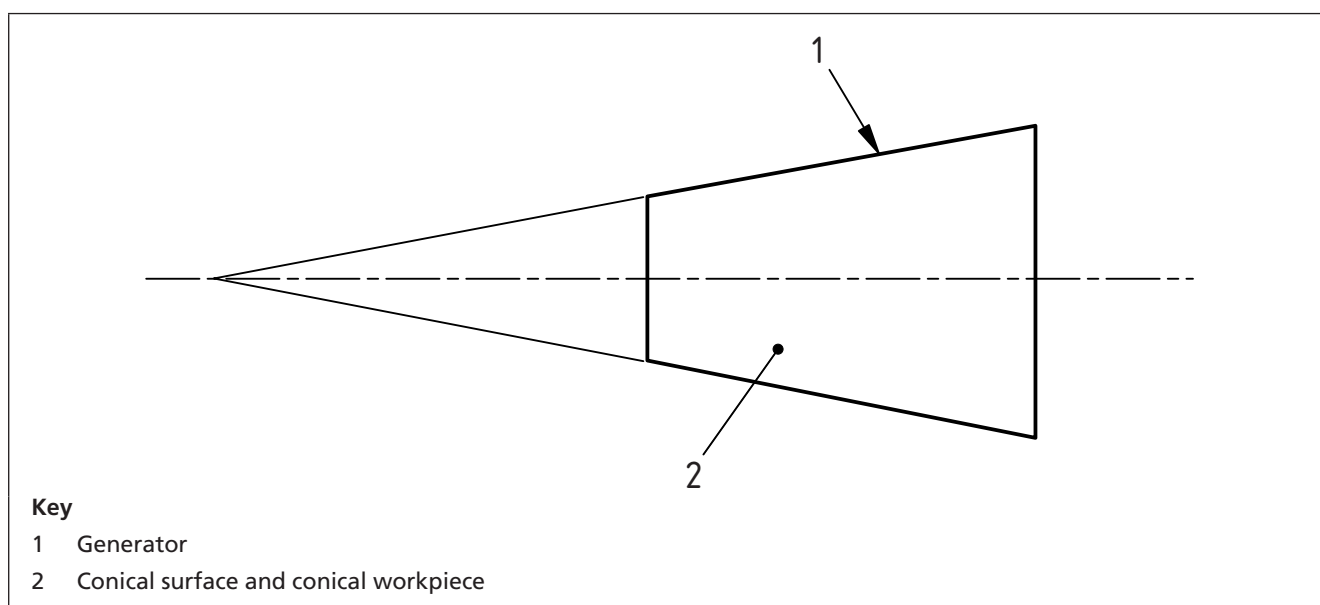


Figure 4 Conical workpiece – external cone

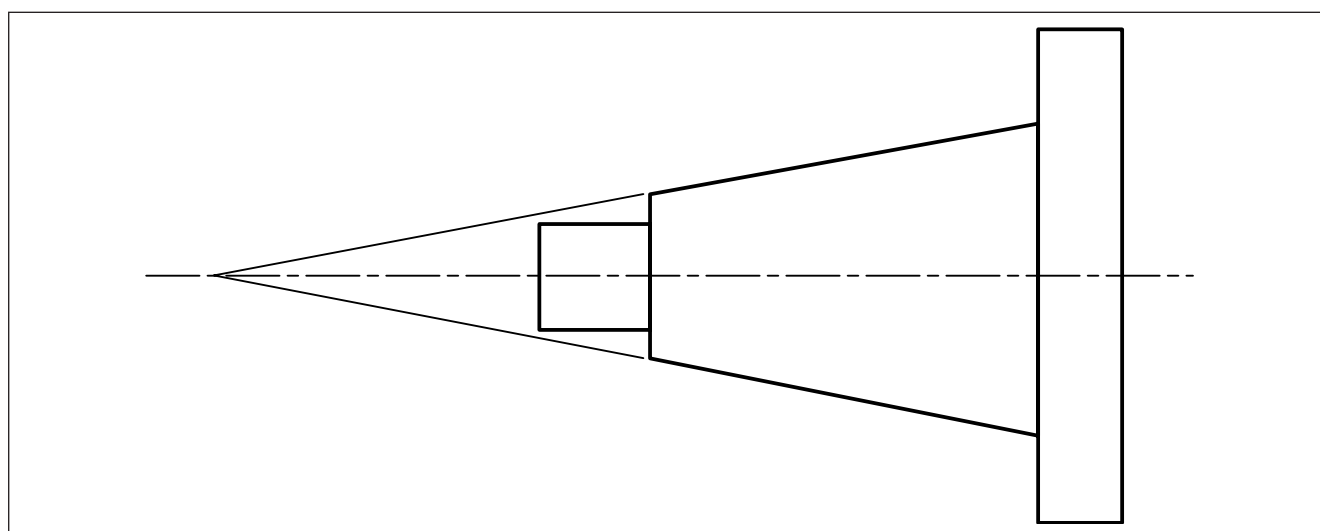


Figure 5 Conical workpiece – internal cone

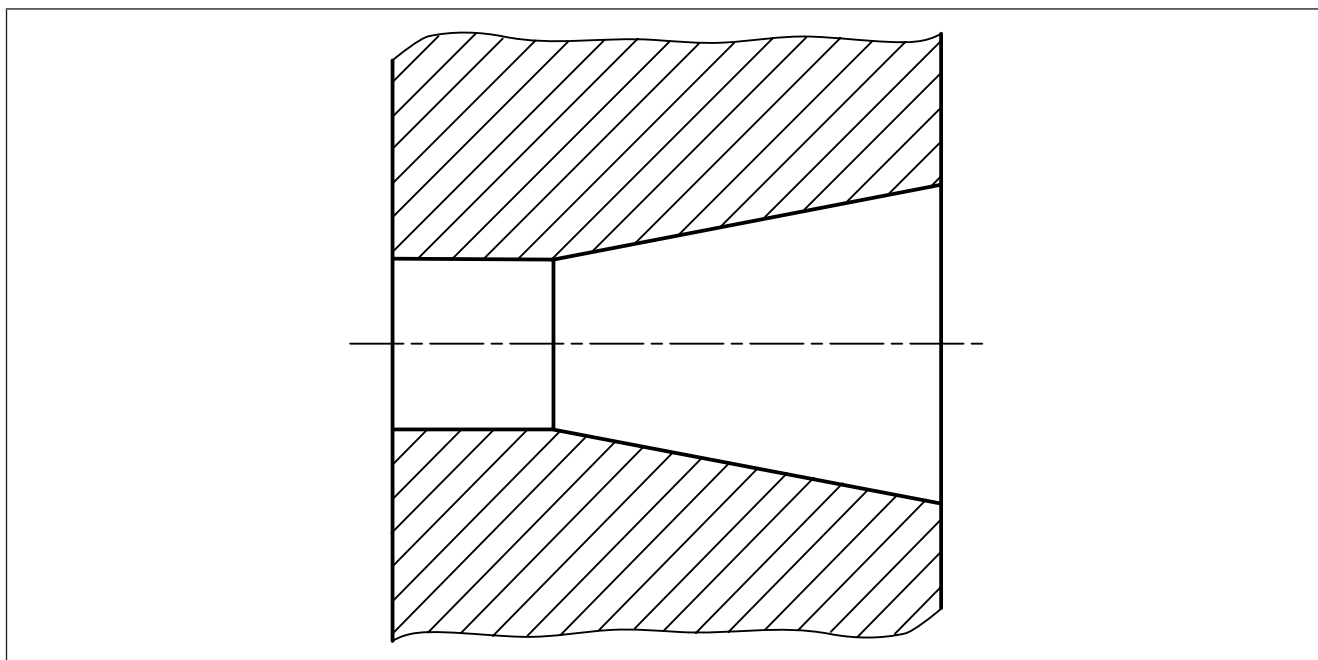


Figure 6 General definitions

