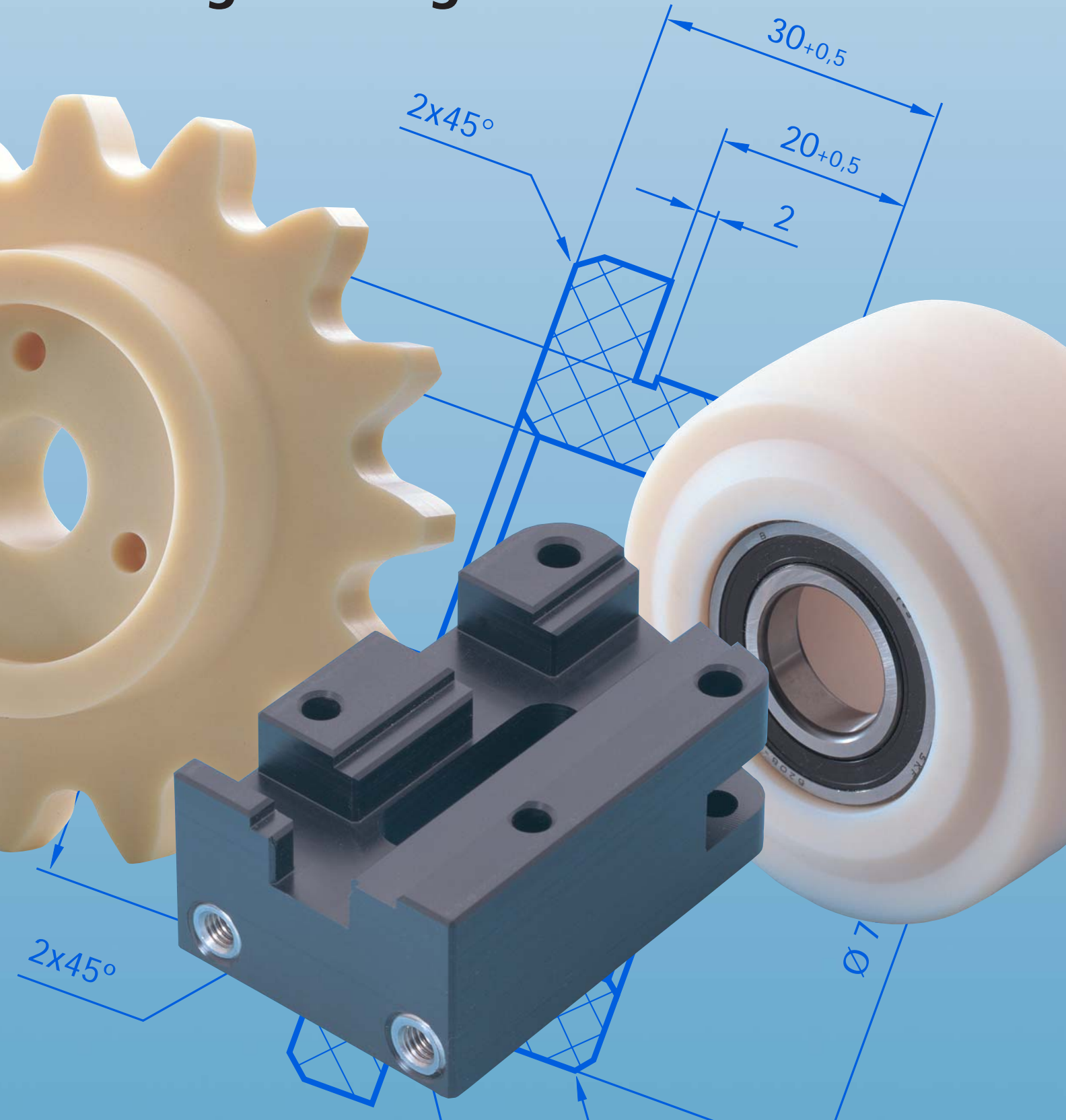
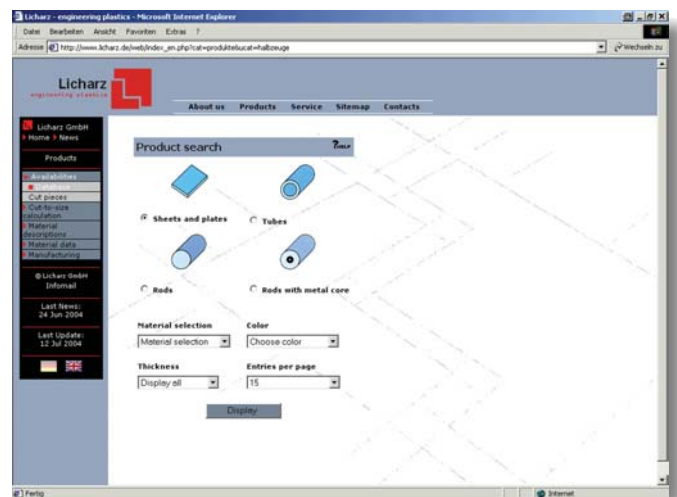




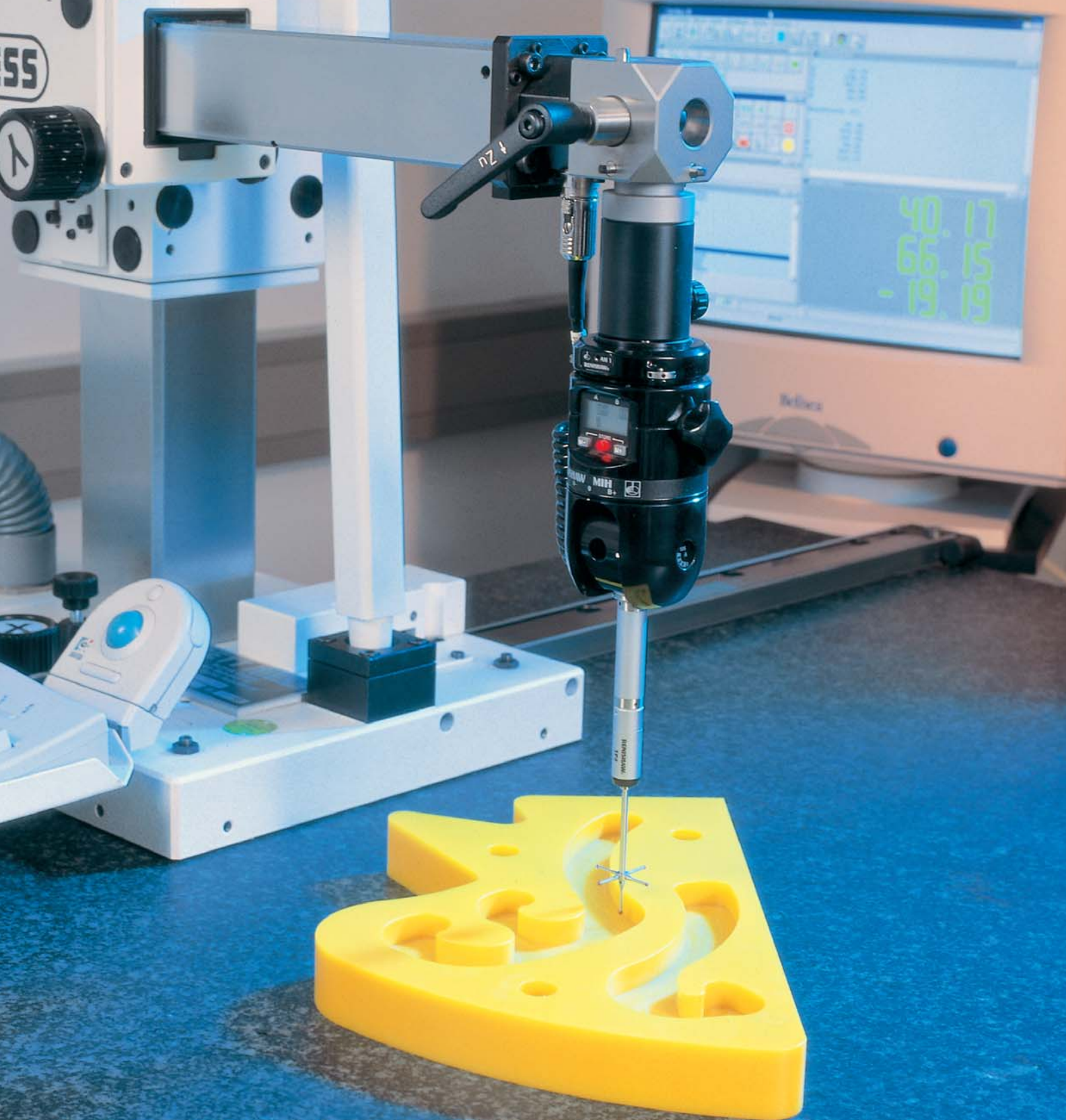
Designing with engineering Plastics



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Tolerances



Tolerances

1. Material-related tolerances for machined plastic construction parts

Plastics are often integrated into existing assemblies to replace conventional materials. As a rule, however, the production drawing is only altered in respect to the new material. Often the tolerances that have been specified for the steel component are not adapted to suit the new material. But even in the case of new designs where plastic is planned as a material, the tolerance fields that are normal for steel are still used.

However, the special features of plastics extensively preclude the choice of the narrow production tolerances required for steel parts.

The decisive factor is not the possibility of manufacturing the parts, since this is virtually no problem with the use of modern CNC machine tools, but rather the permanent compliance with the tolerances after the manufacturing process. This applies especially to dimensions in a class of tolerances with very narrow fields ($< 0.1\text{mm}$). These can change immediately after the part is taken from the machine table due to the visco-elastic behaviour of the plastics. In particular, the higher level of thermal expansion, volume changes due to the absorption of moisture as well as form and dimensional changes caused by the relaxation of production-related residual stresses are just some of the possible causes.

Another problem is the fact that there is no general standard for machined plastic components. The lack of a common basis for material-related tolerance for parts such as this often leads to disagreement between the customer and the supplier in regard to the classification of rejects and/or defects in delivery. Choosing a tolerance field that is suitable for the respective material can avoid disputes and also ensure that the plastic components function and operate safely as intended.

The following sections of this chapter are based on our many years of experience with different plastics and are intended to assist design engineers in defining tolerances. The aim is to create a standard basis and to avoid unnecessary costs caused by rejects due to off-spec tolerances.

The tolerance fields that we recommend can be achieved with conventional production methods and without any additional expenditure. In general, the functioning and operating safety of the components were not limited because of the increased tolerance. Narrower tolerances than those stated here are possible to a certain extent, but would necessitate unjustifiably high processing expenditure, and the materials would also require intermediate treatment (annealing) during the production process. If component parts require tolerance fields of $< 0.1\text{mm}$ or ISO series IT 9 fits and smaller, we will be happy to advise you in the choice of a technically/economically practical and sustainable tolerance field.

2. Plastic-related tolerances

2.1 General tolerances

The general tolerances for untoleranced dimensions can be chosen according to DIN ISO 2768 T1, tolerance class »m«.

In this standard, the tolerances are defined as follows:

Table 1: Limiting dimensions in mm for linear measures (DIN ISO 2768 T1)

Tolerance class	Nominal size range in mm							
	0,5 up to 3	above 3 up to 6	above 6 up to 30	above 30 up to 120	above 120 up to 400	above 400 up to 1000	above 1000 up to 2000	above 2000 up to 4000
f (fine)	± 0,05	± 0,05	± 0,1	± 0,15	± 0,2	± 0,3	± 0,5	-
m (medium)	± 0,1	± 0,1	± 0,2	± 0,3	± 0,5	± 0,8	± 1,2	± 2,0
g (rough)	± 0,15	± 0,2	± 0,5	± 0,8	± 1,2	± 2,0	± 3,0	± 4,0
v (very rough)	-	± 0,5	± 1,0	± 1,5	± 2,5	± 4,0	± 6,0	± 8,0

Table 2: Limiting dimensions in mm for radius of curvature and height of bevel (DIN ISO 2768 T1)

Tolerance class	Nominal size range in mm		
	0,5 up to 3	above 3 up to 6	above 6
f (fine)			
m (medium)	± 0,2	± 0,5	± 1,0
g (rough)			
v (very rough)	± 0,4	± 1,0	± 2,0

Table 3: Limiting dimensions in degrees for angle measurements (DIN ISO 2768 T1)

Tolerance class	Nominal size range of the shorter leg in mm				
	up to 10	above 10 up to 50	above 50 up to 120	above 120 up to 400	above 400
f (fine)	± 1°	± 30'	± 20'	± 10'	± 5'
m (medium)					
g (rough)	± 1° 30'	± 1°	± 30'	± 15'	± 10'
v (very rough)	± 3°	± 2°	± 1°	± 30'	± 20'

In special cases, for longitudinal dimensions it is possible to choose the tolerance class »f«. However, it is important that permanent compliance with the tolerance in regard to component geometry is checked in agreement with the manufacturer.

2.2 Shape and position

The general tolerances for untoleranced dimensions can be selected according to DIN ISO 2768 T2, tolerance class »K«.

In this standard the tolerances are defined as follows:

Table 4: General tolerances for straightness and evenness (DIN ISO 2768 T2)

Tolerance class	Nominal size range in mm					
	up to 10	above 10 up to 30	above 30 up to 100	above 100 up to 300	above 300 up to 1000	above 1000 up to 3000
H	0,02	0,05	0,1	0,2	0,3	0,4
K	0,05	0,1	0,2	0,4	0,6	0,8
L	0,1	0,2	0,4	0,8	1,2	1,6

Table 5: General tolerances for rectangularity (DIN ISO 2768 T2)

Tolerance class	Nominal size range in mm			
	up to 100	above 100 up to 300	above 300 up to 1000	above 1000 up to 3000
H	0,2	0,3	0,4	0,5
K	0,4	0,6	0,8	1,0
L	0,6	1,0	1,5	2,0

Table 6: General tolerances for symmetry (DIN ISO 2768 T2)

Tolerance class	Nominal size range in mm			
	up to 100	above 100 up to 300	above 300 up to 1000	above 1000 up to 3000
H	0,5			
K	0,6		0,8	1,0
L	0,6	1,0	1,5	2,0

The general tolerance for run-out and concentricity for class »K« is 0.2mm.

In special cases for shape and position it is possible to choose tolerance class »H«. The general tolerance for run-out and concentricity for class »H« is 0.1mm.

However, it is important that permanent compliance with the tolerance in regard to component geometry is checked in agreement with the manufacturer.

2.3 Fits

As described above, it is not possible to apply the ISO tolerance system that is usually applied to steel components. Accordingly, the tolerance series IT 01 – 9 should not be used. In addition, to determine the correct tolerance series, the processing method and the type of plastic being used must be considered.

2.3.1 Dimensional categories

The different plastics can be classified into two categories according to their dimensional stability. These are shown in Table 7.

Table 7: Dimension categories for plastics

Dimension category	Plastics	Comments
A	POM, PET, PTFE+glass, PTFE+bronze, PTFE+coal, PC, PVC-U, PVDF, PP-H, PEEK, PEI, PSU, HGW (laminated fabric)	Thermoplastics with or without reinforcement/ fillers (with low moisture absorption)
B	PE-HD, PE-HMW, PE-UHMW, PTFE, PA 6, PA 6 G, PA 66, PA 12	Soft thermoplastics and polyamides with moisture absorption

2.3.2 Classification of tolerance series for milled parts

Classification for milled parts with tolerances

Dimension	A	IT 10 - 12
category:	B	IT 11 - 13

Table 8: ISO basic tolerances in μm according to DIN ISO 286

Nominal size range in mm	ISO tolerance series (IT)										
	6	7	8	9	10	11	12	13	14	15	16
From up to 1-3	6	10	14	25	40	60	100	140	250	400	600
Above up to 3-6	8	12	18	30	48	75	120	180	300	480	750
Above up to 6-10	9	15	22	36	58	90	150	220	360	580	900
Above up to 10-18	11	18	27	43	70	110	180	270	430	700	1100
Above up to 18-30	13	21	33	52	84	130	210	330	520	840	1300
Above up to 30-50	16	25	39	62	100	160	250	390	620	1000	1600
Above up to 50-80	19	30	46	74	120	190	300	460	740	1200	1900
Above up to 80-120	22	35	54	87	140	220	350	540	870	1400	2200
Above up to 120-180	25	40	63	100	160	250	400	630	1000	1600	2500
Above up to 180-250	29	46	72	115	185	290	460	720	1150	1850	2900
Above up to 250-315	32	52	81	130	210	320	520	810	1300	2100	3200
Above up to 315-400	36	57	89	140	230	360	570	890	1400	2300	3600
Above up to 400-500	40	63	97	155	250	400	630	970	1550	2500	4000

2.3.3 Classification of tolerance series for turned parts

Classification for turned parts with tolerances

Dimension	A	IT 10 - 11
category:	B	IT 11 - 12

Table 8: ISO basic tolerances in μm according to DIN ISO 286

Nominal size range in mm	ISO tolerance series (IT)										
	6	7	8	9	10	11	12	13	14	15	16
From up to 1-3	6	10	14	25	40	60	100	140	250	400	600
Above up to 3-6	8	12	18	30	48	75	120	180	300	480	750
Above up to 6-10	9	15	22	36	58	90	150	220	360	580	900
Above up to 10-18	11	18	27	43	70	110	180	270	430	700	1100
Above up to 18-30	13	21	33	52	84	130	210	330	520	840	1300
Above up to 30-50	16	25	39	62	100	160	250	390	620	1000	1600
Above up to 50-80	19	30	46	74	120	190	300	460	740	1200	1900
Above up to 80-120	22	35	54	87	140	220	350	540	870	1400	2200
Above up to 120-180	25	40	63	100	160	250	400	630	1000	1600	2500
Above up to 180-250	29	46	72	115	185	290	460	720	1150	1850	2900
Above up to 250-315	32	52	81	130	210	320	520	810	1300	2100	3200
Above up to 315-400	36	57	89	140	230	360	570	890	1400	2300	3600
Above up to 400-500	40	63	97	155	250	400	630	970	1550	2500	4000

2.4 Surface quality

The degree of surface quality that can be achieved depends on the processing method. Table 9 shows the surface qualities that can be achieved without any additional expenditure for the individual processes.

Table 9: Achievable surface qualities for various machining processes

Form of machining	Max. achievable degree of roughness	Average roughness value R_a (μm)	Averaged depth of roughness R_z (μm)
Milling	N7	1,6	8
Turning	N7	1,6	8
Planing	N8	3,2	12,5
Sawing	N8	3,2	16

It is possible to achieve better surface qualities than those shown in Table 9 in conjunction with higher production expenditure. However, the production possibilities must be discussed with the manufacturer of the component part in regard to the respective plastic and the processing method.

2.5 Tolerances for press fits

2.5.1 Oversize for bushes

To ensure that friction bearing bushes sit properly in the bearing bore, the insertion of an oversized component has proved to be good method. The oversize for plastic bushes is very large compared to metal bearing bushes. However, due to the visco-elastic behaviour of the plastics, this is especially important because of the effects of heat, as otherwise the bearing bush would become loose in the bore. If the maximum service temperature is 50°C , it is possible to do without an additional securing device for the bearing bush if the oversizes from Diagram 1 are complied with. In the case of temperatures above 50°C , we recommend that the bush be secured with a device commonly used in machine engineering (e.g. a retaining ring according to DIN 472, see also the chapter on »Friction bearings« section 2.5).

It should also be considered that when the bearing bush is being inserted, its oversize leads to it being compressed. Consequently the oversize must be considered as an excess to the operating bearing play, and the internal diameter of the bearing must be dimensioned accordingly. Diagram 2 shows the required bearing play in relation to the internal diameter of the bearing. To prevent the bearing from sticking at temperatures above 50°C , it is necessary to correct the bearing play by the factors shown in the chapter on »Friction bearings« section 2.3.

Diagram 1: Press-fit oversize for friction bearings

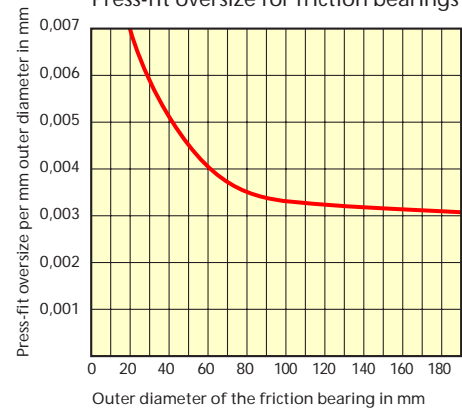
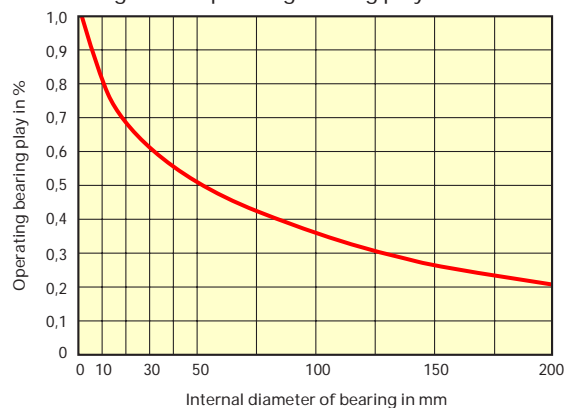


Diagram 2: Operating bearing play



In regard to dimensioning thin walled bearing bushes, rings and similar components, it must be noted that the measuring forces that are applied and the deformation that this causes can result in incorrect measurements. Hence, the tolerances for the outer diameter and wall thickness shown in Figure 1 are recommended.

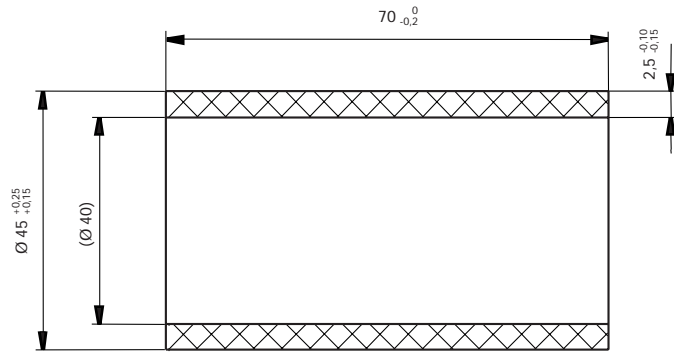
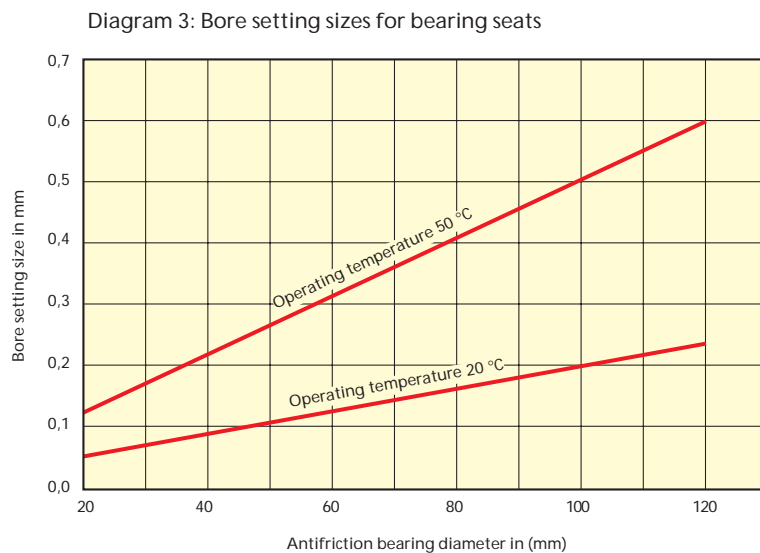


Figure 1: Example of tolerance for a bearing bush

2.5.2 Press-fit undersize for antifriction bearings

Antifriction bearings can be inserted directly into the undersized bearing seat for maximum operating temperatures of up to 50°C. If low stress and low operating temperatures are expected, no additional security is required for the bearing, but this is, however, recommended for higher stresses and operating temperatures. Again this is because of the visco-elastic behaviour of the plastics which can result in a reduction in the compression force and bearing migration. The bearing can also be secured with devices commonly used in machine engineering (e.g. retaining ring according to DIN 472). If the bearing is to be used in areas where high temperatures or loads are expected, it is also possible to place a steel sleeve in the bearing bore. This steel sleeve is fixed in the bearing bore with additional securing elements, and the bearing is pressed in to this ring.

Diagram 3 shows the required temperature-related undersizes for fixing the bearing in the bearing seat by compression.



For bearing seats into which antifriction bearings are inserted for operation at normal temperature and load conditions, we recommend the following press-fit undersizes and tolerances:

- Bearing seat diameter up to 50 mm ⇒ -0.15 / -0.25 mm
- Bearing seat diameter above 50 up to 120 mm ⇒ -0.25 / -0.35 mm
- Bearing seat diameter above 120 mm ⇒ -0.40 / -0.50 mm

In our many years of experience, bearing seats manufactured according to the above exhibit no excessive decrease in compression force and are able to keep the antifriction bearings in position safely and securely.

However, if this recommendation is taken, it should be noted that in the case of extremely small ratios between the bearing seat diameter and the outer diameter it is possible that the bearings loosen despite compliance with our recommendations. This can be attributed to the fact that the stresses caused by insertion can result in elongation of the residual material. As a result of this, the bearing seat diameter becomes larger and the compression force needed to fix the bearing can no longer be maintained. This behaviour is exacerbated by high temperatures and/or flexing that occurs during operation. This can be negated to a certain extent by the securing measures described above.

3. General information

The basic tolerances and dimensions stated above can only be sustainably maintained under normal climatic conditions (23°C/50% rel. humidity). If the environmental conditions differ, they must be considered by applying the respective correction factors. These can be found for the specific cases in the previous chapters.

3.1 Dimensional and volume changes under the influence of temperature

In general it can be said that elongation caused by temperature is approx. 0.1% per 10 K temperature change. In addition, in the case of polyamides, due to the absorption of moisture a change in volume of 0.15 – 0.20% per 1% water absorbed must be considered.

Considering the material-specific coefficient of elongation, the expected elongation and volume changes due to fluctuating temperatures can be calculated approximately. Hence, the expected elongation is

$$\Delta l = l \cdot \alpha \cdot (v_1 - v_2) \quad [\text{mm}]$$

where

Δl = expected elongation

l = original length in mm

α = material-specific coefficient of elongation

v_1 = installation temperature in °C

v_2 = operating temperature in °C

The expected change in volume is calculated – with the assumption that the elongation is not hindered in any direction – from:

$$\Delta V = V \cdot \beta \cdot (v_2 - v_1) \quad [\text{mm}^3]$$

and

$$\beta = 3 \cdot \alpha$$

where

ΔV = expected change in volume

V = original volume in mm³

α = material-specific coefficient of elongation

β = material-specific coefficient of volume expansion

v_1 = installation temperature in °C

v_2 = operating temperature in °C

The material-specific coefficients of elongation can be found in Table 10.

Table 10: Linear coefficients of elongation of various plastics

Material	Abbreviation	Coefficient of elongation $\alpha \cdot 10^{-5} \cdot K^{-1}$
Polyamide 6 cast	PA 6 G	7
Polyamide 6 cast CC	PA 6 G-CC	8
Oilamid	PA 6 G + ÖI	7
Calaumid 612	PA 6/12 G	8
Calaumid 1200	PA 12 G	10
Polyamide 6	PA 6	9
Polyamide 6 + 30% glass fibre	PA 6 GF30	3
Polyamide 66	PA 66	10
Polyamide 12	PA 12	12
Polyacetal	POM -C	10
Polyacetal GF-filled	POM -C-GF30	2,5
Polyethylene terephthalate	PET	7
Polyethylene terephthalate + lubricant additive	PET -GL	8
Polytetrafluoroethylene	PTFE	19
Polytetrafluoroethylene + 25% glass fibre	PTFE -GF25	13
Polytetrafluoroethylene + 25% coal	PTFE -K25	11
Polytetrafluoroethylene + 40% bronze	PTFE -B40	10
Polyethylene 500	PE-HMW	18
Polyethylene 1000	PE-UHMW	18
Polyetheretherketone	PEEK	4
Polyetheretherketone modified	PEEK-GL	3
Polysulphone	PSU	6
Polyether imide	PEI	6

3.2 Geometric shapes

The geometric relationships of a workpiece can cause changes in dimensions and shape after the machining process. Therefore, either the geometric shape has to be changed or the recommended tolerance series for workpieces with extreme geometric shape and wall thickness relationships, e.g. extreme one-sided machining, extremely thin walls, extreme wall thickness differences, must be adapted accordingly. If there is any uncertainty in regard to the definition of shape, dimension or position tolerances, we would be pleased to assist.

3.3 Measuring technology

It is very difficult to measure narrow tolerances in plastic workpieces, especially in thin-walled parts. The pressure exerted on the workpiece by the measuring instrument can deform the plastic part, or the low coefficient of friction of plastics can distort the starting torque of micrometer gauges. This inevitably leads to incorrect measured values. Therefore it is recommended that contactless measuring systems are used.



Our machining capabilities:

- CNC milling machines, workpiece capacity up to max. 2000 x 1000mm
- 5-axis CNC milling machines
- CNC lathes, chucking capacity up to max. 1560 mm diameter and 2000 mm long
- Screw machine lathes up to 100mm diameter spindle swing
- CNC automatic lathes up to 100mm diameter spindle swing
- Gear cutting machines for gears starting at Module 0,5
- Profile milling (shaping and molding)
- Circular saws up to 170mm cutting thickness and 3100mm cutting length
- Four-sided planers up to 125mm thickness and 225mm width
- Thickness planers up to 230mm thickness and 1000mm width



We process:

- Polyamide
- Polyacetal
- Polyethylene terephthalate
- Polyethylene 1000
- Polyethylene 500
- Polyethylene 300
- Polypropylene
- Polyvinyl chloride (hard)
- Polyvinylidene fluoride
- Polytetrafluoroethylene
- Polyetheretherketone
- Polysulphone
- Polyether imide

- PA
- POM
- PET
- PE-UHMW
- PE-HMW
- PE-HD
- PP-H
- PVC-U
- PVDF
- PTFE
- PEEK
- PSU
- PEI

Examples of parts:

- Rope sheaves and castors
- Guide rollers
- Deflection sheaves
- Friction bearings
- Slider pads
- Guide rails
- Gear wheels
- Sprocket wheels
- Spindle nuts
- Curved feed tables
- Feed tables
- Feed screws
- Curved guides
- Metering disks
- Curved disks
- Threaded joints
- Seals
- Inspection glasses
- Valve seats
- Equipment casings
- Bobbins
- Vacuum rails/panels
- Stripper rails
- Punch supports

Information on how to use this documentation

All calculations, designs and technical details are only intended as information and advice and do not replace tests by the users in regard to the suitability of the materials for specific applications. No legally binding assurance of properties and/or results from the calculations can be deduced from this document. The material parameters stated here are not binding minimum values, rather they should be regarded as guiding values. If not otherwise stated, they were determined with standardised samples at room temperature and 50% relative humidity. The user is responsible for the decision as to which material is used for which application and for the parts manufactured from the material. Hence, we recommend that practical tests are carried out to determine the suitability before producing any parts in series.

We expressly reserve the right to make changes to this document. Errors excepted.
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For further information, detailed catalogs are available:

- Information on Licharz machining capabilities of component parts
- Brochure „Material Guiding Values/chemical Resistance“
- Product information on semi-finished products of PA, POM und PET
- Delivery programme

Visit us on the internet at www.licharz.de



Headquarters:

Licharz GmbH
Industriepark Nord
D-53567 Buchholz
Germany

Telefon: ++49 (0) 26 83-977 0
Telefax: ++49 (0) 26 83-977 111
Internet: www.licharz.de
E-Mail: info@licharz.de



Branch offices:

Licharz Ltd.
Daimler Close
Royal Oak Industrial Estate
Daventry, NN11 8QJ
Great Britain
Phone: ++44 (0) 1327 877 500
Fax: ++44 (0) 1327 877 333
Internet: www.licharz.co.uk
E-Mail: sales@licharz.co.uk

ZL Engineering Plastics
PO Box 2270
12 John Walsh Boulevard
Peekskill, NY 10566
USA
Phone: ++1 914 – 736 6066
Fax: ++1 914 – 736 2154
E-Mail: info@zlplastics.com

ZL Engineering Plastics
8485 Unit D
Artesia Boulevard
Buena Park, CA 90621
USA
Phone: ++1 714 – 523 0555
Fax: ++1 714 – 523 4555
E-Mail: info@zlplastics.com