

Tolerances and fits.

This book includes tables and calculations for easy option of fits of machine parts and determination of their dimensional tolerances and deviations. Using this tool the following tasks can be solved:

1. Selection of suitable fits of machine parts according to the international standard ISO 286.
2. Determination of dimensional tolerances and deviations of machine parts according to the international standard ISO 286.
3. Selection of preferred fits of machine parts and determination of their dimensional tolerances and deviations according to ANSI B4.1.
4. Determination of non-prescribed limit deviations of linear and angular dimensions according to ISO 2768.
5. Automatic design of a fit for the given clearance or fit interference respectively.

The data, procedures, algorithms and specialized literature and standards ANSI, ISO, DIN and others were used in the calculations.

List of standards: ANSI B4.1, ANSI B4.2, ISO 286, ISO 1829, ISO 2768, EN 20286, JIS B 0401

Control, structure and syntax of calculations.

Information on the syntax and control of the calculation can be found in the document "[Control, structure and syntax of calculations](#)".

Basic terms.

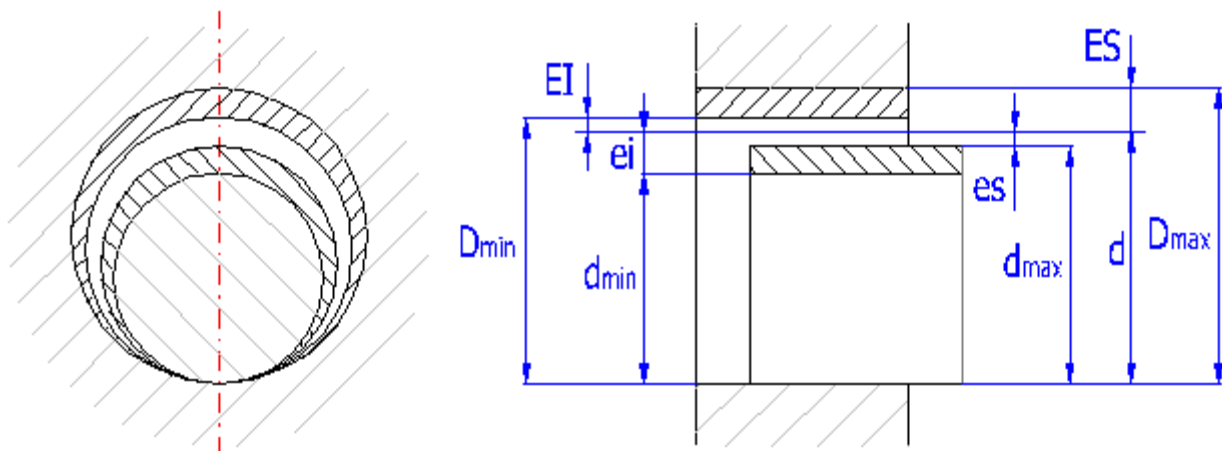
It is necessary that the dimensions, shape and mutual position of surfaces of individual parts of mechanical engineering products are kept within a certain accuracy to achieve their correct and reliable functioning. Routine production processes do not allow maintenance (or measurement) of the given geometrical properties with absolute accuracy. Actual surfaces of the produced parts therefore differ from ideal surfaces prescribed in drawings. Deviations of actual surfaces are divided into four groups to enable assessment, prescription and checking of the permitted inaccuracy during production:

- Dimensional deviations
- Shape deviations
- Position deviations
- Surface roughness deviations

This toll includes the first group and can therefore be used to determine dimensional tolerances and deviations of machine parts.

As mentioned above, it is principally impossible to produce machine parts with absolute dimensional accuracy. In fact, it is not necessary or useful. It is quite sufficient that the actual dimension of the part is found between two limit dimensions and a permissible deviation is kept with production to ensure correct functioning of engineering products. The required level of accuracy of production of the given part is then given by the dimensional tolerance which is prescribed in the drawing. The production accuracy is prescribed with regards to the functionality of the product and to the economy of production as well.

A coupling of two parts creates a fit whose functional character is determined by differences of their dimensions before their coupling.



where:

$d=D$... basic size

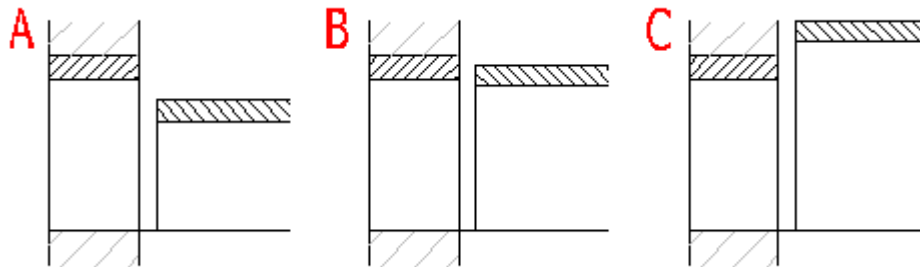
D_{max} , D_{min} ... limits of size for the hole

d_{max} , d_{min} ... limits of size for the shaft

ES ... hole upper deviation
 EI ... hole lower deviation
 es ... shaft upper deviation
 ei ... shaft lower deviation

Depending on the mutual position of tolerance zones of the coupled parts, 3 types of fit can be distinguished:

- A. Clearance fit
- B. Transition fit
- C. Interference fit



ISO 286: ISO system of limits and fits. [1]

This paragraph can be used to choose a fit and determine tolerances and deviations of machine parts according to the standard ISO 286:1988. This standard is identical with the European standard EN 20286:1993 and defines an internationally recognized system of tolerances, deviations and fits. The standard ISO 286 is used as an international standard for linear dimension tolerances and has been accepted in most industrially developed countries in identical or modified wording as a national standard (JIS B 0401, DIN ISO 286, BS EN 20286, CSN EN 20286, etc.). The system of tolerances and fits ISO can be applied in tolerances and deviations of smooth parts and for fits created by their coupling. It is used particularly for cylindrical parts with round sections. Tolerances and deviations in this standard can also be applied in smooth parts of other sections. Similarly, the system can be used for coupling (fits) of cylindrical parts and for fits with parts having two parallel surfaces (e.g. fits of keys in grooves). The term "shaft", used in this standard has a wide meaning and serves for specification of all outer elements of the part, including those elements which do not have cylindrical shapes. Also, the term "hole" can be used for specification of all inner elements regardless of their shape.

Note: All numerical values of tolerances and deviations mentioned in this paragraph are given in the metric system and relate to parts with dimensions specified at 20 °C.

1.1 Basic size.

It is the size whose limit dimensions are specified using the upper and lower deviations. In case of a fit, the basic size of both connected elements must be the same.

Attention: The standard ISO 286 defines the system of tolerances, deviations and fits only for basic sizes up to 3150 mm.

1.2 Tolerance of a basic size for specific tolerance grade.

The tolerance of a size is defined as the difference between the upper and lower limit dimensions of the part. In order to meet the requirements of various production branches for accuracy of the product, the system ISO implements 20 grades of accuracy. Each of the tolerances of this system is marked "IT" with attached grade of accuracy (IT01, IT0, IT1 ... IT18).

Field of use of individual tolerances of the system ISO:

IT01 to IT6	For production of gauges and measuring instruments
IT5 to IT12	For fits in precision and general engineering
IT11 to IT16	For production of semi-products
IT16 to IT18	For structures
IT11 to IT18	For specification of limit deviations of non-tolerated dimensions

Note: When choosing a suitable dimension it is necessary to also take into account the used method of machining of the part in the production process. The dependency between the tolerance and modification of the surface can be found in the table in paragraph [5].

1.3 Hole tolerance zones.

The tolerance zone is defined as a spherical zone limited by the upper and lower limit dimensions of the part. The tolerance zone is therefore determined by the amount of the tolerance and its position related to the basic size. The position of the tolerance zone, related to the basic size (zero line), is determined in the ISO system by a so-called basic deviation. The system ISO defines 28 classes of basic deviations for holes. These classes are marked by capital letters (A, B, C, ... ZC). The tolerance zone for the specified dimensions is prescribed in the drawing by a tolerance mark, which consists of a letter marking of the basic deviation and a numerical marking of the tolerance grade (e.g. H7, H8, D5, etc.). This paragraph includes graphic illustrations of all tolerance zones of a hole which are applicable for the specified basic size [1.1] and the tolerance grade IT chosen from the pop-up list.

Though the general sets of basic deviations (A ... ZC) and tolerance grades (IT1 ... IT18) can be used for prescriptions of hole tolerance zones by their mutual combinations, in practice only a limited range of tolerance zones is used. An overview of tolerance zones for general use can be found in the following table. The tolerance zones not included in this table are considered special zones and their use is recommended only in technically well-grounded cases.

Prescribed hole tolerance zones for routine use (for basic sizes up to 3150 mm):

								A9	A10	A11	A12	A13					
							B8	B9	B10	B11	B12	B13					
							C8	C9	C10	C11	C12	C13					
					CD6	CD7	CD8	CD9	CD10								
				E5	D6	D7	D8	D9	D10	D11	D12	D13					
					E6	E7	E8	E9	E10								
		EF3	EF4	EF5	EF6	EF7	EF8	EF9	EF10								
		F3	F4	F5	F6	F7	F8	F9	F10								
		FG3	FG4	FG5	FG6	FG7	FG8	FG9	FG10								
		G3	G4	G5	G6	G7	G8	G9	G10								
H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18
JS1	JS2	JS3	JS4	JS5	JS6	JS7	JS8	JS9	JS10	JS11	JS12	JS13	JS14	JS15	JS16	JS17	JS18
					J6	J7	J8										
		K3	K4	K5	K6	K7	K8										
		M3	M4	M5	M6	M7	M8	M9	M10								
		N3	N4	N5	N6	N7	N8	N9	N10	N11							
		P3	P4	P5	P6	P7	P8	P9	P10								
		R3	R4	R5	R6	R7	R8	R9	R10								
		S3	S4	S5	S6	S7	S8	S9	S10								
					T5	T6	T7	T8									
					U5	U6	U7	U8	U9	U10							
					V5	V6	V7	V8									
					X5	X6	X7	X8	X9	X10							
						Y6	Y7	Y8	Y9	Y10							
					Z6	Z7	Z8	Z9	Z10	Z11							
					ZA6	ZA7	ZA8	ZA9	ZA10	ZA11							
						ZB7	ZB8	ZB9	ZB10	ZB11							
						ZC7	ZC8	ZC9	ZC10	ZC11							

Note: Tolerance zones with thin print are specified only for basic sizes up to 500 mm.

Hint: For hole tolerances, tolerance zones H7, H8, H9 and H11 are used preferably.

1.4 Shaft tolerance zones.

The tolerance zone is defined as a spherical zone limited by the upper and lower limit dimensions of the part. The tolerance zone is therefore determined by the amount of the tolerance and its position related to the basic size. The position of the tolerance zone, related to the basic size (zero line), is determined in the ISO system by a so-called basic deviation. The system ISO defines 28 classes of basic deviations for shafts. These classes are marked by lower case letters (a, b, c, ... zc). The tolerance zone for the specified dimensions is prescribed in the drawing by a tolerance mark, which consists of a letter marking of the basic deviation and a numerical marking of the tolerance grade (e.g. h7, h6, g5, etc.). This paragraph includes graphic illustrations of all tolerance zones of a shaft which are applicable for the specified basic size [1.1] and the tolerance grade IT chosen from the pop-up list.

Though the general sets of basic deviations (a ... zc) and tolerance grades (IT1 ... IT18) can be used for prescriptions of shaft tolerance zones by their mutual combinations, in practice only a limited range of tolerance zones is used. An

overview of tolerance zones for general use can be found in the following table. The tolerance zones not included in this table are considered special zones and their use is recommended only in technically well-grounded cases.

Prescribed shaft tolerance zones for routine use (for basic sizes up to 3150 mm):

								a9	a10	a11	a12	a13						
							c8	b9	b10	b11	b12	b13						
								c9	c10	c11	c12							
				cd5	cd6	cd7	cd8	cd9	cd10	d11	d12	d13						
				d5	d6	d7	d8	d9	d10									
				e5	e6	e7	e8	e9	e10									
		ef3	ef4	ef5	ef6	ef7	ef8	ef9	ef10									
		f3	f4	f5	f6	f7	f8	f9	f10									
		fg3	fg4	fg5	fg6	fg7	fg8	fg9	fg10									
		g3	g4	g5	g6	g7	g8	g9	g10									
h1	h2	h3	h4	h5	h6	h7	h8	h9	h10	h11	h12	h13	h14	h15	h16	h17	h18	
js1	js2	js3	js4	js5	js6	js7	js8	js9	js10	js11	js12	js13	js14	js15	js16	js17	js18	
				j5	j6	j7												
		k3	k4	k5	k6	k7	k8	k9	k10	k11	k12	k13						
		m3	m4	m5	m6	m7	m8	m9										
		n3	n4	n5	n6	n7	n8	n9										
		p3	p4	p5	p6	p7	p8	p9	p10									
		r3	r4	r5	r6	r7	r8	r9	r10									
		s3	s4	s5	s6	s7	s8	s9	s10									
				t5	t6	t7	t8											
				u5	u6	u7	u8	u9										
				v5	v6	v7	v8											
				x5	x6	x7	x8	x9	x10									
					y6	y7	y8	y9	y10									
					z6	z7	z8	z9	z10	z11								
					za6	za7	za8	za9	za10	za11								
						zb7	zb8	zb9	zb10	zb11								
						zc7	zc8	zc9	zc10	zc11								

Note: Tolerance zones with thin print are specified only for basic sizes up to 500 mm.

Hint: For shaft tolerances, tolerance zones h6, h7, h9 and h11 are used preferably.

1.5 Selection of fit.

This paragraph can be used to choose a recommended fit. If you wish to use another fit than the recommended one, define hole and shaft tolerance zones directly in the paragraphs [1.9, 1.10]. When designing the fit itself, it is recommended to follow several principles:

- Design a fit in a hole basis system in a shaft basis system.
- Use hole tolerances greater or equal to the shaft tolerance.
- Tolerances of the hole and shaft should not differ by more than two grades.

Hint: In case you wish to find a suitable standardized fit with regard to its specific properties (a fixed amount of clearance or fit interference is required), use the function of automatic fit design in paragraph [4].

1.6 System of fit.

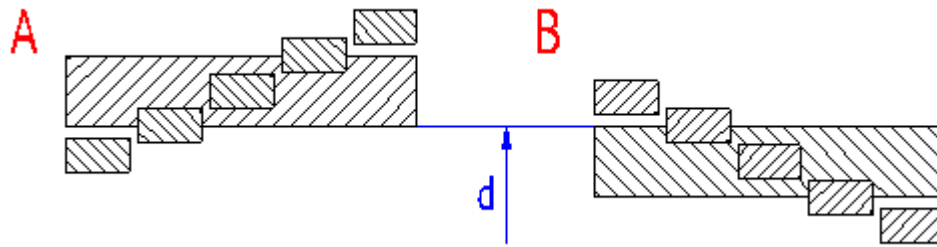
Although there can be generally coupled parts without any tolerance zones, only two methods of coupling of holes and shafts are recommended due to constructional, technological and economic reasons.

A. **Hole basis system**

The desired clearances and interferences in the fit are achieved by combinations of various shaft tolerance zones with the hole tolerance zone "H". In this system of tolerances and fits, the lower deviation of the hole is always equal to zero.

B. **Shaft basis system**

The desired clearances and interferences in the fit are achieved by combinations of various hole tolerance zones with the shaft tolerance zone "h". In this system of tolerances and fits, the upper deviation of the hole is always equal to zero.



where:

$d=D$... basic size

//// ... hole tolerance zone

\\ \\ ... shaft tolerance zone

The option of the system for the specified type of product or production is always influenced by the following factors:

- Constructional design of the product and the method of assembly.
- Production procedure and costs for machining the part.
- Type of semi-product and consumption of material.
- Costs for purchase, maintenance and storage of gauges and production tools.
- Machine holding of the plant.
- Options in use of standardized parts.

Hint: Although both systems are equivalent in the view of functional properties, the hole basis system is used preferably.

1.7 Type of fit.

Depending on the mutual position of tolerance zones of the coupled parts, 3 types of fit can be distinguished:

A. **Clearance fit**

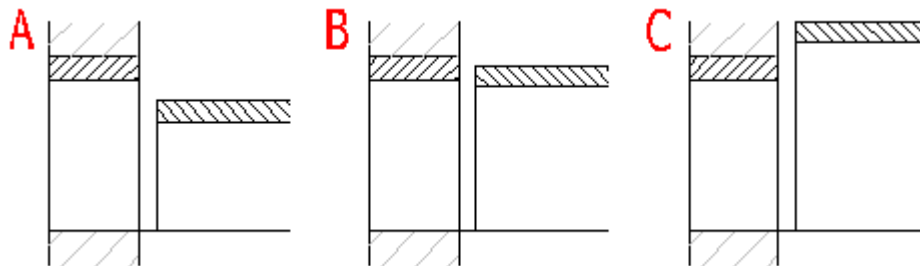
It is a fit that always enables a clearance between the hole and shaft in the coupling. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

B. **Transition fit**

It is a fit where (depending on the actual sizes of the hole and shaft) both clearance and interference may occur in the coupling. Tolerance zones of the hole and shaft partly or completely interfere.

C. **Interference fit**

It is a fit always ensuring some interference between the hole and shaft in the coupling. The upper limit size of the hole is smaller or at least equal to the lower limit size of the shaft.



1.8 Recommended fits.

A sufficient fit can be selected in the pop-up list.

The list of recommended fits given here is for information only and cannot be taken as a fixed listing. The enumeration of actually used fits may differ depending on the type and field of production, local standards and national usage and last but not least, depending on the plant practices. Properties and field of use of some selected fits are described in the following overview. When selecting a fit it is often necessary to take into account not only constructional and technological views, but also economic aspects. Selection of a suitable fit is important particularly in view of those measuring instruments, gauges and tools which are implemented in the production. Therefore, follow proven plant practices when selecting a fit.

Fields of use of selected fits (preferred fits are in bold):

Clearance fits:

H11/a11, **H11/c11**, H11/c9, H11/d11, A11/h11, **C11/h11**, D11/h11

Fits with great clearances with parts having great tolerances.

Use: Pivots, latches, fits of parts exposed to corrosive effects, contamination with dust and thermal or mechanical deformations.

H9/C9, H9/d10, **H9/d9**, H8/d9, H8/d8, **D10/h9**, D9/h9, D9/h8

Running fits with greater clearances without any special requirements for accuracy of guiding shafts.

Use: Multiple fits of shafts of production and piston machines, parts rotating very rarely or only swinging.

H9/e9, H8/e8, H7/e7, **E9/h9, E8/h8, E8/h7**

Running fits with greater clearances without any special requirements for fit accuracy.

Use: Fits of long shafts, e.g. in agricultural machines, bearings of pumps, fans and piston machines.

H9/f8, H8/f8, **H8/f7, H7/f7**, F8/h7, **F8/h6**

Running fits with smaller clearances with general requirements for fit accuracy.

Use: Main fits of machine tools. General fits of shafts, regulator bearings, machine tool spindles, sliding rods.

H8/g7, **H7/g6, G7/h6**

Running fits with very small clearances for accurate guiding of shafts. Without any noticeable clearance after assembly.

Use: Parts of machine tools, sliding gears and clutch disks, crankshaft journals, pistons of hydraulic machines, rods sliding in bearings, grinding machine spindles.

H11/h11, H11/h9

Slipping fits of parts with great tolerances. The parts can easily be slid one into the other and turn.

Use: Easily demountable parts, distance rings, parts of machines fixed to shafts using pins, bolts, rivets or welds.

H8/h9, H8/h8, H8/h7, **H7/h6**

Sliding fits with very small clearances for precise guiding and centring of parts. Mounting by sliding on without use of any great force, after lubrication the parts can be turned and slid by hand.

Use: Precise guiding of machines and preparations, exchangeable wheels, roller guides.

Transition fits:

H8/j7, H7/js6, **H7/j6**, J7/h6

Tight fits with small clearances or negligible interference. The parts can be assembled or disassembled manually.

Use: Easily dismountable fits of hubs of gears, pulleys and bushings, retaining rings, frequently removed bearing bushings.

H8/k7, **H7/k6**, K8/h7, **K7/h6**

Similar fits with small clearances or small interferences. The parts can be assembled or disassembled without great force using a rubber mallet.

Use: Demountable fits of hubs of gears and pulleys, manual wheels, clutches, brake disks.

H8/p7, H8/m7, H8/n7, H7/m6, **H7/n6**, M8/h6, N8/h7, **N7/h6**

Fixed fits with negligible clearances or small interferences. Mounting of fits using pressing and light force.

Use: Fixed plugs, driven bushings, armatures of electric motors on shafts, gear rims, flushed bolts.

Interference fits:

H8/r7, **H7/p6, H7/r6, P7/h6**, R7/h6

Pressed fits with guaranteed interference. Assembly of the parts can be carried out using cold pressing.

Use: Hubs of clutch disks, bearing bushings.

H8/s7, H8/t7, **H7/s6**, H7/t6, **S7/h6**, T7/h6

Pressed fits with medium interference. Assembly of parts using hot pressing. Assembly using cold pressing only with use of large forces.

Use: Permanent coupling of gears with shafts, bearing bushings.

H8/u8, H8/u7, H8/x8, H7/u6, U8/h7, U7/h6

Pressed fits with big interferences. Assembly using pressing and great forces under different temperatures of the parts.

Use: permanent couplings of gears with shafts, flanges.

Hint: If not in contradiction with constructional and technological requirements, preferably use some of the preferred fits. Preferred fits are marked by asterisk "*" in the list.

Note: Preferred fits designed for preferred use in the USA are defined in ANSI B4.2. This standard prescribes the following groups of preferred fits:

- Clearance fits: H11/c11, H9/d9, H8/f7, H7/g6, H7/h6, C11/h11, D9/h9, F8/h7, G7/h6

- Transition fits: H7/k6, H7/n6, K7/h6, N7/h6

- Interference fits: H7/p6, H7/s6, H7/u6, P7/h6, S7/h6, U7/h6

1.9 Hole tolerance zone.

Limit deviations of the hole tolerance zone are calculated in this paragraph for the specified basic size [1.1] and selected hole tolerance zone.

The respective hole tolerance zone is automatically set up in the listing during selection of any of the recommended fits from the list in row [1.8]. If you wish to use another tolerance zone for the hole, select the corresponding combination of a basic deviation (A ... ZC) and a tolerance zone (1 ... 18) in pop-up lists in this row.

Though the general sets of basic deviations (A ... ZC) and tolerance grades (IT1 ... IT18) can be used for prescriptions of hole tolerance zones by their mutual combinations, in practice only a limited range of tolerance zones

is used. An overview of tolerance zones specified for general use can be found in the table in paragraph [1.3]. The tolerance zones which are not included in the selection are considered special zones and their use is recommended only in technically well-grounded cases.

Attention: In case you select a hole tolerance zone which is not defined in the ISO system for the specified basic size, limit deviations will be equal to zero and the tolerance mark will be displayed in red.

Hint: For hole tolerances, tolerance zones H7, H8, H9 and H11 are used preferably.

1.10 Shaft tolerance zones.

Limit deviations of the hole tolerance zone are calculated in this paragraph for the specified basic size [1.1] and selected shaft tolerance zone.

The respective shaft tolerance zone is automatically set up in the listing during selection of any of the recommended fits from the list in row [1.8]. If you wish to use another tolerance zone for the shaft, select the corresponding combination of a basic deviation (a ... zc) and a tolerance zone (1 ... 18) in pop-up lists in this row.

Though the general sets of basic deviations (a ... zc) and tolerance grades (IT1 ... IT18) can be used for prescriptions of shaft tolerance zones by their mutual combinations, in practice only a limited range of tolerance zones is used. An overview of tolerance zones specified for general use can be found in the table in paragraph [1.3]. The tolerance zones which are not included in the selection are considered special zones and their use is recommended only in technically well-grounded cases.

Attention: In case you select a shaft tolerance zone which is not defined in the ISO system for the specified basic size, limit deviations will be equal to zero and the tolerance mark will be displayed in red.

Hint: For shaft tolerances, tolerance zones h6, h7, h9 and h11 are used preferably.

1.11 Parameters of the selected fit.

Parameters of the selected fit are calculated and mutual positions of tolerance zones of the hole and shaft are displayed in this paragraph.

Note: Dimensional data on this picture are given in μm .

ANSI B4.1: Preferred limits and fits for cylindrical parts. [2]

This paragraph can be used for selection of a preferred fit of cylindrical parts according to ANSI B4.1. This standard defines a system of dimensional tolerances and prescribes a series of those preferred fits of cylindrical part, which are specified for preferred use.

Note: All numerical values of tolerances and deviations given in this paragraph are related to those parts, whose dimensions are determined at 68 °F.

2.1 Basic size.

It is the size whose limit dimensions are specified using the upper and lower deviations. In case of a fit, the basic size of both connected elements must be the same.

Note: Standard ANSI B4.1 defines a system of preferred fits only for basic sizes up to 16.69 in.

2.2 Tolerance of a basic size for specific tolerance grade.

The tolerance of a size is defined as the difference between the upper and lower limit dimensions of the part. The standard ANSI B4.1 implements 10 tolerance grades to meet the requirements of various production branches for accuracy of products. The system of tolerances is prescribed by the standard for basic sizes up to 200 in.

Note: When choosing a suitable dimension it is necessary to also take into account the used method of machining of the part in the production process. The dependency between the tolerance and modification of the surface can be found in the table in paragraph [5].

2.4 System of fits.

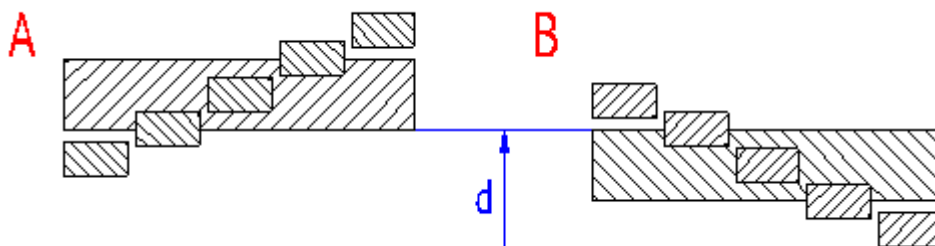
The standard ANSI B4.1 defines two basic methods of coupling of holes and shafts for the selected series of preferred fits.

A. **Hole basis system**

In this system of tolerances and fits, the lower deviation of the hole is always equal to zero.

B. **Shaft basis system**

In this system of tolerances and fits, the upper deviation of the hole is always equal to zero.



where:

d=D ... basic size
///// ... hole tolerance zone
\\\\\\ ... shaft tolerance zone

The option of the system for the specified type of product or production is always influenced by the following factors:

- Constructional design of the product and the method of assembly.
- Production procedure and costs for machining the part.
- Type of semi-product and consumption of material.
- Costs for purchase, maintenance and storage of gauges and production tools.
- Machine holding of the plant.
- Options in use of standardized parts.

Hint: Although both systems are equivalent in the view of functional properties, the hole basis system is used preferably.

2.5 Type of fit.

The standard ANSI B4.1 divides the series of preferred fits into three basic groups according to the type and field of use.

A. Running or sliding fits [RC]

This includes fits with guaranteed clearances which are specified for movable couplings of those parts which have to run or slide one against the other.

B. Locational fits [LC, LT, LN]

This includes clearance or interference fits specified for precise locational positioning of coupled parts. The coupled parts must be fixed mechanically to prevent one moving against the other during assembly. Depending on the locational positioning of tolerance zones of the coupled parts, 3 types of these fits may be distinguished: Clearance fits [LC], interference fits [LN] and transition fits [LT].

C. Force or shrink fits [FN]

This includes guaranteed interference fits specified for fixed (non-demountable) couplings of parts.

Each of these groups is marked using a literal abbreviation, which together with a numerical specification of the class of fit unambiguously defines the selected fit.

2.6 Fit.

Select a suitable fit from the pop-up list.

Properties and field of use of preferred fits are described in the following overview. When selecting a fit it is often necessary to take into account not only constructional and technological but also economic aspects. Selection of a suitable fit is important particularly in view of those measuring instruments, gauges and tools which are implemented in the production. Therefore, follow proven plant practices when selecting a fit.

Field of use of preferred fits:

Running or sliding clearance fits [RC]:

Fits with guaranteed clearance designed for movable couplings of parts (pivots, running and sliding fits of shafts, guiding bushings, sliding gears and clutch disks, pistons of hydraulic machines, etc.). The parts can be easily slid one into the other and turn. The tolerance of the coupled parts and fit clearance increases with increasing class of the fit.

RC 1: Close sliding fits with negligible clearances for precise guiding of shafts with high requirements for fit accuracy.

No noticeable clearance after assembly. This type is not designed for free run.

RC 2: Sliding fits with small clearances for precise guiding of shafts with high requirements for fit precision. This type is not designed for free run; in case of greater sizes a seizure of the parts may occur even at low temperatures.

RC 3: Precision running fits with small clearances with increased requirements for fit precision. Designed for precision machines running at low speeds and low bearing pressures. Not suitable where noticeable temperature differences occur.

RC 4: Close running fits with smaller clearances with higher requirements for fit precision. Designed for precise machines with moderate circumferential speeds and bearing pressures.

RC 5, RC 6: Medium running fits with greater clearances with common requirements for fit precision. Designed for machines running at higher speeds and considerable bearing pressures.

RC 7: Free running fits without any special requirements for precise guiding of shafts. Suitable for great temperature variations.

RC 8, RC 9: Loose running fits with great clearances with parts having great tolerances. Fits exposed to effects of corrosion, contamination by dust and thermal or mechanical deformations.

Locational clearance fits [LC]:

Fits with guaranteed clearances, designed for unmovable couplings where easy assembly and disassembly is required (precise fits of machines and preparations, exchangeable wheels, bearing bushings, retaining and distance rings, parts of machines fixed to shafts using pins, bolts, rivets or welds, etc.). The coupled parts must be fixed mechanically to prevent one moving against the other during assembly. These fits are defined by the standard in a wide range of tolerances and clearances, from tight fits with negligible clearances designed for precise guiding and

centring of parts [LC 1, LC 2] up to free fits with great clearances and maximum tolerances [LC 10, LC 11] where easy assembly is the primary requirement. The tolerance of coupled parts and fit clearance increases with increasing class of the fit.

Locational transition fits [LT]:

These types include clearance or interference fits designed for demountable unmovable couplings where precision of fits of the coupled parts is the main requirement. The part must be fixed mechanically to prevent one moving against the other during assembly.

LT 1, LT 2: Tight fits with small clearances or negligible interferences (easy detachable fits of hubs of gears, pulleys and bushings, retaining rings, bearing bushings, etc.). The part can be assembled or disassembled manually.

LT 3, LT 4: Similar fits with small clearances or interferences (demountable fits of hubs of gears and pulleys, manual wheels, clutches, brake disks, etc.). The parts can be coupled or disassembled without any great force by using a rubber mallet.

LT 5, LT 6: Fixed fits with negligible clearances or small interferences (fixed plugs, driven bushings, armatures of electric motors on shafts, gear rims, flushed bolts, etc.). Assembly of parts using low pressing forces.

Locational interference fits [LN]:

Fits with small interferences designed for fixed couplings where precision and rigidity of fits of the coupled parts is the main requirement. These fits cannot be used for transfers of torsional moments using friction forces only; the parts must be secured to prevent one moving against the other. The parts can be assembled or disassembled using cold pressing and greater forces or hot pressing.

Force or shrink fits [FN]:

Fits with guaranteed interferences designed for fixed (undetachable) coupling of parts (permanent couplings of gears with shafts, bearing bushings, flanges, etc.). These fits are designed, above all, for transfers of torsional moments using friction forces between shafts and hubs. The amount of interference (loading capacity of the fit) increases with increasing class of the fit. Mounting of the parts using cold pressing with great pressing forces at different temperatures of the parts.

FN 1: Light drive fits with small interferences designed for thin sections, long fits or fits with cast iron external members.

FN 2: Medium drive fits with medium interferences designed for ordinary steel parts or fits with high-grade cast iron external members.

FN 3: Heavy drive fits with great interferences designed for heavier steel parts.

FN 4, FN 5: Force fits with maximum interferences designed for highly loaded couplings.

2.7 Hole tolerance zone.

The tolerance zone is defined as a spherical zone limited by the upper and lower limit dimensions of the part. The tolerance zone is therefore determined by the amount of the tolerance and its position related to the basic size. Limit deviations of the hole tolerance zone are calculated in this paragraph for the specified basic size [2.1] and selected hole tolerance zone. The respective hole tolerance zone is set up according to the preferred fit selected in row [2.6].

2.8 Shaft tolerance zone.

The tolerance zone is defined as a spherical zone limited by the upper and lower limit dimensions of the part. The tolerance zone is therefore determined by the amount of the tolerance and its position related to the basic size. Limit deviations of the shaft tolerance zone are calculated in this paragraph for the specified basic size [2.1] and selected shaft tolerance zone. The respective shaft tolerance zone is set up according to the preferred fit selected in row [2.6].

2.9 Parameters of the selected fit.

Parameters of the selected fit are calculated and mutual positions of tolerance zones of the hole and shaft are displayed in this paragraph.

Note: Dimensional data in the picture are given in thousandths of inches.

ISO 2768-1: General tolerances for linear and angular dimensions without individual tolerance indications. [3]

All dimensions of machine parts prescribed in the production documentation should be specified using limit dimensions (tolerances) to avoid any uncertainty and dispute during production, checks and assembly. Important functional dimensions (particularly those that could cause confusion in mounting of the parts) are tolerated usually individually by the addition of a tolerance mark or numerical value of the deviation to the respective basic size. Other dimensions where high precision of production is not required can be tolerated using a general record in the drawing. The standard ISO 2768-1:1989 is an internationally recognized standard for tolerancing of these linear and angular dimensions.

The standard ISO 2768-1 is designed for tolerancing of dimensions of machine parts produced using cutting operations or forming of sheets. It is advisable to use limit deviations defined here also with non-metallic materials. This standard prescribes limit deviations of linear and angular dimensions in four classes of accuracy. When choosing

a tolerance class it is necessary (in addition to the constructional aspects) to also take into account, above all, the usual accuracy of the production shop.

General limit deviations according to ISO 2768-1 are divided into 3 groups (tables): Limit deviations for linear dimensions [3.1], limit deviations for broken edges [3.2] and limit deviations for angular dimensions [3.3]. With dimensions up to 0.5mm (tables [3.1, 3.2]) the limit deviations are prescribed right after the respective basic size.

Note: In case general limit deviations of dimensions according to this standard have to be applied, a respective record must be placed in the drawing (in the description field or in its vicinity). E.g. for the medium tolerance class "**ISO 2768 - m**".

Hint: If not in contradiction with constructional and technological requirements, use preferably a medium class of accuracy "**m**" for machined metal parts.

Design of fit for specific allowance. [4]

This paragraph can be used for a design (matching) of a suitable standardized fit of machine parts for a known clearance or interference respectively. The fit design is based on the standard ISO 286 (see [1]). The fit design is processed automatically and after its completion, the calculation provides the user with a set of 15 fits whose parameters meet the best requirements entered in paragraph [4.1].

4.2 System of fit.

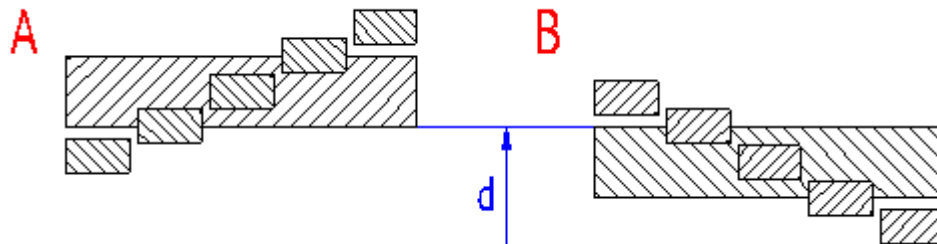
Although there can be generally coupled parts without any tolerance zones, only two methods of coupling of holes and shafts are recommended due to constructional, technological and economic reasons.

A. Hole basis system

The desired clearances and interferences in the fit are achieved by combinations of various shaft tolerance zones with the hole tolerance zone "**H**". In this system of tolerances and fits, the lower deviation of the hole is always equal to zero.

B. Shaft basis system

The desired clearances and interferences in the fit are achieved by combinations of various hole tolerance zones with the shaft tolerance zone "**h**". In this system of tolerances and fits, the upper deviation of the hole is always equal to zero.



where:

$d=D$... basic size

//// ... hole tolerance zone

\\\\ ... shaft tolerance zone

The option of the system for the specified type of product or production is always influenced by the following factors:

- Constructional design of the product and the method of assembly.
- Production procedure and costs for machining the part.
- Type of semi-product and consumption of material.
- Costs for purchase, maintenance and storage of gauges and production tools.
- Machine holding of the plant.
- Options in use of standardized parts.

Hint: Although both systems are equivalent in the view of functional properties, the hole basis system is used preferably.

4.3 Type of fit.

Depending on the mutual position of tolerance zones of the coupled parts, 3 types of fit can be distinguished:

A. Clearance fit

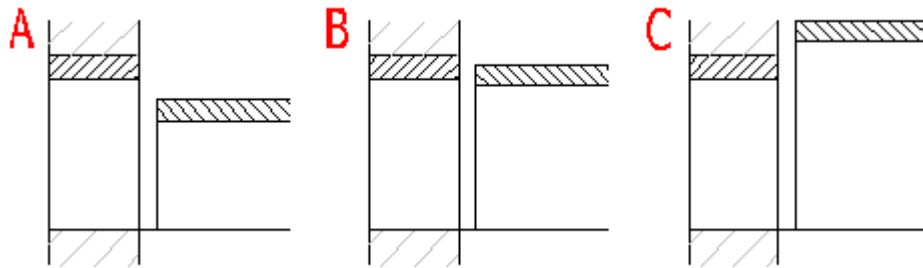
It is a fit that always enables a clearance between the hole and shaft in the coupling. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

B. Transition fit

It is a fit where (depending on the actual sizes of the hole and shaft) both clearance and interference may occur in the coupling. Tolerance zones of the hole and shaft partly or completely interfere.

C. Interference fit

It is a fit always ensuring some interference between the hole and shaft in the coupling. The upper limit size of the hole is smaller or at least equal to the lower limit size of the shaft.



4.4 Basic size.

Enter a common theoretical size of the coupled parts.

Attention: The standard ISO 286 defines the system of tolerances, deviations and fits only for basic sizes up to 3150 mm.

4.5, 4.6 Limit deviations for the fit.

Depending on the selected type of fit [1.3], enter desired limit values of clearance or interference resp. of the designed fit in rows [4.5, 4.6].

4.7 Design and selection of the fit.

This paragraph can be used for the fit design itself. After setting all desired parameters of the fit in paragraph [4.1], initiate automatic fit design using the button on this row. The design processes all combinations of prescribed hole and shaft tolerance zones (see tables in paragraphs [1.3, 1.4]) and selects 15 optimal standardized fits. The user is informed on processing of the calculations in a dialogue.

The qualitative criterion for selection of a fit includes a sum of deviations (in absolute values) of limit values of the clearance or interference resp. of the designed fit from desired values [4.5, 4.6]. After completion of calculations, the selected fits are transferred to the table. The table of designed fits is divided into two parts. The lower part includes selected fits listed from the best to the least optimal. The upper part of the table gives one of the preferred fits, particularly the one whose parameters best meet the desired limit deviations [4.5, 4.6]. After selection of any fit in the table, its parameters are displayed in paragraph [4.8].

Note: Dimensional data in the table are given in μm .

4.8 Parameters of the selected fit.

Parameters of the selected fit are calculated and mutual positions of tolerance zones of the hole and shaft are displayed in this paragraph.

Note: Dimensional data on this picture are given in μm .

Relationship of tolerance to surface finish. [5]

This paragraph includes a table describing the relationship of surfaces of machine parts to their dimensional tolerances. Individual tolerance grades available for the given method of machining of the parts are marked in the table using a green field.

Hint: A table describing the relationship between surface roughness and the method of machining of machine parts can be found in the book "Units converter".

Setting calculations, change the language.

Information on setting of calculation parameters and setting of the language can be found in the document "[Setting calculations, change the language](#)".

Workbook modifications (calculation).

General information on how to modify and extend calculation workbooks is mentioned in the document "[Workbook \(calculation\) modifications](#)".