MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University named after M. Ye. Zhukovsky
“Kharkiv Aviation Institute”

INTERCHANGEABILITY AND STANDARDISATION.

INSTRUCTIONS FOR PERFORMANCE OF CALCULATION-GRAPHIC PAPER

Kharkiv “KhAI” 2017

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I64

Наведено основні визначення єдиної системи допусків і посадок. Викладено формули для розрахунків гладких з’єднань валу і отвору, розмірів калібрів, аналізу з’єднань на основі закону Гаусса. Подано приклади виконання завдань розрахунково-графічної роботи, а також фрагменти стандартів і рекомендації щодо проведення розрахунків і позначень параметрів на ескізах деталей.

Для студентів механічних спеціальностей, які вивчають дисципліну «Взаємозамінність і стандартизація».

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Basic definitions of Unified System of Tolerances and Fits are submitted. Formulas for calculations of slick joints of shaft and hole, gauges dimensions, analysis of joints with Gauss law are derived. Examples for performance of tasks of Calculation-Graphic Paper are submitted, as well as fragments of Standards and recommendations for calculations and designations of parameters in drawings of parts.

These instructions are for students of mechanical engineering specialties studying discipline “Interchangeability and Standardisation”.

Figures 21. Tables 3. Bibliogr.: 8 references

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INTRODUCTION

The purpose of this Calculation-Graphic Paper (CGP) is to obtain practical knowledge and competences in applications of Unified System of Tolerances and Fits (USTF), method of inspection with fixed gauges, statistical methods for analysis of slick joins.

The knowledge obtained in performance of this Paper will be useful for students learning the disciplines “Machines Parts”, “Designing of Aircraft Engines”, “Designing of Airplanes and Helicopters”, “Manufacturing Technologies for Engines and Power Plants”, “Manufacturing Technologies for Airplanes and Helicopters” and other designing and manufacturing disciplines in educational direction of mechanical engineering.

The graphic part of the Paper is recommended to perform on the standard formats A3. Only the CGP graphic part with calculations results is submitted to a teacher.

1. UNIFIED SYSTEM OF TOLERANCES AND FITS

The USTF standard DSTU 2500-94 (ISO 286) states the definitions for three types of elements of machines parts.

Shaft is any *external* element of an item including not round (the first group).

Hole is any *internal* element of an item including not round (the second group).

There are also ***other elements*** *not relating to shafts and holes* (the third group).

Dimensions (sizes) of the first group (*shafts*) include dimensions of external (male) surfaces. Dimensions of the second group (*holes*) include dimensions of internal (female) surfaces. Dimensions of the third group (*neither shafts nor holes*) include dimensions coordinating positions of various elements (features) relative to other features: steps and flat spots (position of one flat surface relative to another flat surface); holes depths; slots depths; bosses heights; dimensions coordinating starts and ends of threaded, conical, curvilinear surfaces; positions of axes and planes of symmetry for holes, slots, ribs, etc.; dimensions of rounding radii, fillets, chamfers, etc. *Feature* is any point, line or surface. Examples of main elements are shown in Fig. 1.1.

Thus, according to the USTF, **shaft** is an external element that can be created by one or several surfaces. For example, dimension (size) of external element – cylindrical surface ***d*** (ref. Fig. 1.1, i). Here the design element is created by segment of one surface having diametrical dimension. In another case – dimension ***l*** (ref. Fig. 1.1, ii) – the design element “bead” is created by three features: two flat surfaces (faces) and segment of cylindrical surface, located between two faces. Dimensions ***d*** and ***l*** are related to the bodies of rotation. In prismatic bodies shaft-type elements are ribs, beads, etc. with width dimension ***b*** (ref. Fig. 1.1, iii). In this case the design element is created by two faces and one flat surface located between the faces.

According to the USTF **hole** can be created by one or several surfaces, for example, internal element – cylindrical surface of diameter ***D*** (ref. Fig. 1.1, iv). Here the de-

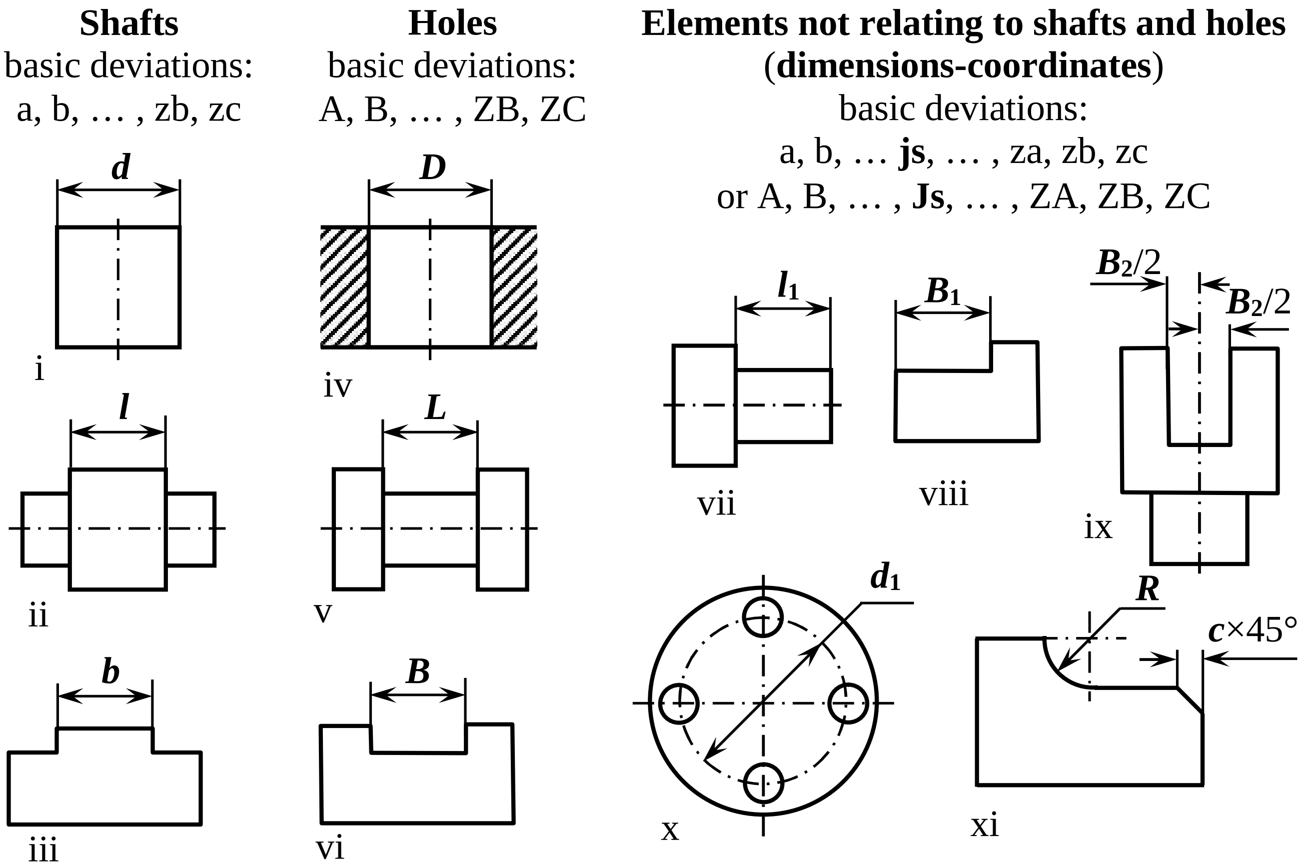


Fig. 1.1. Design elements and their dimensions

sign element is created by segment of one surface having diametrical dimension. In another case – design element "groove" of dimension ***L*** (ref. Fig. 1.1, v) – is created by three features: two flat surfaces (faces) and segment of cylindrical surface, located between two faces. In the case of design element "slot" of dimension ***B*** (ref. Fig. 1.1, vi) is created by two faces and segment of flat surface located between the faces.

Design elements of the third group (elements not relating to "shafts" and "holes") are: steps, elements of inclined surfaces, rounding radii, chamfers, elements with axes of symmetry, elements with holes axes, etc.

By their essence the design dimensions of the third group are *dimensions-coordinates*, because they determine positions (coordinates) of one features relative to others: one surface relative to another (ref. Fig. 1.1, vii and 1.1, viii), one or several surfaces relative to axis (ref. Fig. 1.1, xi and 1.1, ix), several axes relative to another one (ref. Fig. 1.1, x), point of beginning or finish of inclined surface relative to another surface, line or point (ref. Fig. 1.1, xi, dimension c×45°), etc.

Two limit dimensions (***maximum*** and ***minimum***) of element are specified in the form of ***nominal dimension*** (*basic size*) and ***two limit deviations*** – ***upper*** and ***lower***. Symbols applied for various types of elements are: capital letters for holes $D = D_{nom}{}_{EI}^{ES}$; small letters for shafts $d = d_{nom}{}_{ei}^{es}$; capital or small letters for other elements $b = b_{nom}{}_{aI}^{aS}$. Frequently in the USTF standards nominal dimension symbol is written without subscript “***nom***”: D_{nom} as simple ***D***; d_{nom} as simple ***d***; b_{nom} as simple ***b***.

The USTF standard DSTU 2500-94 introduces term “*basic deviation*”.

Basic deviation (*fundamental deviation*) is one of two limit deviations (upper or lower), which determines position of tolerance band relative to zero line. *Basic deviation* is a deviation nearest to zero line.

Positions of tolerance bands are determined by standardised values of 28 basic deviations for shafts and 28 basic deviations for holes, which are designated by Roman letters (Fig. 1.2):

- Small letters from **a** to **zc** for shafts;
- Capital letters from **A** to **ZC** for holes.

Zero line shows zero deviations from nominal dimension. Hence, *position of zero line is determined by nominal dimension value*.

Basic deviations and tolerances are standardised (Appendix 1). In the standard DSTU 2500-94 each letter symbol of basic deviation has numerical value depending on nominal dimension value.

For nominal dimensions 20 accuracy (tolerance) grades are established for different required levels of accuracy. They are designated by numbers increasing with tolerance value increase: 01; 0; 1; 2; 3… 17; 18 (ref. Appendix 1). Tolerance value is specified by letters ***IT*** and number of grade, for example: ***IT***6, ***IT***12.

Combination of symbol for basic deviation and number of accuracy grade creates ***tolerance band*** *(zone, class)*. Tolerance band shows positions of tolerance and limit deviations relative to zero line (nominal dimension) and thus determining maximum and minimum limit dimensions. Example of specifying the dimension with tolerance band:

Ø16s6,

where Ø – diameter symbol; 16 – nominal value of dimension; s – basic deviation; 6 – accuracy grade; s6 – tolerance band (class).

Tolerance is numerical value of tolerance band, which can be assigned by selection of suitable accuracy grade ***ITn*** and determined from the standard DSTU 2500-94 (ref. Appendix 1). But tolerance itself does not give full information to calculate maximum and minimum limit dimensions.

Tolerance band includes the basic deviation and tolerance value; therefore it can give information about upper and lower limit deviations. In combination with nominal dimension the tolerance band gives satisfactory data to calculate maximum and minimum limit dimensions (limits of size).

In ***manufacturing engineering*** nominal dimensions, tolerances and limit deviations are not standardised, because of economical reasons. When developing a *manufacturing process* documentation, production engineer specifies *operation* (*executive*) *dimensions* in sketches for *manufacturing operations* to be performed by workers.

Executive dimensions (Fig. 1.3) are dimensions, which are specified in technological manufacturing documentation.

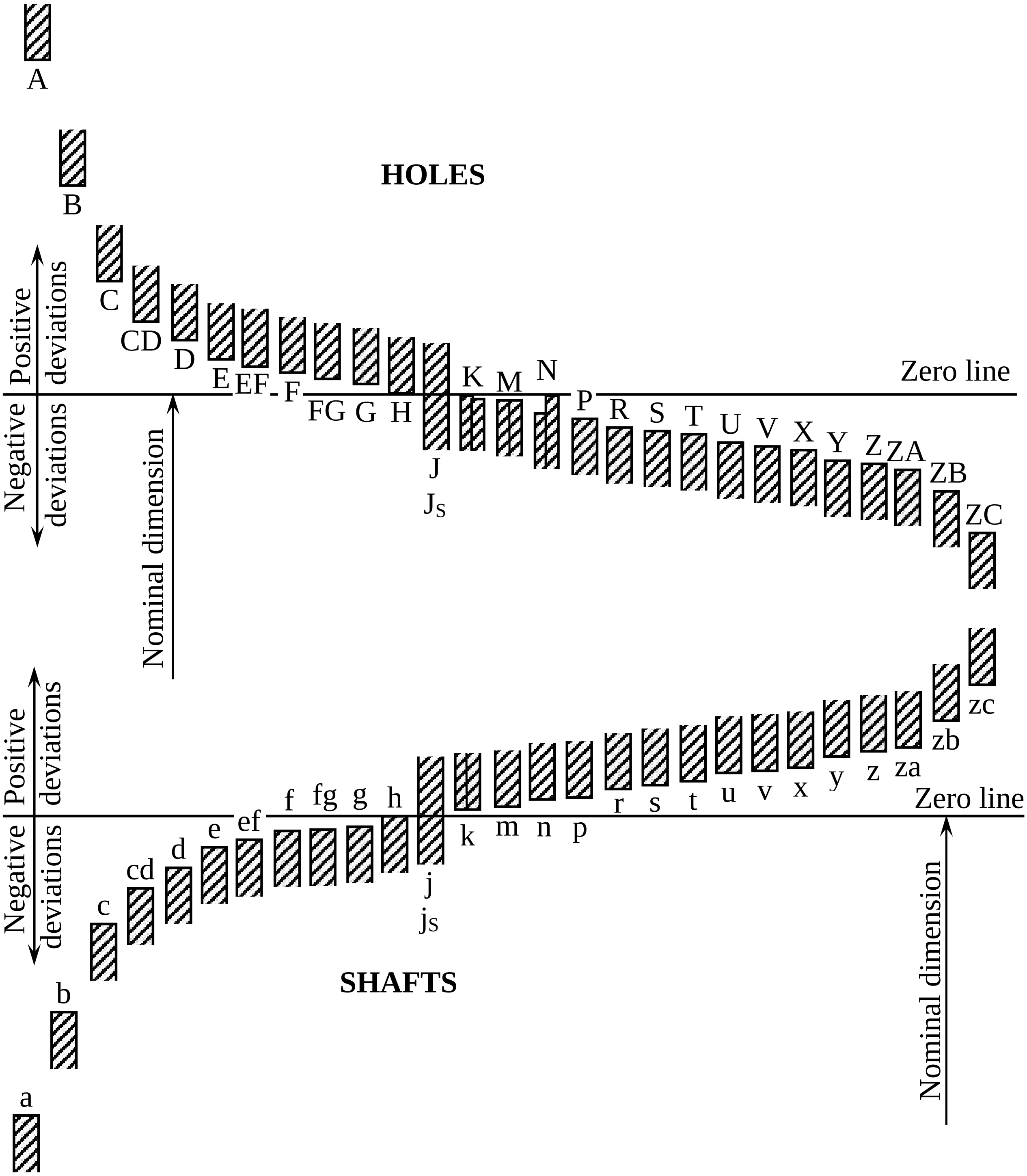


Fig. 1.2. Diagram for positions of basic deviations and their letter symbols

For holes executive dimension is a minimum limit dimension with positive upper deviation equal to the tolerance $\boldsymbol{D} = \boldsymbol{D}_{\boldsymbol{min}}{}^{+\boldsymbol{T_D}}_{0}$ and lower deviation being zero, that corresponds to **H** basic deviation (ref. Fig. 1.3, a). *For shafts* executive dimension is a maximum limit dimension with negative lower deviation equal to the tolerance $\boldsymbol{d} = \boldsymbol{d}_{\boldsymbol{max}}{}^{0}_{-\boldsymbol{T_d}}$ and upper deviation being zero, that corresponds to **h** basic deviation

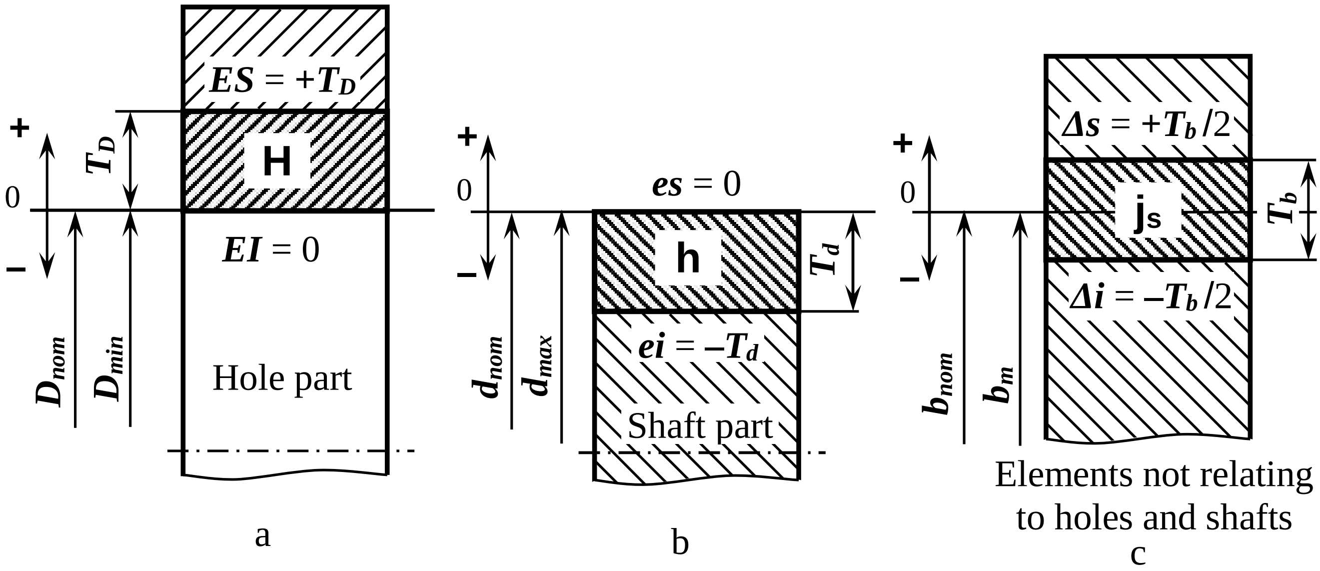


Fig. 1.3. Diagram of positions of tolerance bands for specifying the executive (manufacturing) dimensions: a – for hole type parts (basic hole dimension); b – for shaft type parts (basic shaft dimension); c – for elements of parts not relating to holes and shafts (dimension with symmetric deviations)

(ref. Fig. 1.3, b). That is, in technological sketches deviations are specified "into body" of workpiece (into metal) that ensures *maximum material condition* for manufacture and higher probability of quality items. And for the elements of the third group executive dimensions are specified with symmetric (positive and negative) limit deviations $b = b_m \pm \frac{T_b}{2}$, where $b_m = (b_{max} + b_{min})/2$, that corresponds to $\mathbf{j_s}$ basic deviation (ref. Fig. 1.3, c).

The USTF establishes fits in the *system of hole* and in the *system of shaft* (Fig. 1.4).

In the ***system of hole*** (*hole-basis system of fits*) the required clearances and interferences of fits are formed by combination of various tolerance bands of shafts with tolerance band of *basic hole* (**H**).

In the ***system of shaft*** (*shaft-basis system of fits*) the required clearances and interferences of fits are formed by combination of various tolerance bands of holes with tolerance band of *basic shaft* (**h**).

In a fit hole typically has lower accuracy (larger grade number IT_n) and shaft has higher accuracy (smaller grade number IT_{n-1}), for example, $\varnothing 90\frac{H7}{g6}$, $\varnothing 16\frac{D10}{h9}$.

System of hole and system of shaft are formally equal. But ***system of hole is preferable*** in the most of cases. It is more economically sound, because shafts are easier and cheaper for production as compared with holes of the same accuracy grade. *For machining of shafts* mainly versatile cutting tools are applied, access to work surfaces (outside open surfaces) is convenient. *For machining of holes* more complicated and

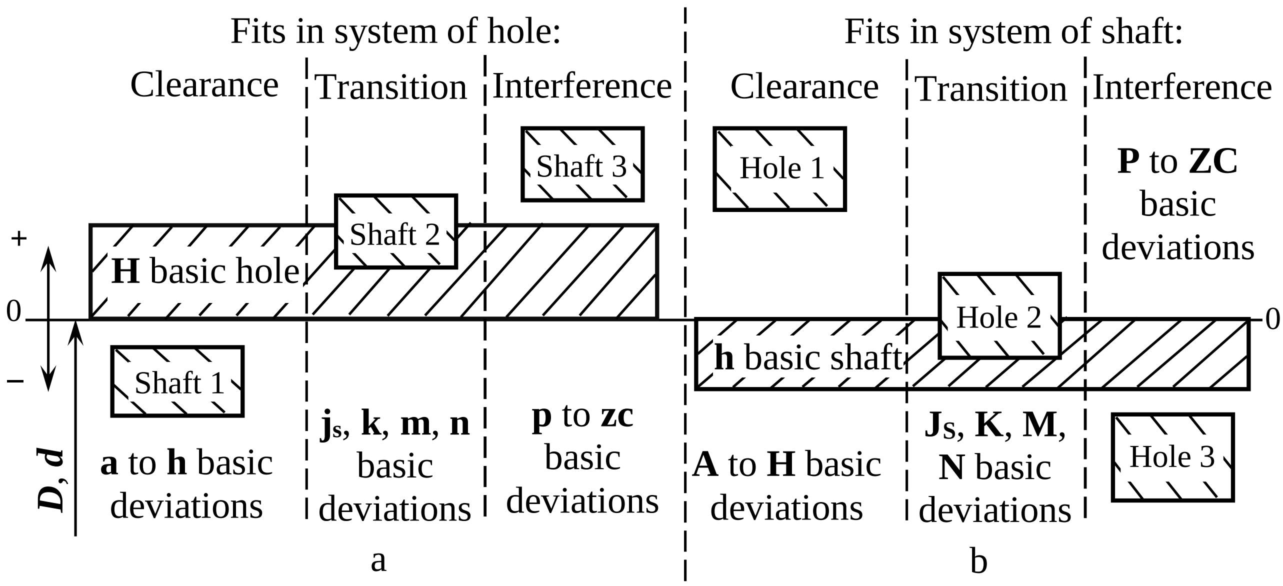


Fig. 1.4. Diagram of positions of tolerance bands in system of hole and system of shaft to create clearance, transition and interference fits: a – fits in system of hole with tolerance bands of representative Shaft 1, Shaft 2 and Shaft 3 respectively according to Fig. 1.2; b – fits in system of shaft with tolerance bands of representative Hole 1, Hole 2 and Hole 3 respectively according to Fig. 1.2

precise cutting tools (drills, core drills, reamers, broaches, cutting tools fixed on boring bars) are applied, access to work surfaces (internal semi-closed surfaces) is restricted. These precision cutting tools are produced in a great amount for machining of H holes (basic holes).

But in some cases the system of shaft is more preferable – cheaper and technically more reasonable.

2. STUDY OF USTF SYSTEM (CGP Sheet 1)

Sheet 1 of Calculation-Graphic Paper contains three tasks: study of recommended fits in graphic form; calculations of clearances and interferences values of various fits; methods for specifying the design and manufacturing (executive) dimensions in drawings and operation sketches. Also students obtain habit in selection of upper and lower limit deviations by tolerance band and nominal dimension from the standards.

2.1. Standard GOST 25347-82 contains tables with recommended fits in the system of hole and in the system of shaft (Appendix 2, Tables A.2.3 and A.2.4). For this task basic hole H7 of accuracy grade IT7 and basic shaft h6 of accuracy grade IT6 are selected for study of fits in both systems respectively. Basic hole H7 and basic shaft h6 are common data for all the tasks given to students. The distinctive value will be *only nominal diameter* value. These features are shown in the title of Sheet 1, as well as the basic interval of dimensions selected from the standard according to a student's task and limits of middle range for linear dimensions 1 to 500 mm. For example the title for student's task Ø160H7/k6 is shown in Fig. 2.1. In this example the basic hole H7, recommended for study of fits, coincided with the symbol H7 in this task.

Diagram for location of recommended tolerance bands for fits in system of hole at accuracy grade IT7 and in system of shaft at IT6 of basic interval of dimensions of 120 to 180 mm in middle range of 1–500 mm

Fig. 2.1. Example of the Sheet 1 Title for Ø160

2.2. Plot diagram with all recommended fits in system of hole H7 and system of shaft h6 (Fig. 2.2) according to the standard GOST 25347-82 (ref. Appendix 2).

Among recommended fits the standard GOST 25347-82 contains preferred fits. Tolerance bands of preferred shafts and holes for joints with basic hole and basic shaft are shown by thick-line frames.

2.3. Use the diameter value, specified in student's task, for determination of dimensions interval, basic deviations and tolerances from the standard DSTU 2500-94 (Appendix 1: Table A.1.1 – Tolerances, Table A.1.2 – Basic deviations for shafts, Table A.1.3 – Basic deviations for holes). Specify boundaries of different fits types with vertical lines and writings.

Basic (fundamental) deviation *is one of two limit deviations* ***nearest to zero line*** (ref. Fig. 1.2). Second (non-basic) deviation of tolerance band is determined with help of basic deviation and tolerance:

- For shafts (ref. Fig. 1.2 and Fig. 2.2)

- basic deviation from **a** to **h** (upper limit deviation ***es***)

$$ei = es - T_d, \tag{2.1}$$

- basic deviation from **k** to **zc** (lower limit deviation ***ei***)

$$es = ei + T_d; \tag{2.2}$$

- For holes (ref. Fig. 1.2 and Fig. 2.2)

- basic deviation from **A** to **H** (lower limit deviation ***EI***)

$$ES = EI + T_D, \tag{2.3}$$

- basic deviation from **K** to **ZC** (upper limit deviation ***ES***)

$$EI = ES - T_D. \tag{2.4}$$

Symmetric limit deviations of **Js** holes and j_s shafts are found from the expression $\pm ITn/2$, where ***ITn*** is tolerance value by ***n***-th accuracy grade.

For example, for shaft Ø160c8, the **c** basic deviation is upper limit deviation (ref. Fig. 2.2). According to the standard DSTU 2500-94 and nominal dimension Ø160 its numerical value equals $es = -210$ µm (ref. Appendix 1, Table A.1.2). Tolerance according to the 8th accuracy grade is $T_d = 63$ µm (ref. Appendix 1, Table A.1.1). Hence, from the formula (2.1) lower limit deviation is $ei = (-210) - 63 = -273$ µm.

For shaft Ø160j_s6 (ref. Fig. 2.2) symmetric limit deviations are: the upper $es = +IT6/2 = +25/2 = +12.5$ µm; the lower $ei = -IT6/2 = -25/2 = -12.5$ µm.

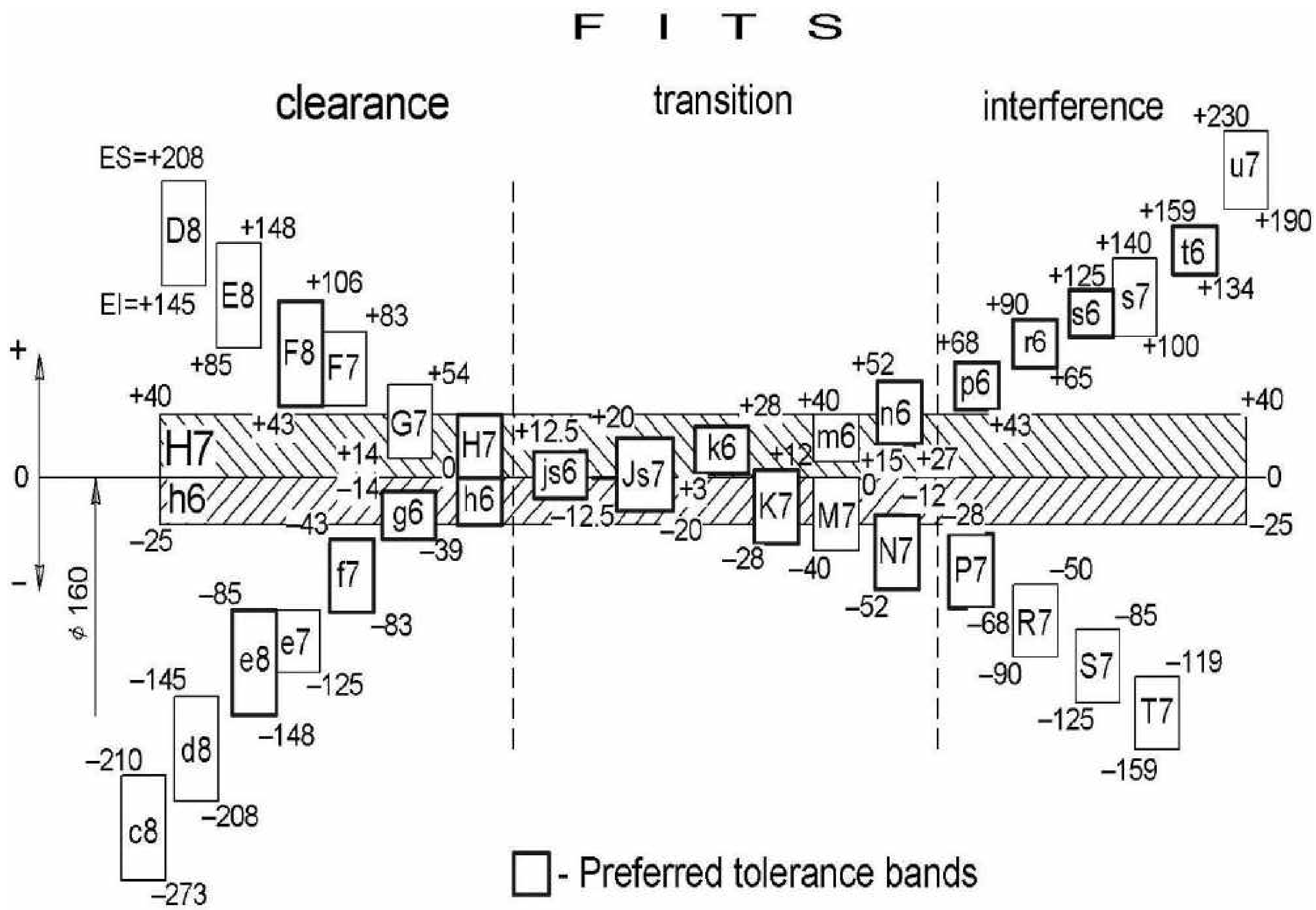


Fig. 2.2. Diagram for positions of tolerance bands of shafts and holes for the recommended fits in the system of hole H7 and in the system of shaft h6

For shaft Ø160p6, the **p** basic deviation is lower limit deviation (ref. Fig. 2.2) and according to the standard DSTU 2500-94 and nominal dimension Ø160 its numerical value equals ei = + 43 μm (ref. Appendix 1, Table A.1.2). Tolerance according to the 6th accuracy grade is T_d = 25 μm (ref. Appendix 1, Table A.1.1). Hence, from the formula (2.2) upper limit deviation is es = (+ 43) + 25 = + 68 μm.

For example, for hole Ø160F8, the **F** basic deviation is lower limit deviation (ref. Fig. 2.2) and according to the standard DSTU 2500-94 and nominal dimension Ø160 its numerical value is EI = + 43 μm (ref. Appendix 1, Table A.1.3). Tolerance according to the 8th accuracy grade is T_D = 63 μm (ref. Appendix 1, Table A.1.1). Hence, from the formula (2.3) upper limit deviation is ES = (+ 43) + 63 = + 106 μm.

For hole Ø160N7, the **N** basic deviation is upper limit deviation $ES = -27 + \Delta$ (ref. Appendix 1, Table A1.3), where Δ = 15 (the special rule) for 7th accuracy grade. Hence, upper limit deviation ES = – 27 + 15 = – 12 μm. Tolerance is T_D = 40 μm (ref. Appendix 1, Table A.1.1). From the formula (2.4) lower limit deviation is EI = (– 12) – 40 = – 52 μm (ref. Fig. 2.2).

Check the correctness of upper and lower deviations with the GOST 25347-82 standard (ref. Appendix 2).

Limit deviations for other tolerance bands are selected from the GOST 25347-82 standard and written down in the Sheet 1 diagram (ref. Fig. 2.2).

2.4. Select arbitrary per any 3 fits in system of hole (Fig. 2.3) and in system of shaft (Fig. 2.4) including clearance fits, transition fits and interference fits. Calculate maximum, mean and minimum dimensions, tolerances, clearances and interferences from the formulas (here D is D_{nom} and d is d_{nom}):

- Maximum hole diameter $D_{max} = D + ES$; (2.5)
- Minimum hole diameter $D_{min} = D + EI$; (2.6)
- Mean hole diameter $D_m = (D_{max} + D_{min})/2 = D + EM$, where $EM = (ES + EI)/2$; (2.7)
- Tolerance of hole diameter $T_D = D_{max} - D_{min} = ES - EI$; (2.8)
- Maximum shaft diameter $d_{max} = d + es$; (2.9)
- Minimum shaft diameter $d_{min} = d + ei$; (2.10)
- Mean shaft diameter $d_m = (d_{max} + d_{min})/2 = d + em$, where $em = (es + ei)/2$; (2.11)
- Tolerance of shaft diameter $T_d = d_{max} - d_{min} = es - ei$; (2.12)
- Maximum and minimum clearances of fit

$$S_{max} = D_{max} - d_{min} = ES - ei; \quad S_{min} = D_{min} - d_{max} = EI - es; \tag{2.13}$$

- Mean clearance of fit

$$S_m = D_m - d_m = EM - em; \tag{2.14}$$

- Maximum and minimum interferences of fit

$$N_{max} = d_{max} - D_{min} = es - EI; \quad N_{min} = d_{min} - D_{max} = ei - ES; \tag{2.15}$$

- Mean interference of fit

$$N_m = d_m - D_m = em - EM; \tag{2.16}$$

- Fit tolerance (variation of fit) $T_\Sigma = T_D + T_d$. (2.17)

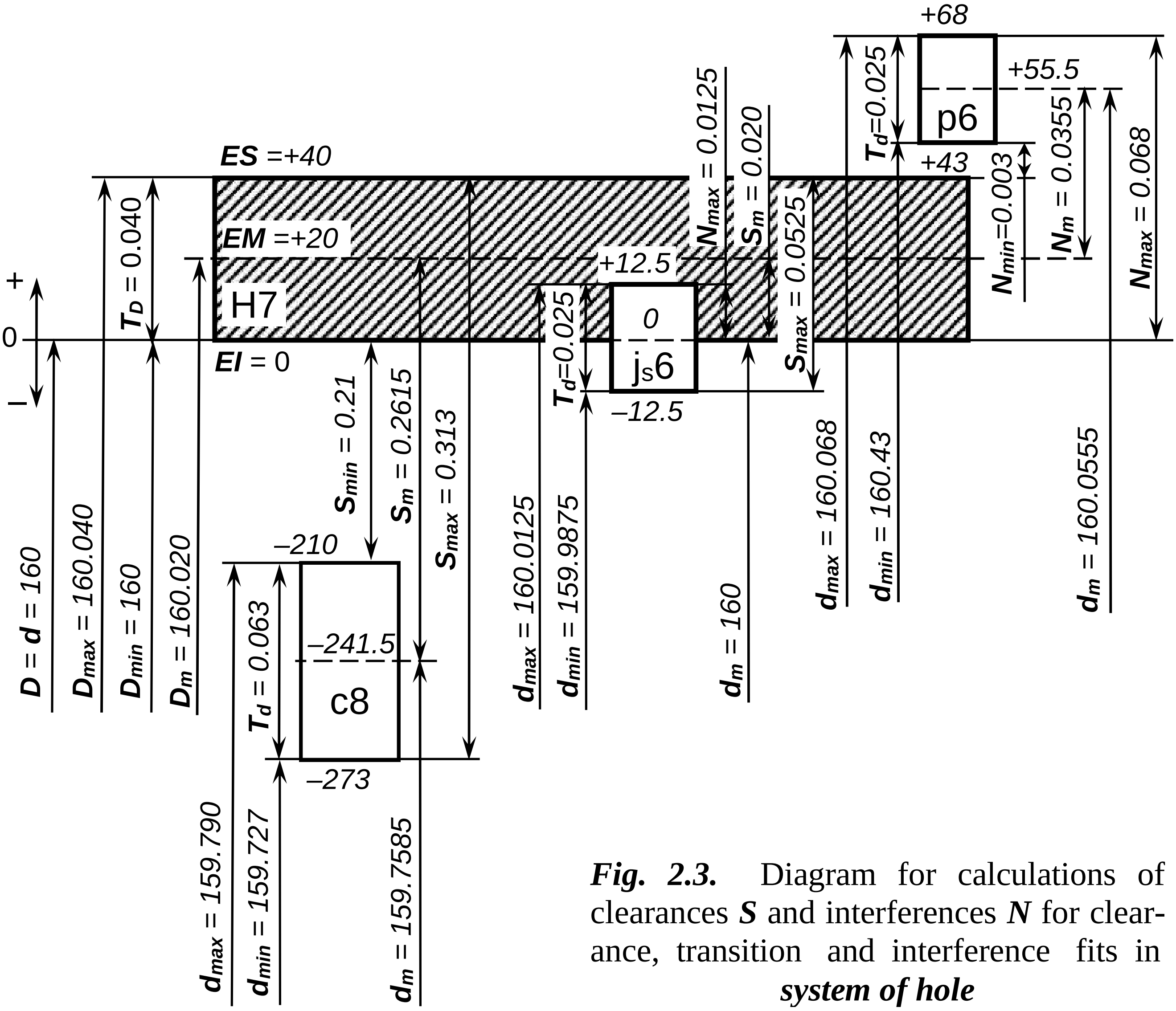


Fig. 2.3. Diagram for calculations of clearances ***S*** and interferences ***N*** for clearance, transition and interference fits in ***system of hole***

Pay attention to transition fits. They have only maximum clearance S_{max} and maximum interference N_{max} (no minimum clearance and no minimum interference) and mean clearance or mean interference depending on what is larger, mean-diameter shaft or mean-diameter hole.

The calculation results for the fits presented in Fig. 2.3 and Fig.2.4 are submitted in the Sheet 1 Table (Table 2.1).

Example of calculations for the clearance fit Ø160H7/c8 is submitted below. Here it should be taken into account that deviations are given in micrometres (μm) and their converting to millimetres (mm) is needed (**1 μm = 0.001 mm**).

Parameters of basic hole Ø160H7 are from the formulas (2.5), (2.6), (2.7), (2.8) (ref. Fig. 2.3 and Table 2.1):

$D_{max} = D + ES = 160 + (+0.040) = 160.040;$

$D_{min} = D + EI = 160 + 0 = 160;$

$D_m = (D_{max} + D_{min})/2 = (160.040 + 160)/2 = 160.020;$

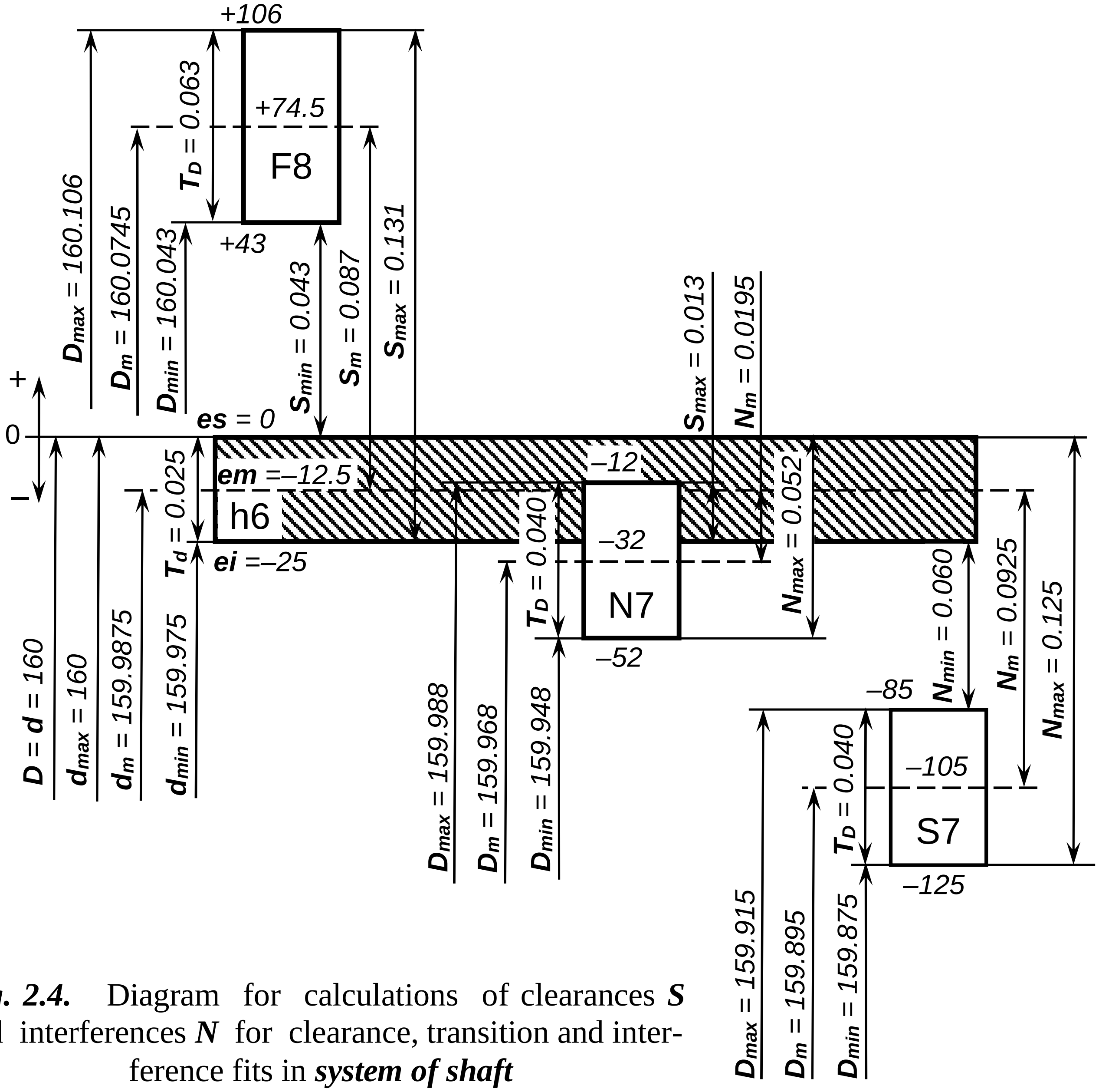


Fig. 2.4. Diagram for calculations of clearances ***S*** and interferences ***N*** for clearance, transition and interference fits in ***system of shaft***

$EM = (ES + EI)/2 = (+40 + 0)/2 = +20$ μm $= +0.020$ mm;

$D_m = D + EM = 160 + (+0.020) = 160.020$;

$T_D = D_{max} – D_{min} = 160.040 – 160 = 0.040$;

$T_D = ES – EI = (+40) – 0 = 40$ μm $= 0.040$ mm.

Parameters of shaft Ø160c8 are from the formulas (2.9), (2.10), (2.11), (2.12):

$d_{max} = d + es = 160 + (–0.210) = 159.790$;

$d_{min} = d + ei = 160 + (–0.273) = 159.727$;

$d_m = (d_{max} + d_{min})/2 = (159.790 + 159.727) /2 = 159.7585$;

$em = (es + ei)/2 = ((–210) + (–273))/2 = –241.5$ μm $= – 0.2415$ mm;

$d_m = d + em = 160 + (– 0.2415) = 159.7585$;

$T_d = d_{max} – d_{min} = 159.790 – 159.727 = 0.063$;

$T_d = es – ei = (–210) – (–273) = 63$ μm $= 0.063$ mm.

Table 2.1. Calculations results for fits in the system of hole and system of shaft

System of hole				
Basic hole **H7** (EI = 0)				
D, mm	D_{max}, mm	D_m, mm	D_{min}, mm	T_D, mm
160	160.040	160.020	160	0.040
Fits		clearance	transition	interference
Shafts		c8	js6	p6
d	max	159.790	160.0125	160.068
	mean	159.7585	160.000	160.0555
	min	159.727	159.9875	160.043
$+S$ $-N$	max	+0.313	+0.0525 –0.0125	–0.068
	mean	+0.2615	+0.020	–0.0355
	min	+0.210	——	–0.003
T_d, mm		0.063	0.025	0.025
$T_\Sigma = T_D + T_d$		0.103	0.065	0.065

System of shaft				
Basic shaft **h6** (es = 0)				
d, mm	d_{max}, mm	d_m, mm	d_{min}, mm	T_d, mm
160	160	159.9875	159.975	0.025
Fits		clearance	transition	interference
Holes		F8	N7	S7
D	max	160.106	159.988	159.915
	mean	160.0745	159.968	159.895
	min	160.043	159.948	159.875
$+S$ $-N$	max	+0.131	+0.013 –0.052	–0.125
	mean	+0.087	–0.0195	–0.0925
	min	+0.043	——	–0.060
T_D, mm		0.063	0.040	0.040
$T_\Sigma = T_D + T_d$		0.088	0.065	0.065

Parameters of the ***clearance*** fit Ø160H7/c8 (ref. Fig. 2.2) are calculated from the formulas (2.13), (2.14) and (2.17) (ref. Fig. 2.3 and Table 2.1):

$S_{max} = D_{max} - d_{min}$ = 160.040 – 159.727 = 0.313 (with assigned "+" for clearances);

$S_{max} = ES - ei$ = (+40) – (–273) = 313 μm = 0.313 mm;

$S_{min} = D_{min} - d_{max}$ = 160 – 159.790 = 0.210 (with assigned "+" for clearances);

$S_{min} = EI - es$ = 0 – (–210) = 210 μm = 0.210 mm;

$S_m = D_m - d_m$ = 160.020 – 159.7585 = 0.2615 (with assigned "+" for clearances);

$S_m = EM - em$ = (+20) – (–241.5) = 261.5 μm = 0.2615 mm;

$T_\Sigma = T_D + T_d$ = 0.040 + 0.063 = 0.103.

Example of calculations for the interference fit Ø160H7/p6 is submitted below.

Parameters of basic hole Ø160H7 are calculated from the formulas (2.5), (2.6), (2.7), (2.8) and submitted above and in Fig. 2.3 and Table 2.1.

Parameters of shaft Ø160p6 are from the formulas (2.9), (2.10), (2.11), (2.12):

$d_{max} = d + es$ = 160 + (+0.068) = 160.068;

$d_{min} = d + ei$ = 160 + (+0.043) = 160.043;

$d_m = (d_{max} + d_{min})/2$ = (160.068 + 160.043) /2 = 160.0555;

$em = (es + ei)/2$ = ((+68) + (+43))/2 = +55.5 μm = +0.0555 mm;

$d_m = d + em$ = 160 + (+0.0555) = 160.0555;

$T_d = d_{max} - d_{min}$ = 160.068 – 160.043 = 0.025;

$T_d = es - ei$ = (+68) – (+43) = 25 μm = 0.025 mm.

Parameters of the ***interference*** fit Ø160H7/p6 (ref. Fig. 2.2) are calculated from the formulas (2.15), (2.16) and (2.17) (ref. Fig. 2.3 and Table 2.1):

$N_{max} = d_{max} - D_{min}$ = 160.068 – 160 = 0.068 (with assigned "–" for interferences);

N_{max} = es – EI = (+68) – 0 = 68 μm = 0.068 mm;
N_{min} = d_{min} – D_{max} = 160.043 – 160.040 = 0.003 (with assigned "–" for interferences);
N_{min} = ei – ES = +43 – (+40) = 3 μm = 0.003 mm;
N_m = d_m – D_m = 160.0555 – 160.020 = 0.0355 (with assigned "–" for interferences);
N_m = em – EM = (+55.5) – (+20) = 35.5 μm = 0.0355 mm;
T_Σ = T_D + T_d = 0.040 + 0.025 = 0.065.

Example of calculations for the transition fit Ø160H7/j_s6 is submitted below.

Parameters of basic hole Ø160H7 are calculated from the formulas (2.5), (2.6), (2.7), (2.8) and submitted above and in Fig. 2.3 and Table 2.1.

Parameters of shaft Ø160j_s6 are from the formulas (2.9), (2.10), (2.11), (2.12):
d_{max} = d + es = 160 + (+0.0125) = 160.0125;
d_{min} = d + ei = 160 + (–0.0125) = 159.9875;
d_m = (d_{max} + d_{min})/2 = (160.0125 + 159.9875) /2 = 160.0;
em = (es + ei)/2 = ((+12.5) + (–12.5))/2 = 0;
d_m = d + em = 160 + 0 = 160.0;
T_d = d_{max} – d_{min} = 160.0125 – 159.9875 = 0.025;
T_d = es – ei = (+12.5) – (–12.5) = 25 μm = 0.025 mm.

Parameters of the ***transition*** fit Ø160H7/j_s6 (ref. Fig. 2.2) are calculated from the formulas (2.13), (2.15), (2.14) and (2.17) (ref. Fig. 2.3 and Table 2.1):
N_{max} = d_{max} – D_{min} = 160.0125 – 160 = 0.0125 (with assigned "–" for interferences);
N_{max} = es – EI = (+12.5) – 0 = 12.5 μm = 0.0125 mm;
S_{max}= D_{max} – d_{min} = 160.040 – 159.9875 = 0.0525 (with assigned "+" for clearances);
S_{max}= ES – ei = (+40) – (–12.5) = 52.5 μm = 0.0525 mm.

Formula (2.14) for mean clearance S_m is selected because mean-diameter hole is larger than mean-diameter shaft $D_m > d_m$, that corresponds to $EM > em$:
S_m = D_m – d_m = 160.020 – 160.0 = 0.020 (with assigned "+" for clearances);
S_m = EM – em = (+20) – 0 = 20 μm = 0.020 mm;
T_Σ = T_D + T_d = 0.040 + 0.025 = 0.065.

Calculations of parameters for the fits in system of shaft are produced with the same formulas (2.5) to (2.17). The only difference is that parameters of basic shaft (for example, Ø160h6) are calculated one time for all the holes in respective fits (ref. Fig. 2.4 and Table 2.1).

2.5. Draw the sketches of hole, shaft and slick joint of hole and shaft (Fig. 2.5). Specify various types of ***design dimensions*** for your personal task: 1) with tolerance band (Ø160H7, Ø160k6); 2) with limit deviations (Ø$160^{+0.04}$, Ø$160^{+0.028}_{+0.003}$); 3) in combined form – both with tolerance band and limit deviations (Ø160H7$\left(^{+0.04}\right)$, Ø160k6$\left(^{+0.028}_{+0.003}\right)$) (ref. Fig. 2.5, a, b, d, e).

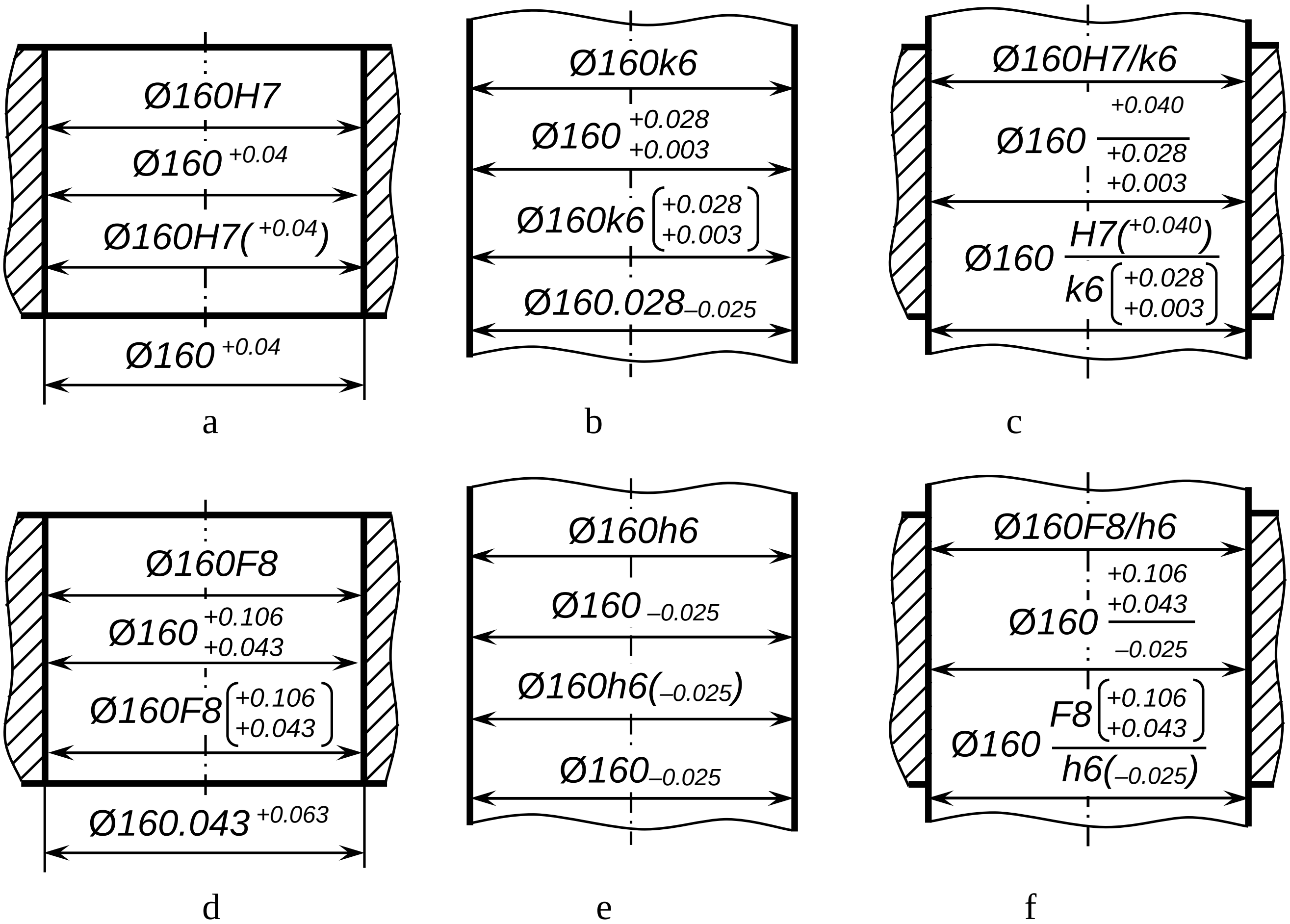


Fig. 2.5. Specifying dimensions in drawings and operation sketches for holes (a, d), shafts (b, e) and for assembly units (c, f) in system of hole and in system of shaft

Also specify ***executive (manufacturing) dimensions*** for hole and shaft (tolerance is directed into "body of part"): for hole $\boldsymbol{D} = \boldsymbol{D}_{min}^{+T_D}$ (Ø160$^{+0.04}$ and Ø160.043$^{+0.063}$ in Fig. 2.5, a and Fig. 2.5, d, respectively) and for shaft $\boldsymbol{d} = \boldsymbol{d}_{max_{-T_d}}$ (Ø160.028$_{-0.025}$ and Ø160$_{-0.025}$ in Fig. 2.5, b and Fig. 2.5, e, respectively).

With this purpose calculate the needed values from the formulas:

- Minimum hole diameter $D_{min} = D_{nom} + EI$. For example, D_{min} = 160 + 0 = 160 (ref. Fig. 2.5, a) and D_{min} = 160 + (+0.043) = 160.043 (ref. Fig. 2.5, d);
- Tolerance of hole diameter $T_D = ES - EI$. For example, T_D = (+0.040) – 0 = 0.040 (ref. Fig. 2.5, a) and T_D = (+0.106) – (+0.043) = 0.063 (ref. Fig. 2.5, d);
- Maximum shaft diameter $d_{max} = d_{nom} + es$. For example, d_{max} = 160 + (+0.028) = = 160.028 (ref. Fig. 2.5, b) and d_{max} = 160 + 0 = 160 (ref. Fig. 2.5, e);
- Tolerance of shaft diameter $T_d = es - ei$. For example, T_d = (+0.028) – (+0.003) = = 0.025 (ref. Fig. 2.5, b) and T_d = 0 – (–0.025) = 0.025 (ref. Fig. 2.5, e)

Show three types of ***design dimensions for the fit*** in similar manner in the joint of hole and shaft parts (ref. Fig. 2.5, c and Fig. 2.5, f).

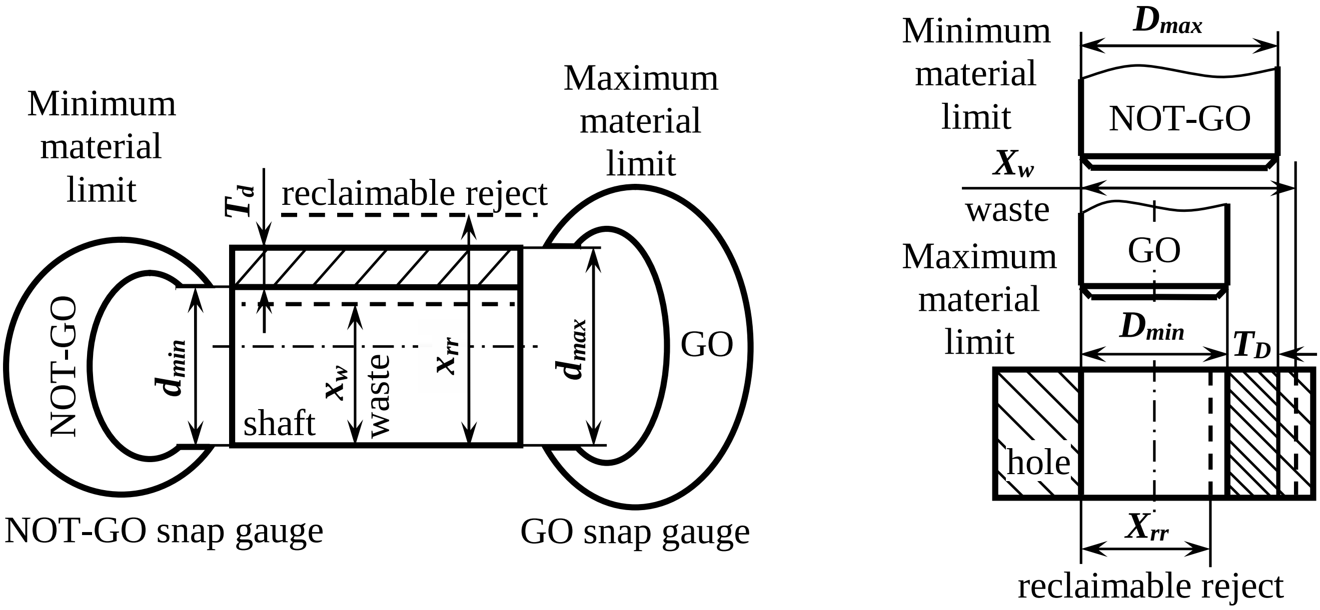
3. STUDY OF FIXED GAUGES (CGP Sheet 2)

The ***similarity principle*** is a basis for *check* of parts with *fixed gauges*.

According to the similarity principle *fixed gauge* should imitate that item, which will be in contact with a checked part. Hole is checked by shaft-gauge (plug gauge), and shaft is checked by hole-gauge (ring gauge and snap gauge).

Maximum limit dimension of shaft d_{max} and minimum limit dimension of hole D_{min} are checked with *GO-gauges*. These limits are called *maximum material limits* (Fig. 3.1). Minimum limit dimension of shaft d_{min} and maximum limit dimension of hole D_{max} are checked with *NOT-GO gauges* and respectively the limits are called *minimum material limits*.

Fixed gauges are high accuracy parts produced under the requirements of the GOST 24853-81 standard. The standard states *tolerances* for work and reference gauges (H – for plug gauges, H_1 – for snap gauges, H_P – for reference plug gauges), wear limits y for plug gauges and y_1 for snap gauges depending on accuracy and nominal dimensions of hole and shaft parts (Figs. 3.2 and 3.3). According to the standard the nominal dimensions of GO gauges are displaced at values Z and Z_1 relative to maximum material limits of parts. Nominal dimensions of gauges equal mean values (d_m, D_m) and therefore design dimensions are written with basic deviation Js (symmetrical upper and lower limit deviations): for work plug gauges $d_P = d_{Pm} \pm \frac{H}{2}$; for work snap gauges $D_S = D_{Sm} \pm \frac{H_1}{2}$; for reference plug gauges $d_R = d_{Rm} \pm \frac{H_P}{2}$ (ref. Appendix 3, Table A.3.1).



a b

Fig. 3.1. Diagram for check of a shaft with snap gauges (a) and check of a hole with plug gauges (b)

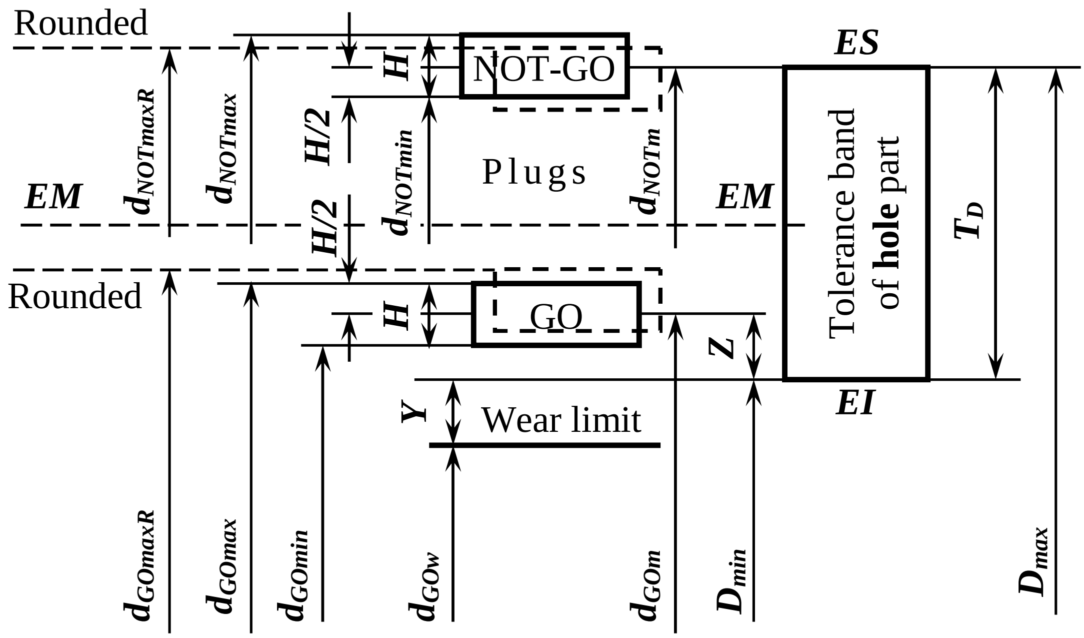


Fig. 3.2. Diagram for calculations of dimensions of work plug gauges for check of hole part

Executive (manufacturing) dimensions are rounded off according to the rules:

1) dimensions of work gauges are rounded off to the value divisible by 0.5 μm (0.0005 mm) – *the fourth digit after decimal point should be* 5 or 0;

2) Dimensions of gauges are rounded off in such a manner that rounded dimensions are displaced inward of manufacturing tolerance to the mean deviation ***EM*** (or ***em***) for the part (hole or shaft) – see Figs. 3.2 and 3.3;

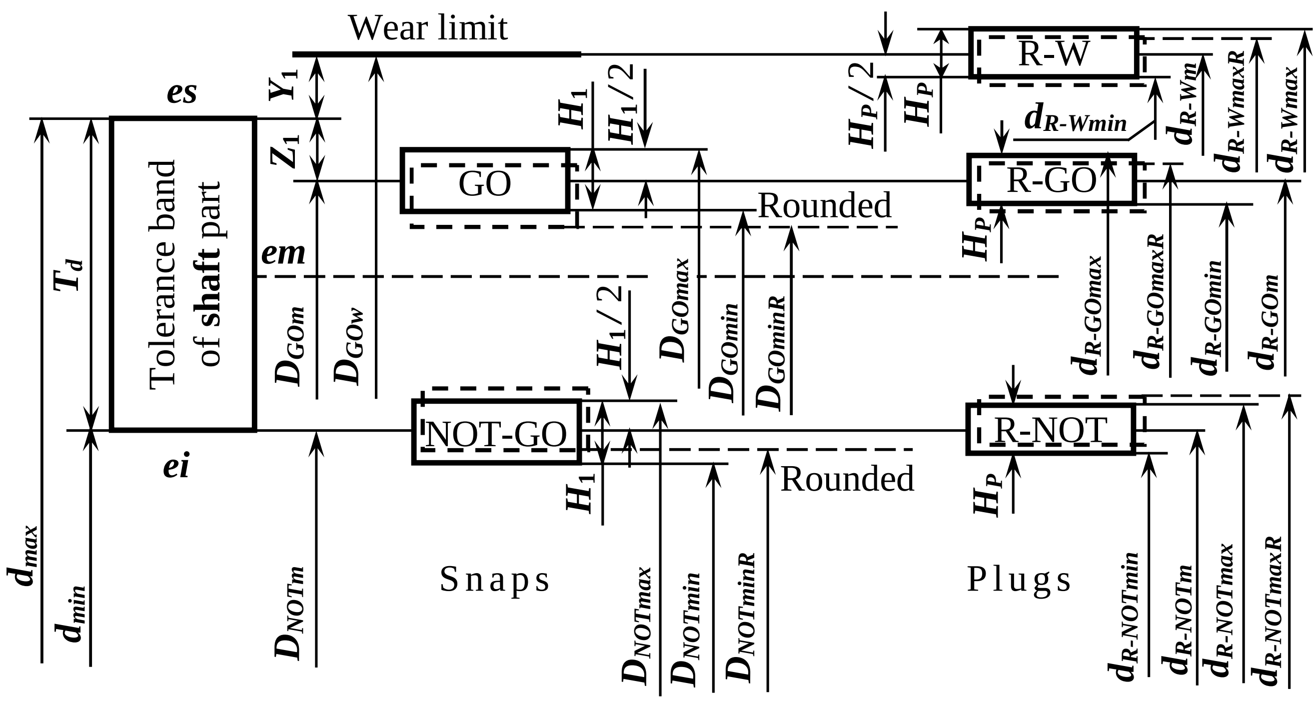


Fig. 3.3. Diagram for calculations of dimensions of work snap and ring gauges for check of hole part and reference plug gauges for check of work gauges

3) in a drawing the deviations of executive dimensions of gauges are specified "in-to body" of gauge – for plugs $\boldsymbol{d} = \boldsymbol{d}_{max}{}_{-\boldsymbol{T_d}}^{\;0}$ (basic shaft h, $\boldsymbol{es} = 0$) and for snaps $\boldsymbol{D} = \boldsymbol{D}_{min}{}^{+\boldsymbol{T_D}}_{\;0}$ (basic hole H, $\boldsymbol{EI} = 0$).

Dimensions of ***work plug gauges*** are calculated from the formulas compiled from Fig. 3.2:

- GO gauge dimensions:
  - mean (nominal) dimension $\boldsymbol{d_{GOm}} = \boldsymbol{D_{min}} + \boldsymbol{Z}$; (3.1)
  - maximum limit dimension $\boldsymbol{d_{GOmax}} = \boldsymbol{d_{GOm}} + \boldsymbol{H}/2$; (3.2)
  - minimum limit dimension $\boldsymbol{d_{GOmin}} = \boldsymbol{d_{GOm}} - \boldsymbol{H}/2$; (3.3)
  - wear limit dimension $\boldsymbol{d_{GOw}} = \boldsymbol{D_{min}} - \boldsymbol{Y}$; (3.4)
- NOT-GO gauge dimensions:
  - mean (nominal) dimension $\boldsymbol{d_{NOTm}} = \boldsymbol{D_{max}}$; (3.5)
  - maximum limit dimension $\boldsymbol{d_{NOTmax}} = \boldsymbol{d_{NOTm}} + \boldsymbol{H}/2$; (3.6)
  - minimum limit dimension $\boldsymbol{d_{NOTmin}} = \boldsymbol{d_{NOTm}} - \boldsymbol{H}/2$. (3.7)

Executive (manufacturing) ***dimensions of plug gauges*** are rounded off (shown by dotted lines in Fig. 3.2) according to the rounding rules and specified in the form of basic shaft dimension ($\boldsymbol{es} = 0$):

- GO plug gauge $\boldsymbol{d_{GO}} = \boldsymbol{d}_{\boldsymbol{GO\,max\,R}}{}_{-\boldsymbol{H}}^{\;0}$; (3.8)
- NOT-GO plug gauge $\boldsymbol{d_{NOT}} = \boldsymbol{d}_{\boldsymbol{NOT\,max\,R}}{}_{-\boldsymbol{H}}^{\;0}$. (3.9)

Also the GOST 24853-81 standard states parameters of work (snap and ring) gauges for check of shaft parts and reference plug gauges for check of work gauges (ref. Fig. 3.3).

Dimensions of ***work snap gauges*** are calculated from the formulas compiled from Fig. 3.3 (see also Appendix 3, Table A.3.1):

- GO gauge dimensions:
  - mean (nominal) dimension $\boldsymbol{D_{GOm}} = \boldsymbol{d_{max}} - \boldsymbol{Z_1}$; (3.10)
  - maximum limit dimension $\boldsymbol{D_{GOmax}} = \boldsymbol{D_{GOm}} + \boldsymbol{H_1}/2$; (3.11)
  - minimum limit dimension $\boldsymbol{D_{GOmin}} = \boldsymbol{D_{GOm}} - \boldsymbol{H_1}/2$; (3.12)
  - wear limit dimension $\boldsymbol{D_{GOw}} = \boldsymbol{d_{max}} + \boldsymbol{Y_1}$; (3.13)
- NOT-GO gauge dimensions:
  - mean (nominal) dimension $\boldsymbol{D_{NOTm}} = \boldsymbol{d_{min}}$; (3.14)
  - maximum limit dimension $\boldsymbol{D_{NOTmax}} = \boldsymbol{D_{NOTm}} + \boldsymbol{H_1}/2$; (3.15)
  - minimum limit dimension $\boldsymbol{D_{NOTmin}} = \boldsymbol{D_{NOTm}} - \boldsymbol{H_1}/2$. (3.16)

Executive (manufacturing) ***dimensions of snap gauges*** are rounded off (shown by dotted lines in Fig. 3.3) according to the rounding rules and specified in the form of basic hole dimension ($\boldsymbol{EI} = 0$):

- GO snap gauge $D_{GO} = D_{GO\,min\,R}\,{}^{+H_1}_{0}$; (3.17)

- NOT-GO snap gauge $D_{NOT} = D_{NOT\,min\,R}\,{}^{+H_1}_{0}$. (3.18)

Dimensions of ***reference plug gauges*** are calculated from the formulas compiled from Fig. 3.3:

- R-GO reference gauge dimensions:
  - mean (nominal) dimension $d_{R\text{-}GOm} = D_{GOm}$; (3.19)
  - maximum limit dimension $d_{R\text{-}GOmax} = d_{R\text{-}GOm} + H_P/2$; (3.20)
  - minimum limit dimension $d_{R\text{-}GOmin} = d_{R\text{-}GOm} - H_P/2$; (3.21)
- R-W reference gauge dimensions:
  - mean (nominal) dimension $d_{R\text{-}Wm} = D_{GOw}$; (3.22)
  - maximum limit dimension $d_{R\text{-}Wmax} = d_{R\text{-}Wm} + H_P/2$; (3.23)
  - minimum limit dimension $d_{R\text{-}Wmin} = d_{R\text{-}Wm} - H_P/2$; (3.24)
- R-NOT reference gauge dimensions:
  - mean (nominal) dimension $d_{R\text{-}NOTm} = D_{NOTm} = d_{min}$; (3.25)
  - maximum limit dimension $d_{R\text{-}NOTmax} = d_{R\text{-}NOTm} + H_P/2$; (3.26)
  - minimum limit dimension $d_{R\text{-}NOTmin} = d_{R\text{-}NOTm} - H_P/2$. (3.27)

Executive (manufacturing) ***dimensions of reference plug gauges*** are rounded off (shown by dotted lines in Fig. 3.3) according to the rounding rules and specified in the form of basic shaft dimension (es = 0):

- R-GO reference gauge $d_{R\text{-}GO} = d_{R\text{-}GO\,max\,R}\,{}^{0}_{-H_P}$; (3.28)
- R-W reference gauge $d_{R\text{-}W} = d_{R\text{-}W\,max\,R}\,{}^{0}_{-H_P}$; (3.29)
- R-NOT reference gauge $d_{R\text{-}NOT} = d_{R\text{-}NOT\,max\,R}\,{}^{0}_{-H_P}$. (3.30)

3.1. When performing the CGP Sheet 2, plot diagram of tolerance bands for hole, shaft and fixed gauges for indiviadual task (example submitted in Fig. 3.4). Use the GOST 24853-81 standard (ref. Appendix 3) to plot tolerance bands of work GO gauges relative to maximum material limit (minimum limit dimension D_{min} of hole part and maximum limit dimension d_{max} of shaft part) and NOT-GO gauges relative to minimum material limit (maximum limit dimension D_{max} of hole part and minimum limit dimension d_{min} of shaft part). Select numerical values of parameters of tolerance bands for gauges: H; Z; Y; H_1; Z_1; Y_1; H_P. Write down them in diagram and in the Sheet 2 Table (Table 3.1). Pay attention that parameters of tolerance bands are given in the standard in micrometres (μm) and their converting to millimetres (mm) is needed (**1 μm = 0.001 mm**) when performing the calculations.

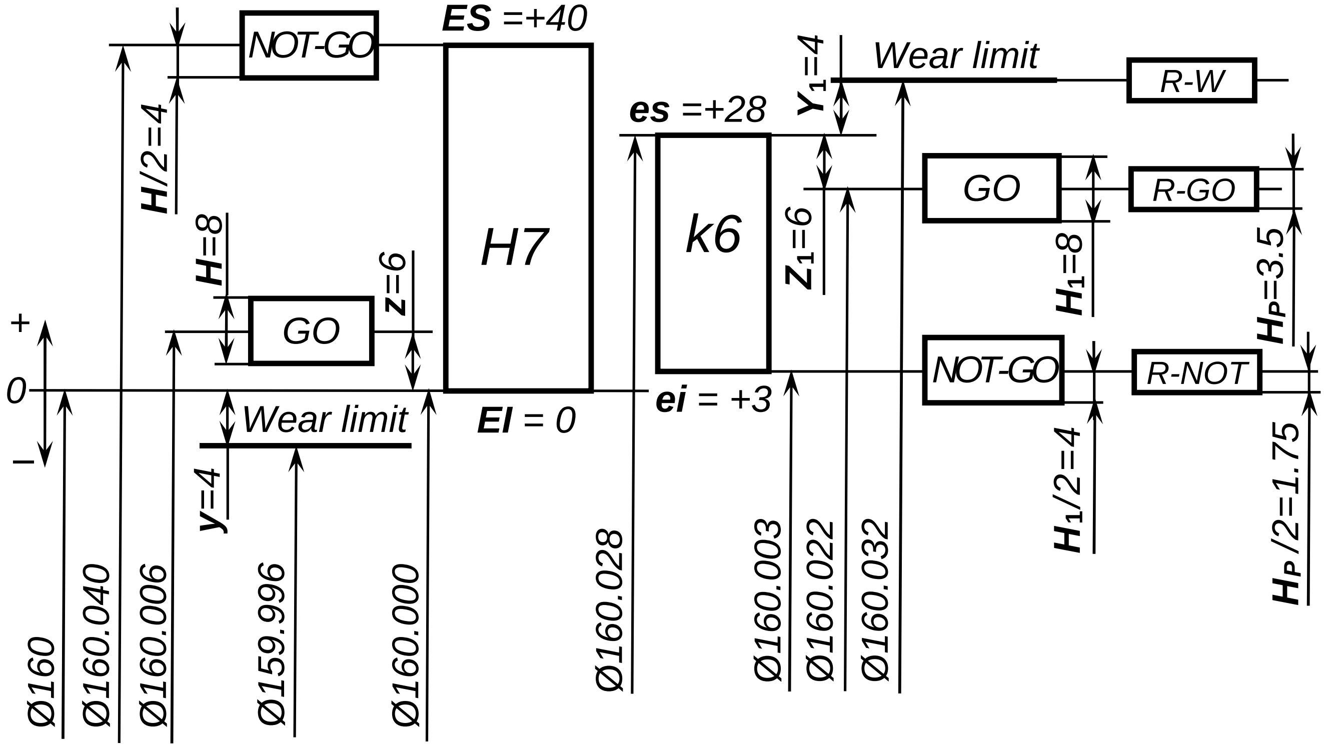


Fig. 3.4. Example of diagram for calculations of dimensions for work and reference gauges

Table 3.1. Calculations results of dimensions for fixed gauges for hole Ø160H7 and shaft Ø160k6

Gauge		Z Z_1	H H_1 H_P	Y Y_1	Dimensions		
					limit		executive (rounded off)
					max	min	
For hole	GO new	6	8	–	160.010	160.002	$160.010_{-0.008}$
	GO warn	–	–	4	–	159.996	–
	NOT-GO	–	8	–	160.044	160.036	$160.044_{-0.008}$
For shaft	GO new	6	8	–	160.026	160.018	$160.018^{+0.008}$
	GO warn	–	–	4	160.032	–	–
	NOT-GO	–	8	–	160.007	159.999	$159.999^{+0.008}$
	R-GO	6	3.5	–	160.02375	160.02025	$160.0235_{-0.0035}$
	R-W	–	3.5	4	160.03375	160.03025	$160.0335_{-0.0035}$
	R-NOT	–	3.5	–	160.00475	160.00125	$160.0050_{-0.0035}$

3.2. Perform calculations of dimensions of plugs (for hole) and snaps (for shaft) according to the diagrams and formulas above and write down the results into Table 3.1.

Specify executive dimensions for gauges as for basic shaft $\boldsymbol{d} = \boldsymbol{d}_{\boldsymbol{max}}{}_{-T_d}^{\;0}$ (plugs) or for basic hole $\boldsymbol{D} = \boldsymbol{D}_{\boldsymbol{min}}{}_{\;0}^{+T_D}$ (snaps). If necessary, round off executive dimensions according to the rules.

Example of calculations of dimensions with formulas (3.1) to (3.9) **for work plug gauges** for check of hole part Ø160H7 is the following:

- GO plug gauge dimensions:

- mean (nominal) dimension $d_{GOm} = D_{min} + Z = 160 + 0.006 = 160.006$;
- maximum limit dimension $d_{GOmax} = d_{GOm} + H/2 = 160.006 + 0.004 = 160.010$;
- minimum limit dimension $d_{GOmin} = d_{GOm} – H/2 = 160.006 – 0.004 = 160.002$;
- wear limit dimension $d_{GOw} = D_{min} – Y = 160 – 0.004 = 159.996$;

- NOT-GO plug gauge dimensions:

- mean (nominal) dimension $d_{NOTm} = D_{max} = 160.040$;
- maximum limit dimension $d_{NOTmax} = d_{NOTm} + H/2 = 160.040 + 0.004 = 160.044$;
- minimum limit dimension $d_{NOTmin} = d_{NOTm} – H/2 = 160.040 – 0.004 = 160.036$;

- executive (manufacturing) dimensions of plug gauges (no rounding off needed):

- GO plug gauge $d_{GO} = d_{GO\,max}{}_{-H}^{\;0} = 160.010_{–0.008}$;
- NOT-GO plug gauge $d_{NOT} = d_{NOT\,max}{}_{-H}^{\;0} = 160.044_{–0.008}$.

Example of calculations of dimensions with formulas (3.10) to (3.18) **for work snap gauges** for check of shaft part Ø160k6 is the following:

- GO snap gauge dimensions:

- mean (nominal) dimension $D_{GOm} = d_{max} – Z_1 = 160.028 – 0.006 = 160.022$;
- maximum limit dimension $D_{GOmax} = D_{GOm} + H_1/2 = 160.022 + 0.004 = 160.026$;
- minimum limit dimension $D_{GOmin} = D_{GOm} – H_1/2 = 160.022 – 0.004 = 160.018$;
- wear limit dimension $D_{GOw} = d_{max} + Y_1 = 160.028 + 0.004 = 160.032$;

- NOT-GO snap gauge dimensions:

- mean (nominal) dimension $D_{NOTm} = d_{min} = 160.003$;
- maximum limit dimension $D_{NOTmax} = D_{NOTm} + H_1/2 = 160.003 + 0.004 = 160.007$;
- minimum limit dimension $D_{NOTmin} = D_{NOTm} – H_1/2 = 160.003 – 0.004 = 159.999$;

- executive (manufacturing) dimensions of snap gauges (no rounding off needed):

- GO snap gauge $D_{GO} = D_{GO\,min}{}_{\;0}^{+H_1} = 160.018^{+0.008}$;
- NOT-GO snap gauge $D_{NOT} = D_{NOT\,min}{}_{\;0}^{+H_1} = 159.999^{+0.008}$.

Example of calculations of dimensions with formulas (3.19) to (3.30) **for reference plug gauges** for check of work snap gauges is the following:

- R-GO reference gauge dimensions:

- mean (nominal) dimension $\boldsymbol{d_{R\text{-}GOm}} = \boldsymbol{D_{GOm}}$ = 160.022;
- maximum limit dimension $\boldsymbol{d_{R\text{-}GOmax}} = \boldsymbol{d_{R\text{-}GOm}} + \boldsymbol{H_P}/2$ = 160.022 + 0.00175 = 160.02375;
- minimum limit dimension $\boldsymbol{d_{R\text{-}GOmin}} = \boldsymbol{d_{R\text{-}GOm}} - \boldsymbol{H_P}/2$ = 160.022 – 0.00175 = 160.02025;

- R-W reference gauge dimensions:

- mean (nominal) dimension $\boldsymbol{d_{R\text{-}Wm}} = \boldsymbol{D_{GOw}}$ = 160.032;
- maximum limit dimension $\boldsymbol{d_{R\text{-}Wmax}} = \boldsymbol{d_{R\text{-}Wm}} + \boldsymbol{H_P}/2$ = 160.032 + 0.00175 = 160.03375;
- minimum limit dimension $\boldsymbol{d_{R\text{-}Wmin}} = \boldsymbol{d_{R\text{-}Wm}} - \boldsymbol{H_P}/2$ = 160.032 – 0.00175 = 160.03025;

- R-NOT reference gauge dimensions:

- mean (nominal) dimension $\boldsymbol{d_{R\text{-}NOTm}} = \boldsymbol{D_{NOTm}} = \boldsymbol{d_{min}}$ = 160.003;
- maximum limit dimension $\boldsymbol{d_{R\text{-}NOTmax}} = \boldsymbol{d_{R\text{-}NOTm}} + \boldsymbol{H_P}/2$ = 160.003 + 0.00175 = 160.00475;
- minimum limit dimension $\boldsymbol{d_{R\text{-}NOTmin}} = \boldsymbol{d_{R\text{-}NOTm}} - \boldsymbol{H_P}/2$ = 160.003 – 0.00175 = 160.00125;

- executive (manufacturing) dimensions of reference plug gauges are rounded off:

- R-GO reference gauge $\boldsymbol{d_{R\text{-}GO}} = \boldsymbol{d_{R\text{-}GOmax}}{}_{-\boldsymbol{H_P}}^{\;0}$ = $160.0235_{-0.0035}$;
- R-W reference gauge $\boldsymbol{d_{R\text{-}W}} = \boldsymbol{d_{R\text{-}Wmax}}{}_{-\boldsymbol{H_P}}^{\;0}$ = $160.0335_{-0.0035}$;
- R-NOT reference gauge $\boldsymbol{d_{R\text{-}NOT}} = \boldsymbol{d_{R\text{-}NOTmax}}{}_{-\boldsymbol{H_P}}^{\;0}$ = $160.0050_{-0.0035}$.

3.3. Draw sketches of gauges: work plug gauges (Fig. 3.5) and work snap gauges (Fig. 3.6). Write down special information related to parts dimensions to be checked. Specify executive dimensions in gauges sketches. Specify requirements for form accuracy and roughness on work surfaces of gauges according to the recommendations submitted in the Appendix 4.

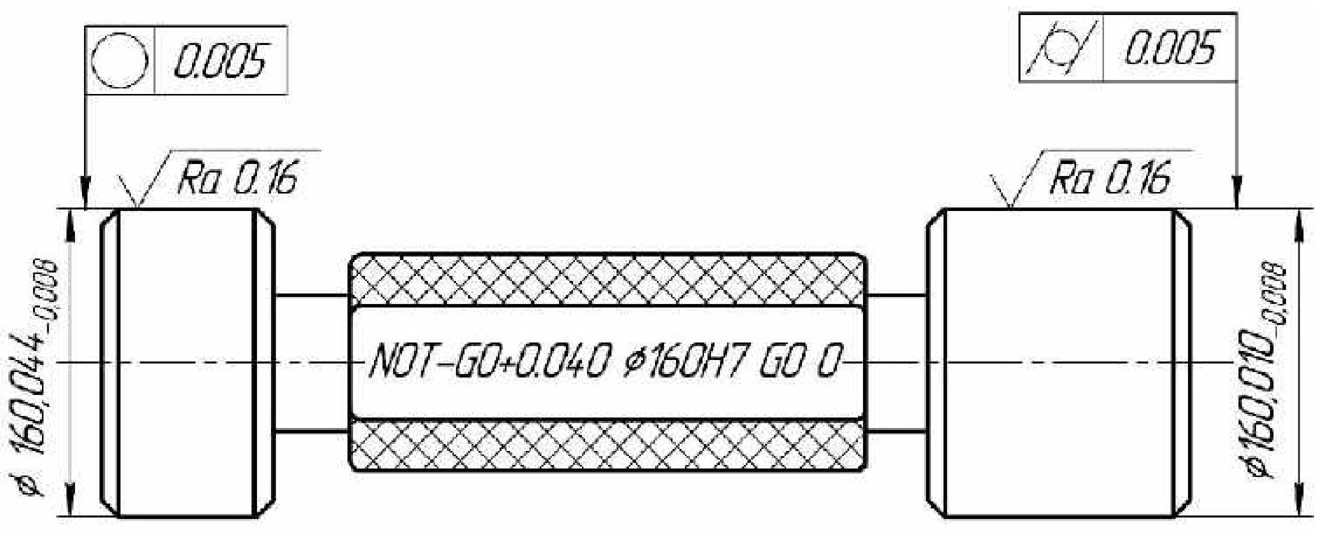


Fig. 3.5. Example of sketch for double-end double-limit plug gauge for check of hole part Ø160H7

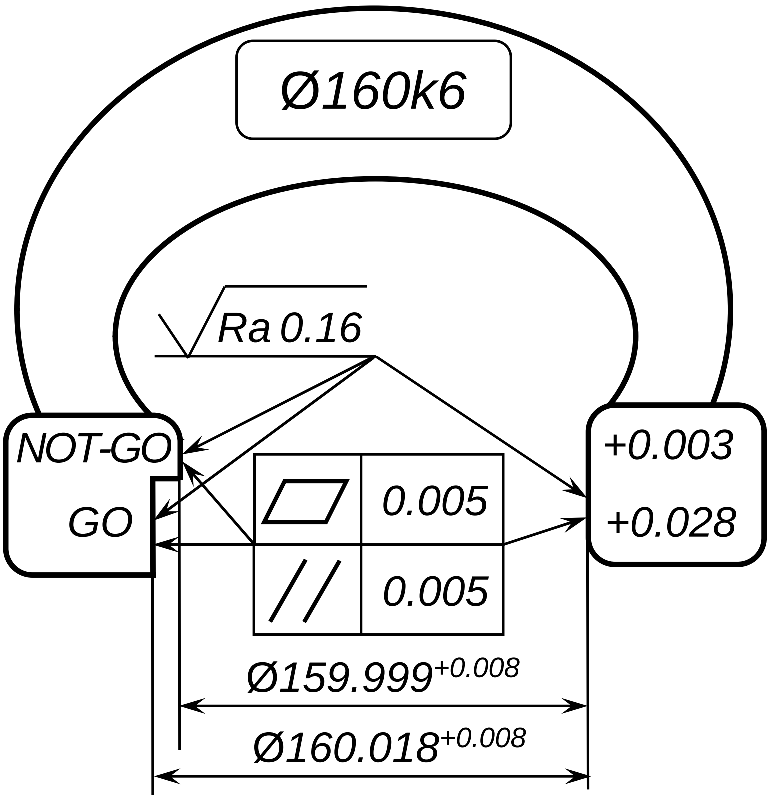


Fig. 3.6. Example of sketch for single-end double-limit snap gauge for check of shaft part Ø160k6

4 ANALYSIS OF FITS FOR SLICK JOINTS (CGP Sheet 3)

4.1. Write down initial data in the right top corner of the CGP Sheet 3 (Fig. 4.1), for **example Ø160H7/k6.**

4.2. Plot diagram of tolerance bands for hole and shaft parts according to the fit specified in your task (ref. Fig. 4.1). Calculate maximum and minimum clearances and/or interferences with selecting proper formulas applied to your type of fit (clearance, transition or interference):

$$S_{max} = ES - ei; \qquad S_{min} = EI - es;$$

$$N_{max} = es - EI; \qquad N_{min} = ei - ES.$$

In the considered **example for transition fit**

$$S_{max} = ES - ei = +40 - (+3) = 37\ \mu m;$$

$$N_{max} = es - EI = +28 - 0 = 28\ \mu m.$$

Specify the calculated values in the diagram with dimension lines (ref. Fig. 4.1). Also write down *mean deviations* of tolerance bands of hole and shaft:

$$EM = \frac{ES + EI}{2}; \qquad em = \frac{es + ei}{2}.$$

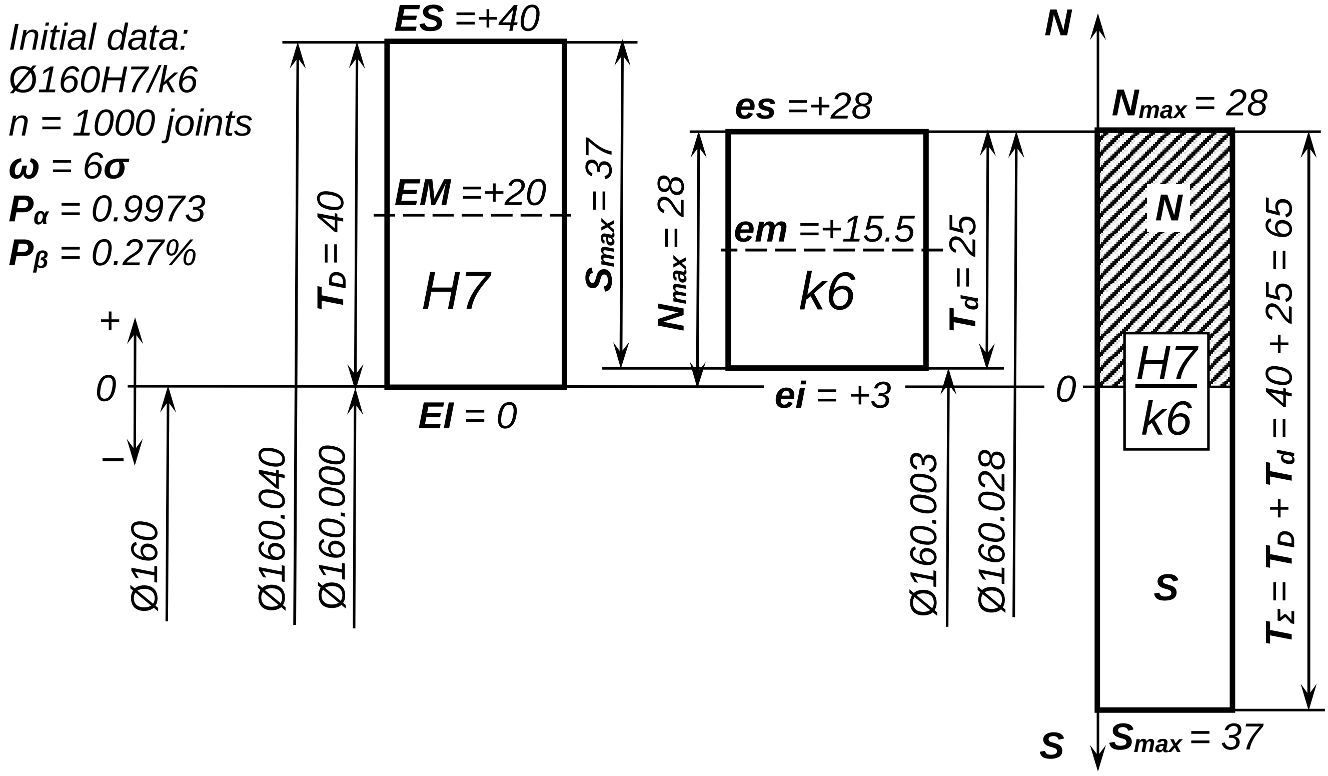


Fig. 4.1. Example of tolerance bands for hole, shaft, fit and their parameters for transition fit Ø160H7/k6

In the considered example:

$$\boldsymbol{EM} = \frac{(+40)+0}{2} = +20 \text{ µm}; \quad \boldsymbol{em} = \frac{(+28)+(+3)}{2} = +15.5 \text{ µm}.$$

4.3. Plot diagram of tolerance band for the fit (ref. Fig. 4.1). Axes for clearance ***S*** and interference ***N*** are directed in opposite sides. Portion of interferences is hatched, portion of clearances is clear (without hatching).

4.4. Calculate the tolerances and standard deviations in micrometres (µm) from the formulas:

- For hole $T_D = ES - EI$; $\sigma_D = T_D / 6$;

- For shaft $T_d = es - ei$; $\sigma_d = T_d / 6$;

- For fit $T_\Sigma = T_D + T_d$; $\sigma_\Sigma = \sqrt{\sigma_D^2 + \sigma_d^2}$.

Here it is assumed for theoretical analysis of fits that tolerances of parts are $T = 6\sigma$.

In the considered example the calculations are:

- For hole: T_D = (+40) – 0 = 40 µm; σ_D = 40/ 6 ≈ 6.667 µm;

- For shaft: T_d = (+28) – (+3) = 25 µm; σ_d = 25 / 6 ≈ 4.167 µm;

- For fit: $T_\Sigma = T_D + T_d$ = 40 + 25 = 65 µm; $\sigma_\Sigma = \sqrt{6.667^2 + 4.167^2}$ ≈ 7.862 µm.

Write down the results of calculations into Table 4.1.

Table 4.1. Calculations results for plotting Gauss curves for hole, shaft and fit Ø160H7/k6

T_D	T_d	T_Σ	σ_D	σ_d	σ_Σ
40	25	65	6.667	4.167	7.862

z	0	0.5	1.0	1.5	2.0	3.0	4.0
t(z)	0.3989	0.3521	0.2420	0.1295	0.0540	0.0044	0.00013
$y_D=(t/\sigma_D)\times10^3$	59.83	52.81	36.30	19.42	8.10	0.66	–
$y_d=(t/\sigma_d)\times10^3$	95.73	84.50	84.50	58.08	31.08	12.96	–
$y_\Sigma=(t/\sigma_d)\times10^3$	50.74	44.79	30.78	16.47	6.87	0.56	0.02
$\Delta x = z \times \sigma_\Sigma$	0.00	3.93	7.86	11.79	15.72	23.59	31.45

4.5. Select ***t*** values of Laplace function from the ***t***(***z***) table for ***z*** equals 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 (Appendix 5). Calculate probability density y_D for hole, y_d for shaft, y_Σ for fit and absolute deviation Δx values from the formulas respectively

$$y_D = \frac{t}{\sigma_D} \times 10^3; \qquad y_d = \frac{t}{\sigma_d} \times 10^3; \qquad y_\Sigma = \frac{t}{\sigma_p} \times 10^3; \qquad \Delta x = z \times \sigma_\Sigma,$$

where 10^3 is a scale coefficient for plotting ***y*** curves; ***t*** – normalised distribution density.

Write down the results into the Table 4.1.

4.6. Use these data for plotting distribution curves for hole and shaft actual dimensions (Fig. 4.2). It is convenient to plot curves of $y(\Delta x)$ function with ***y*** and Δx values expressed in millimetres with specifying numbers of σ.

From the middle point of the tolerance band draw axis ***y***. Put the $y(\Delta x)$ values as points at Δx equal to 0, $\pm0.5\sigma_\Sigma$, $\pm1\sigma_\Sigma$, $\pm1.5\sigma_\Sigma$, $\pm2\sigma_\Sigma$, $\pm3\sigma_\Sigma$ (ref. Table 4.1). Connect points with a smooth line to obtain Gaussian distribution curves $y(\Delta x)$.

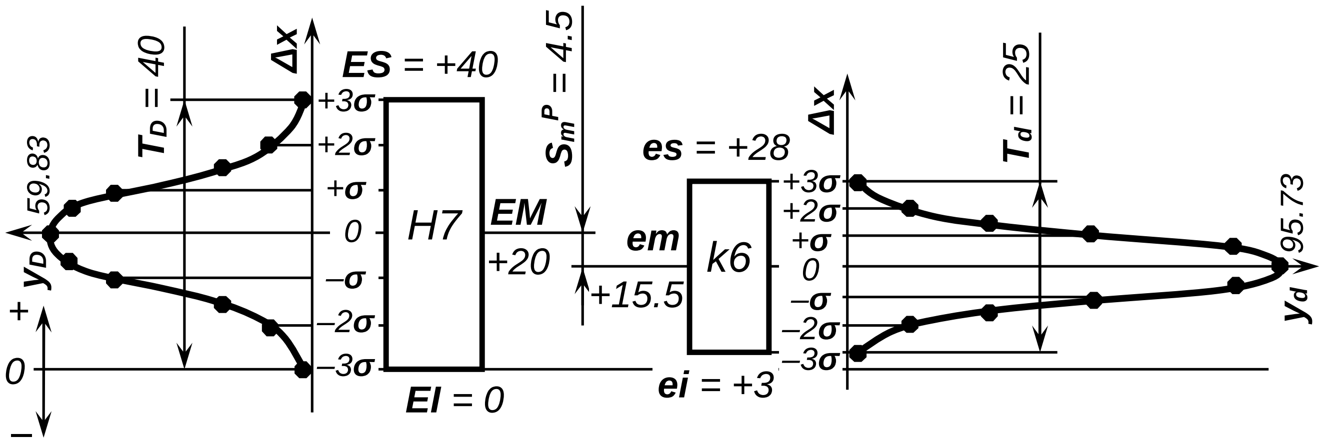


Fig. 4.2. Example of plotting Gaussian curves for hole Ø160H7 and shaft Ø160k6 tolerance bands

Calculate ***mean-probability value*** of clearance or of interference from the pertinent formula

$$\boldsymbol{S_m^p = EM - em} \quad \text{or} \quad \boldsymbol{N_m^p = em - EM}.$$

Specify the calculated value in the sketch (ref. Fig. 4.2).

Selection of proper formula depends on the larger value of mean dimension of hole $\boldsymbol{D_m}$ (respectively ***EM***) or mean dimension of shaft $\boldsymbol{d_m}$ (respectively ***em***).

In the considered example (ref. Fig. 4.2) *the mean-diameter hole is larger than mean-diameter shaft* (***EM*** > ***em***) and so this mean-probabilistic fit will be with *clearance*. Hence, the selected formula is

$$\boldsymbol{S_m^p = EM - em} = (+20) - (+15.5) = 4.5\ \mu\text{m}.$$

4.7. Plot the distribution curve for clearances and/or interferences in the joint (Fig. 4.3). Start from axes $\boldsymbol{\Delta x}$ and $\boldsymbol{z}$. Select arbitrary, but proper scale, for example, scale for $\boldsymbol{\Delta x}$ could be 2 millimetre per 1 micrometre from Table 4.1 (like in this example).

From zero point draw vertical axis $\boldsymbol{y}$. Put the $\boldsymbol{y}(\boldsymbol{\Delta x})$ values as points at $\boldsymbol{\Delta x}$ equals 0, $\pm0.5\sigma_\Sigma$, $\pm1\sigma_\Sigma$, $\pm1.5\sigma_\Sigma$, $\pm2\sigma_\Sigma$, $\pm3\sigma_\Sigma$, $\pm4\sigma_\Sigma$. Connect points with a smooth line to obtain Gaussian distribution curve. Write down values of fit tolerance $\boldsymbol{T_\Sigma}$ and confidence interval for fit $\boldsymbol{\omega} = 6\sigma_\Sigma$ at the sketch (ref. Fig. 4.3).

Determine extreme points of the fit tolerance $\boldsymbol{T_\Sigma}$ in portions of deviation σ_Σ:

$$\Delta x_{max} = z_{max} \cdot \sigma_\Sigma, \quad \text{where } z_{max} = \frac{T_\Sigma}{2\sigma_\Sigma};$$

$$\Delta x_{min} = z_{min} \cdot \sigma_\Sigma, \quad \text{where } z_{min} = -z_{max}.$$

In the considered example (ref. Fig. 4.3) the calculations are:

$$z_{max} = \frac{T_\Sigma}{2\sigma_\Sigma} = \frac{65}{2 \cdot 7.862} \approx +4.134; \quad z_{min} = -z_{max} \approx -4.134;$$

$$\Delta x_{max} = z_{max} \cdot \sigma_\Sigma = +4.134\sigma_\Sigma; \quad \Delta x_{min} = z_{min} \cdot \sigma_\Sigma = -4.134\sigma_\Sigma.$$

Write down the results along the axes $\boldsymbol{\Delta x}$ and $\boldsymbol{z}$ (ref. Fig. 4.3).

Calculate the difference between extreme points of the fit tolerance band $\boldsymbol{T_\Sigma}$ and confidence interval $\boldsymbol{\omega}$ in portions of deviation σ_Σ:

$$\Delta T_\Sigma = (T_\Sigma - \omega)/2 = (8.268\sigma_\Sigma - 6\sigma_\Sigma)/2 = 1.134\sigma_\Sigma,$$

where:

- fit tolerance $T_\Sigma = (z_{max} - z_{min})\sigma_\Sigma = (+4.134 - (-4.134))\sigma_\Sigma = 8.268\sigma_\Sigma = 65\ \mu\text{m}$;
- confidence interval $\omega = 6\sigma_\Sigma = 6 \times 7.862 \approx 47.17\ \mu\text{m}$.

In the considered example (ref. Fig. 4.3) this value equals

$$\Delta T_\Sigma = (65 - 47.17)/2 = 8.915\ \mu\text{m}, \quad \Delta T_\Sigma = 1.134\sigma_\Sigma \approx 8.915\ \mu\text{m}.$$

Write down the calculated value in portions of σ_Σ and in micrometres in the sketch symmetrically (ref. Fig. 4.3).

For limit deviations of confidence interval ($\pm3\sigma_\Sigma$) the **probabilistic values of maximum and minimum values of clearance and interference** are calculated from:

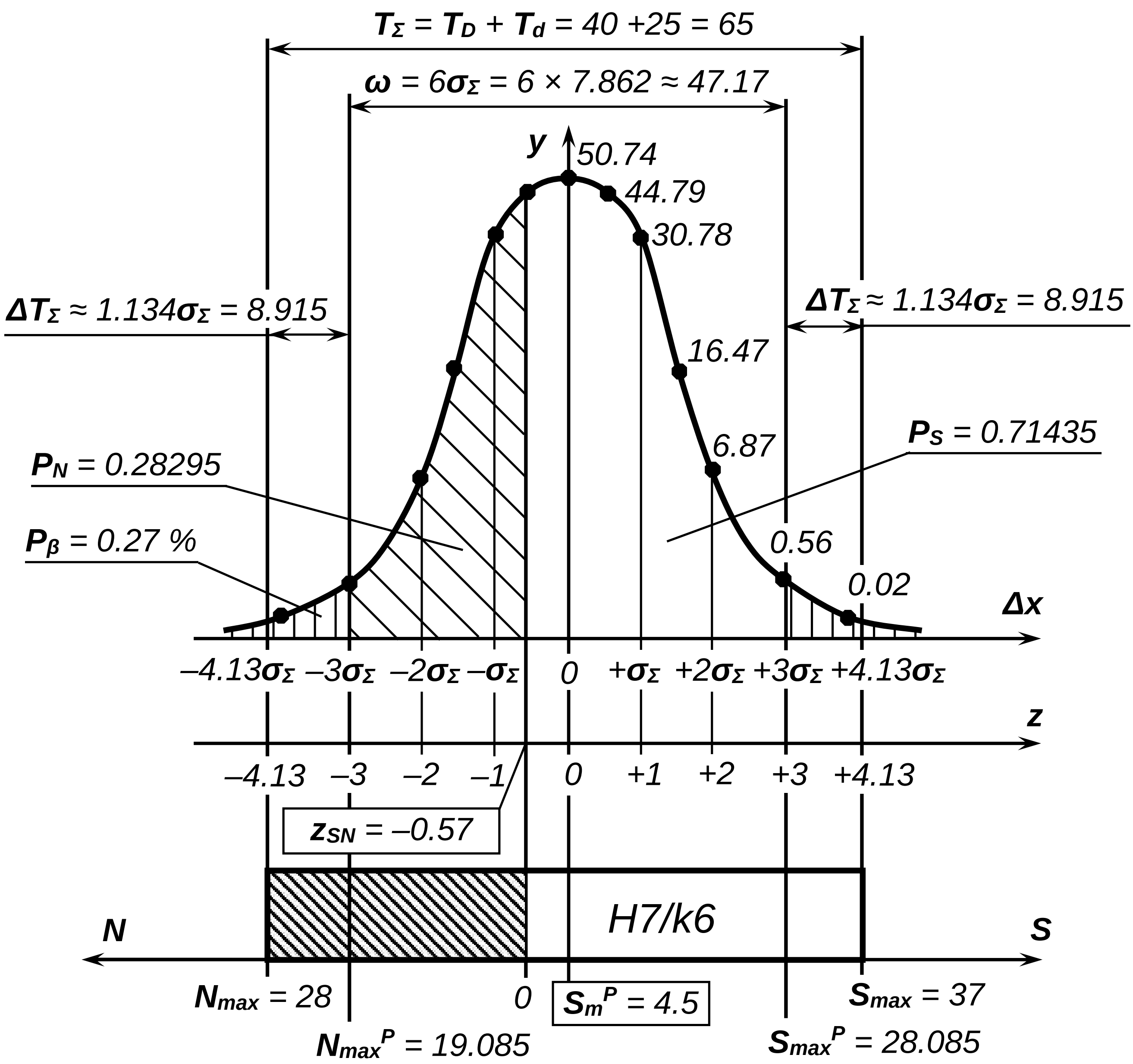


Fig. 4.3. Example of plotting Gaussian curve for tolerance band of transition fit Ø160H7/k6 and respective parameters

$$S_{max}^{P} = S_{max} - \Delta T_{\Sigma}; \qquad S_{min}^{P} = S_{min} + \Delta T_{\Sigma};$$

$$N_{max}^{P} = N_{max} - \Delta T_{\Sigma}; \qquad N_{min}^{P} = N_{min} + \Delta T_{\Sigma}.$$

Select proper formulas for the individual task (type of fit) and specify the calculated values in the diagram (ref. Fig. 4.3).

4.8. Below the Gaussian curve and axis ***z*** draw the fit tolerance band along axis ***S–N***. Specify maximum theoretical clearance S_{max} and maximum theoretical interference N_{max} for a transition fit (ref. Fig. 4.3), or maximum N_{max} and minimum N_{min} values for interference fit (Fig. 4.4), or maximum S_{max} and minimum S_{min} values for clearance fit (Fig. 4.5).

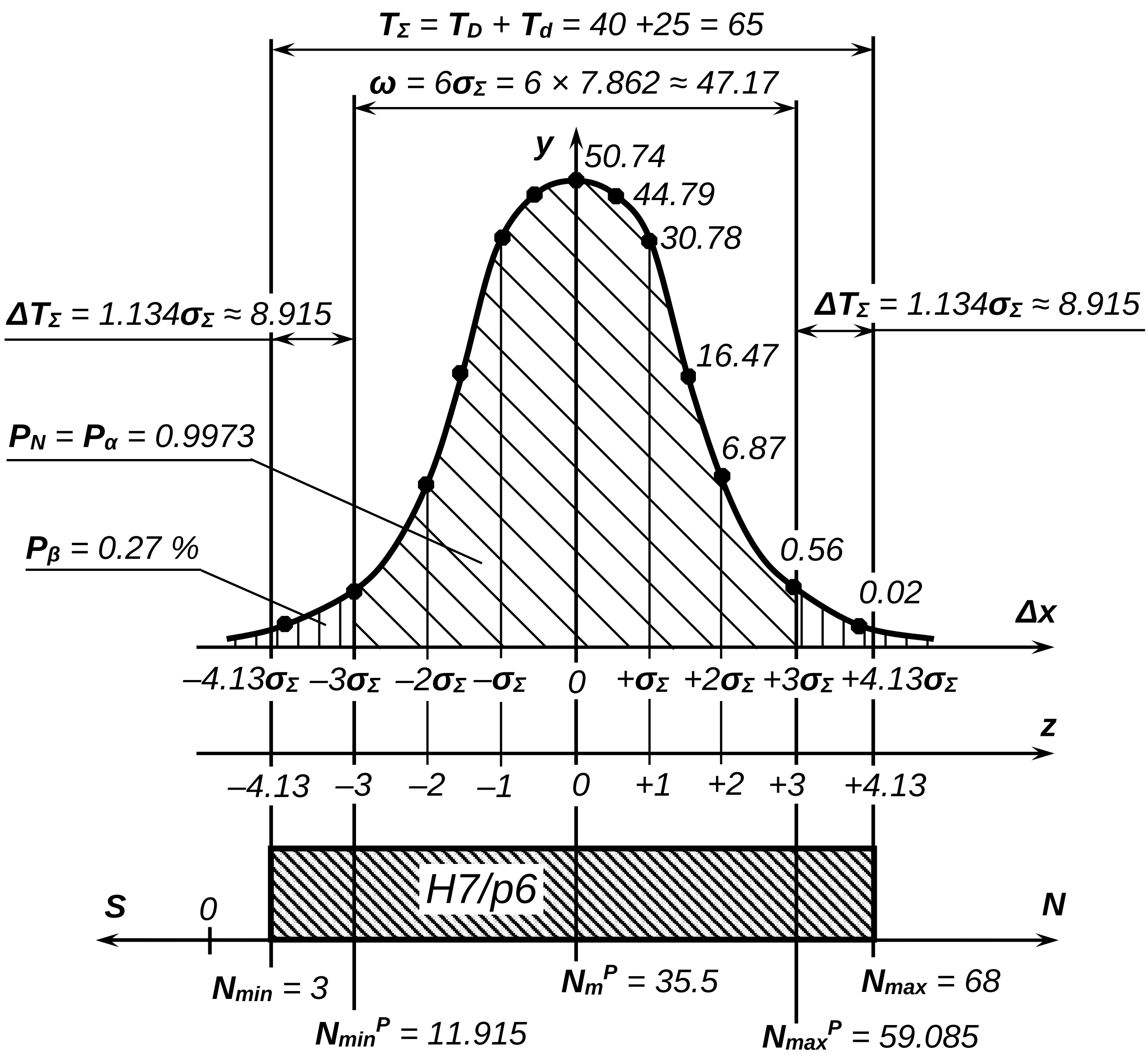


Fig. 4.4. Example of plotting Gaussian curve for tolerance band of interference fit Ø160H7/p6 and respective parameters (ref. Fig. 2.3 and Table 2.1)

For the example of **interference fit Ø160H7/p6** in Fig. 4.4 (for deviations see Fig. 2.3) the calculations are:

- $N_{max} = es - EI = (+68) - 0 = 68$ µm; $N_{min} = ei - ES = (+43) - (+40) = 3$ µm;
- $EM = \frac{ES + EI}{2} = \frac{(+40)+0}{2} = +20$ µm; $em = \frac{es + ei}{2} = \frac{(+68)+(+43)}{2} = +55.5$ µm;
- For hole: $T_D = (+40) - 0 = 40$ µm; $\sigma_D = 40/6 \approx 6.667$ µm;
- For shaft: $T_d = (+68) - (+43) = 25$ µm; $\sigma_d = 25/6 \approx 4.167$ µm;
- For fit: $T_\Sigma = T_D + T_d = 40 + 25 = 65$ µm;

$$\sigma_\Sigma = \sqrt{\sigma_D^2 + \sigma_d^2} = \sqrt{6.667^2 + 4.167^2} \approx 7.862 \text{ µm};$$

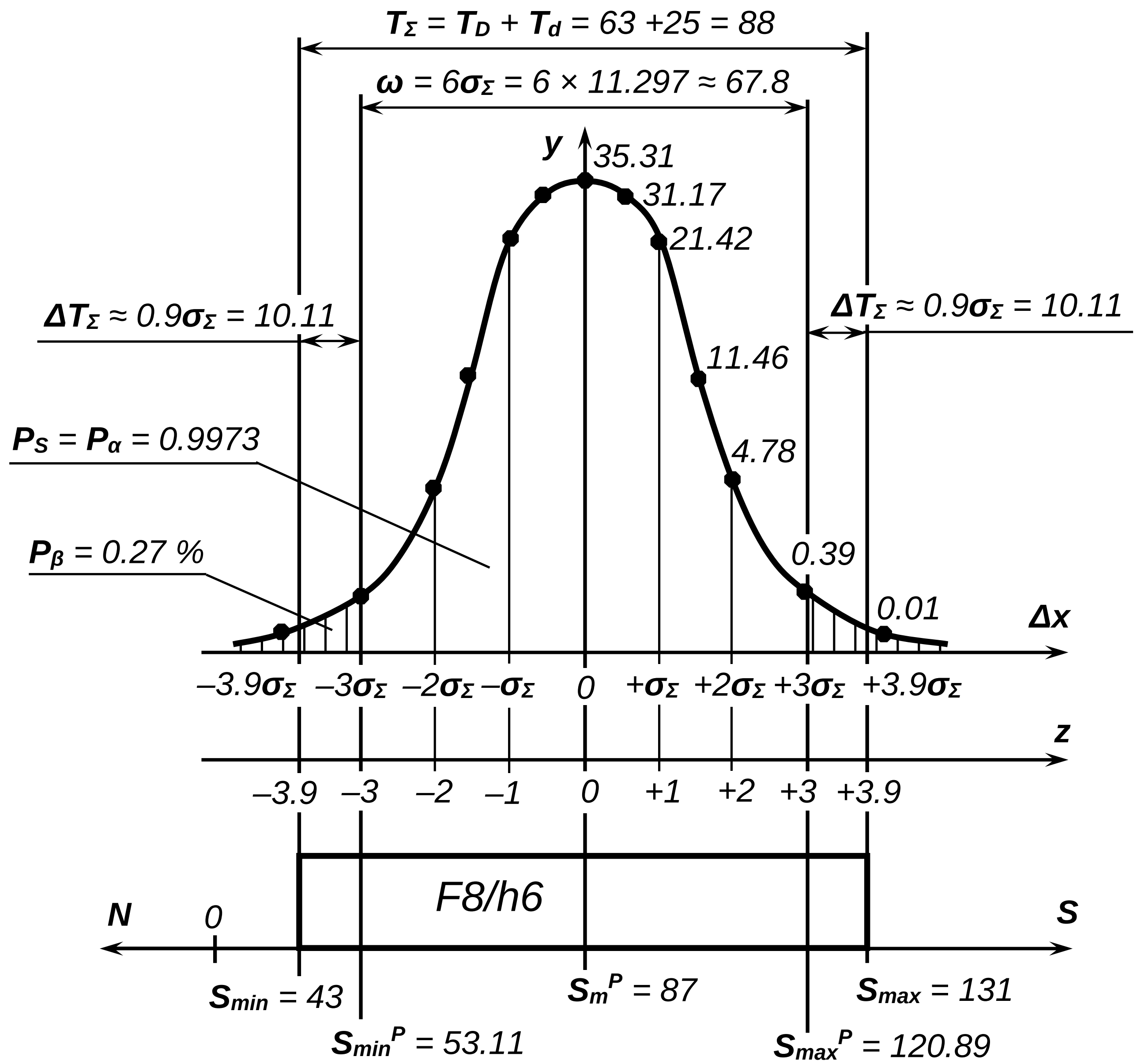


Fig. 4.5. Example of plotting Gaussian curve for tolerance band of clearance fit Ø160F8/h6 and respective parameters (ref. Fig. 2.4 and Table 2.1)

- $N_m^p = em - EM$ = +55.5 – (+20) = 35.5 µm;
- $z_{max} = \dfrac{T_p}{2\sigma_p} = \dfrac{65}{2 \cdot 7.862}$ ≈ +4.134; $z_{min} = -z_{max}$ ≈ – 4.134;
- $\Delta x_{max} = z_{max} \cdot \sigma_\Sigma = +4.134\sigma_\Sigma$; $\Delta x_{min} = z_{min} \cdot \sigma_\Sigma = -4.134\sigma_\Sigma$;
- $T_\Sigma = (z_{max} - z_{min})\sigma_\Sigma = (+4.134 - (-4.134))\sigma_\Sigma = 8.268\sigma_\Sigma$ = 65 µm;
- $\omega = 6\sigma_\Sigma = 6 \times 7.862 \approx 47.17$ µm;
- $\Delta T_\Sigma = (T_\Sigma - \omega)/2 = (65 - 47.17)/2 = 8.915$ µm; $\Delta T_\Sigma = 1.134\sigma_\Sigma \approx 8.915$ µm;
- $N_{min}^p = N_{min} + \Delta T_\Sigma = 3 + 8.915 = 11.915$ µm;
- $N_{max}^p = N_{max} - \Delta T_\Sigma = 68 - 8.915 = 59.085$ µm.

Specify the calculated values in the sketch (ref. Fig. 4.4).

For the example of **clearance fit Ø160F8/h6** in Fig. 4.5 (for deviations see Fig. 2.4) the calculations are:

- $S_{max} = ES - ei$ = (+106) – (–25) = 131 μm; $S_{min} = EI - es$ = (+43) – 0 = 43 μm;

- $EM = \frac{ES + EI}{2} = \frac{(+106)+(+43)}{2}$ = +74.5; $em = \frac{es + ei}{2} = \frac{0+(-25)}{2}$ = –12.5 μm;

- For hole: T_D = (+106) – (+43) = 63 μm; σ_D = 63/ 6 = 10.5 μm;

- For shaft: T_d = 0 – (–25) = 25 μm; σ_d = 25 / 6 ≈ 4.167 μm;

- For fit: $T_\Sigma = T_D + T_d$ = 63 + 25 = 88 μm;

$$\sigma_\Sigma = \sqrt{\sigma_D^2 + \sigma_d^2} = \sqrt{10.5^2 + 4.167^2} \approx 11.297 \text{ μm};$$

- $S_m^p = EM - em$ = (+74.5) – (–12.5) = 87 μm;

- $z_{max} = \frac{T_\Sigma}{2\sigma_\Sigma} = \frac{88}{2 \times 11.297} \approx +3.895$; $z_{min} = -z_{max} \approx -3.895$;

- $\Delta x_{max} = z_{max} \cdot \sigma_\Sigma = +3.895\sigma_\Sigma$; $\Delta x_{min} = z_{min} \cdot \sigma_\Sigma = -3.895\sigma_\Sigma$;

- $T_\Sigma = (z_{max} - z_{min})\sigma_\Sigma = (+3.895 - (-3.895))\sigma_\Sigma = 7.79\sigma_\Sigma$ = 88 μm;

- $\omega = 6\sigma_\Sigma$ = 6 × 11.297 ≈ 67.78 μm;

- $\Delta T_\Sigma = (T_\Sigma - \omega)/2$ = (88 – 67.78)/2 = 10.11 μm; $\Delta T_\Sigma = 0.895\sigma_\Sigma$ ≈ 10.11 μm

- $S_{min}^p = S_{min} + \Delta T_\Sigma$ = 43 + 10.11 = 53.11 μm;

- $S_{max}^p = S_{max} - \Delta T_\Sigma$ = 131 – 10.11 = 120.89 μm.

Specify the calculated values in the sketch (ref. Fig. 4.5).

For interference and clearance fits the values N_m^p or S_m^p along axis S–N coincide with "0" value along axes Δx and z. Also in these two cases probability of interference fits or clearance fits is equal to probability of event P_α = 0.9973 in confidence interval $\omega = 6\sigma_\Sigma$ (ref. Fig. 4.4 and Fig. 4.5).

4.9. ***For transition fits*** calculate the coordinate z_{SN} for mean-probability value of clearance (or interference)

$$z_{SN} = -S_m^p/\sigma_\Sigma \quad \text{or} \quad z_{SN} = +N_m^p/\sigma_\Sigma.$$

These formulas are valid for the given directions of axes N and S (ref. Fig. 4.3).

For the considered fit Ø160H7/k6

$$z_{SN} = -S_m^p/\sigma_\Sigma = -4.5 / 7.862 \approx -0.57.$$

Plot vertical line (starting from coordinate 0 along axis S–N and coordinate z_{SN} along axis z) on the Gaussian distribution with coordinate $\Delta x_{SN} = z_{SN} \times \sigma_\Sigma$ to divide area under the curve into 2 portions (ref. Fig. 4.3).

4.10. ***For transition fits*** calculate probabilities (quantities) of clearance fits and interference fits (Fig. 4.6) from the formulas for the directions of axes shown in Fig. 4.3:

- Probability of interference fits $P_N = \Phi_0(3) - \Phi_0(z_{SN})$;
- Probability of clearance fits $P_S = \Phi_0(3) + \Phi_0(z_{SN})$.

The $\Phi_0(z)$ values are from the table of Laplace integral function (ref. Appendix 5).

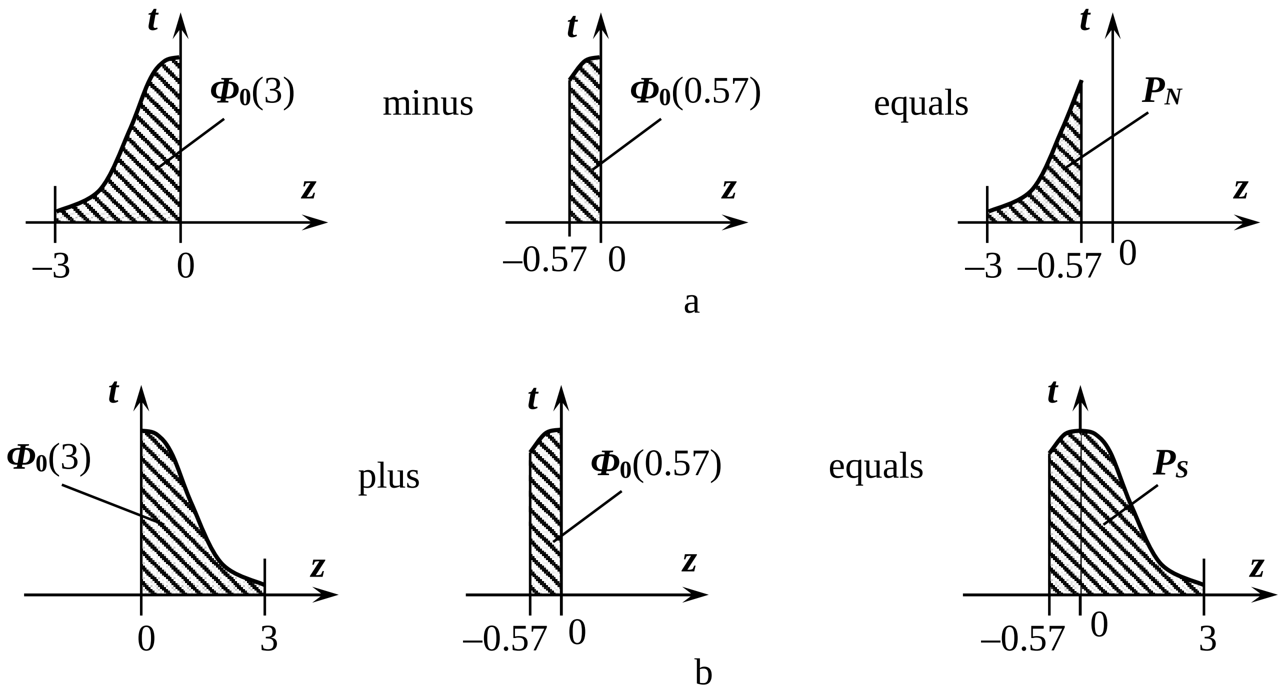


Fig. 4.6. Graphic illustration for calculations of quantities of interference P_N (a) and clearance P_S (b) joints for transition fit Ø160H7/k6 with boundary coordinate between clearances and interferences $z_{SN} = -0.57$

***The formulas above are valid for the considered fit* H7/k6**. If necessary modify these formulas for your individual task taking into account the following.

According to the properties of Laplace function it is odd function and hence $\Phi_0(-z) = -\Phi_0(z)$ at some *definite* **z** *value*.

On the other hand, the ***integral*** Laplace function $\Phi_0(z)$ is considered as an area under the curve of normalised function $t(z)$ in *definite range* of **z** argument (ref. Fig. 4.6). In this sense the area $\Phi_0(z)$ will be always positive even at *negative value* of argument **z**. Thus, in the range from 0 to +**z** the function $\Phi_0(z)$ value is positive

$$\Phi_0(z) = \int_0^z t(z)dz = \Phi_0(z)\Big|_0^z = \Phi_0(z) - \Phi_0(0) = \Phi_0(z) - 0 = \Phi_0(z)$$

and in the range from –**z** to 0 $\Phi_0(z)$ is also positive

$$\Phi_0(-z) = \int_{-z}^0 t(z)dz = \Phi_0(z)\Big|_{-z}^0 = \Phi_0(0) - \Phi_0(-z) = 0 + \Phi_0(z) = \Phi_0(z)$$

That is, in the sense of areas under the curve $\Phi_0(-z) = \Phi_0(z)$ (see Fig. 4.6).

Write down the calculated values P_N and P_S in the sketch (ref. Fig. 4.3).

4.11. Check the calculations results and plotted diagrams along all sheets, **put number of group, name and signature on each sheet**. Submit the CGP to teacher.

Appendix 1

DSTU 2500-94. Basic norms of interchangeability. Unified system of tolerances and fits. Terms and definitions. Designations and general norms (fragment)

Tables A.1.1, A.1.2 and A.1.3 contain numerical values of tolerances and basic deviations for dimensions up to 500 mm.

These data allow to apply the system without formulas and rules used for their determination.

The second deviation is calculated with aid of the basic deviation from the formulas:

- For shafts $ei = es - IT$ or $es = ei + IT$
- For holes $ES = EI + IT$ or $EI = ES - IT$.

Notes:

1. Shafts "js" and holes "Js" have no basic deviations. Both limit deviations are determined only from the tolerance ***IT*** for a certain accuracy grade.

2. Values of basic deviations are determined from the Tables A.1.2 and A.1.3.

3. Values of basic deviations for holes K, M, N from the 5th up to the 8th accuracy grade including and for holes from P to ZC from the 5th up to the 7th accuracy grade including for dimensions more than 3 mm are determined as specified in the Table A1.3, by adding of the Δ value submitted in the column of respective accuracy grade for the considered dimension interval. The value Δ is submitted in the right-hand columns of the Table A1.3. The value Δ is equal to difference ($IT_n - IT_{n-1}$) between tolerance of considered accuracy grade and tolerance of the nearest more precise accuracy grade.

Table A.1.1. Tolerance values, micrometer (fragment)

Accuracy grade		4	5	6	7	8	9	10	11	12	13	14	15	16
For dimension intervals, mm (above – up to)	Up to 3	3	4	6	10	14	25	40	60	100	140	250	400	600
	3 to 6	4	5	8	12	18	30	48	75	120	180	300	480	750
	6 to 10	4	6	9	15	22	36	58	90	150	220	360	580	900
	10 to 18	5	8	11	18	27	43	70	110	180	270	430	700	1100
	18 to 30	6	9	13	21	33	52	84	130	210	330	520	840	1300
	30 to 50	7	11	16	25	39	62	100	160	250	390	620	1000	1600
	50 to 80	8	13	19	30	46	74	120	190	300	460	740	1200	1900
	80 to 120	10	15	22	35	54	87	140	220	350	540	870	1400	2200
	120 to 180	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
	180 to 250	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
	250 to 315	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
	315 to 400	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
	400 to 500	20	27	40	63	97	155	250	400	630	970	1550	2500	4000

Notes. 1. For dimensions less than 1 mm the accuracy grades from 14 to 18 are not applied. 2. Accuracy grades 01, 0, 1, 2, 3, 17 and 18 are not shown.

Table A.1.2. Values of basic deviations for shafts, micrometer

Designation: Letter symbol	Upper deviation ***es***														
Letter symbol	a	b	c	cd	d	e	ef	f	fg	g	h	js*	j		
Accuracy grade	All accuracy grades												5, 6	7	8
For dimension intervals, mm (above – up to, including)															
Up to 3	–270	–140	–60	–34	–20	–14	–10	–6	–4	–2	0	Limit deviations ± ***IT***/ 2	–2	–4	–6
3 – 6	–270	–140	–70	–46	–30	–20	–14	–10	–6	–4	0		–2	–4	–
6 – 10	–280	–150	–80	–56	–40	–25	–18	–13	–8	–5	0		–2	–5	–
10 – 14	–290	–150	–95	–	–50	–32	–	–16	–	–6	0		–3	–6	–
14 – 18															
18 – 24	–300	–160	–110	–	–65	–40	–	–20	–	–7	0		–4	–8	–
24 – 30															
30 – 40	–310	–170	–120	–	–80	–50	–	–25	–	–9	0		–5	–10	–
40 – 50	–320	–180	–130												
50 – 65	–340	–190	–140	–	–100	–60	–	–30	–	–10	0		–7	–12	–
65 – 80	–360	–200	–150												
80 – 100	–380	–220	–170	–	–120	–72	–	–36	–	–12	0		–9	–15	–
100 – 120	–410	–240	–180												
120 – 140	–460	–260	–200	–	–145	–85	–	–43	–	–14	0		–11	–18	–
140 – 160	–520	–280	–210												
160 – 180	–580	–310	–230												
180 – 200	–660	–340	–240	–	–170	–100	–	–50	–	–15	0		–13	–21	–
200 – 225	–740	–380	–260												
225 – 250	–820	–420	–280												
250 – 280	–920	–480	–300	–	–190	–110	–	–56	–	–17	0		–16	–26	–
280 – 315	–1050	–540	–330												
315 – 355	–1200	–600	–360	–	–210	–125	–	–62	–	–18	0		–18	–28	–
355 – 400	–1350	–680	–400												
400 – 450	–1500	–760	–440	–	–230	–135	–	–68	–	–20	0		–20	–32	–
450 – 500	–1650	–840	–480												

Note. * Symmetric deviations ± IT/2 for j_S of accuracy grades from 7 to 11 can be rounded off, if the IT value is odd. Substitution is performed with the nearest smaller even number.

Table A.1.2, continued

Letter symbol	Lower deviation ***ei***															
	k		m	n	p	r	s	t	u	v	x	y	z	za	zb	zs
Accuracy grade	4 to 7	Up to 3 and above 7	All accuracy grades													
Up to 3	0	0	+2	+4	+6	+10	+14	–	+18	–	+20	–	+26	+32	+40	+60
3 – 6	+1	0	+4	+8	+12	+15	+19	–	+23	–	+28	–	+35	+42	+50	+80
6 – 10	+1	0	+6	+10	+15	+19	+23	–	+28	–	+34	–	+42	+52	+67	+97
10 – 14	+1	0	+7	+12	+18	+23	+28	–	+33	–	+40	–	+50	+64	+90	+130
14 – 18										+39	+45	–	+60	+77	+108	+150
18 – 24	+2	0	+8	+15	+22	+28	+35	–	+41	+47	+54	+63	+73	+98	+136	+188
24 – 30								+41	+48	+55	+64	+75	+88	+118	+160	+218
30 – 40	+2	0	+9	+17	+26	+34	+43	+48	+60	+68	+80	+94	+112	+148	+200	+274
40 – 50								+54	+70	+81	+97	+114	+136	+180	+242	+325
50 – 65	+2	0	+11	+20	+32	+41	+53	+66	+87	+102	+122	+144	+172	+226	+300	+405
65 – 80						+43	+59	+75	+102	+120	+146	+174	+210	+274	+360	+480
80 – 100	+3	0	+13	+23	+37	+51	+71	+91	+124	+146	+178	+214	+258	+335	+445	+585
100–120						+54	+79	+104	+144	+172	+210	+254	+310	+400	+525	+690
120–140	+3	0	+15	+27	+43	+63	+92	+122	+170	+202	+248	+300	+365	+470	+620	+800
140–160						+65	+100	+134	+199	+228	+280	+340	+415	+535	+700	+900
160–180						+68	+108	+146	+210	+252	+310	+380	+465	+600	+780	+1000
180–200	+4	0	+17	+31	+50	+77	+122	+166	+236	+284	+350	+425	+520	+670	+880	+1150
200–225						+80	+130	+180	+258	+310	+385	+470	+575	+740	+960	+1250
225–250						+84	+140	+196	+284	+340	+425	+520	+640	+820	+1050	+1350
250–280	+4	0	+20	+34	+56	+94	+158	+218	+315	+385	+475	+580	+710	+920	+1200	+1550
280–315						+98	+170	+240	+350	+425	+525	+650	+790	+1000	+1300	+1700
315–355	+4	0	+21	+37	+62	+108	+190	+268	+390	+475	+590	+730	+900	+1150	+1500	+1900
355–400						+114	+208	+294	+435	+530	+660	+820	+1000	+1300	+1650	+2100
400–450	+5	0	+23	+40	+68	+126	+232	+330	+490	+595	+740	+920	+1100	+1450	+1850	+2400
450–500						+132	+252	+360	+540	+660	+820	+1000	+1250	+1600	+2100	+2600

Table A.1.3. Values of basic deviations for holes, micrometer

Designation																	
Letter symbol	Lower deviation ***EI***												Upper deviation ***ES***				
	A	B	C	CD	D	E	EF	F	FG	G	H	J_S*	J			K	
Accuracy grade	All accuracy grades												6	7	8	Up to 8	Above 8
For dimension intervals, mm (above – up to including)																	
Up to 3	+270	+140	+60	+34	+20	+14	+10	+6	+4	+2	0	Limit deviations ± ***IT***/ 2	+2	+4	+6	0	0
3 – 6	+270	+140	+70	+46	+30	+20	+14	+10	+6	+4	0		+5	+6	+10	–1+***Δ***	–
6 – 10	+280	+150	+80	+56	+40	+25	+18	+13	+8	+5	0		+5	+8	+12	–1+***Δ***	–
10 – 14	+290	+150	+95	–	+50	+32	–	+16	–	+6	0		+6	+10	+15	–1+***Δ***	–
14 – 18																	
18 – 24	+300	+160	+110	–	+65	+40	–	+20	–	+7	0		+8	+12	+20	–2+***Δ***	–
24 – 30																	
30 – 40	+310	+170	+120	–	+80	+50	–	+25	–	+9	0		+10	+14	+24	–2+***Δ***	–
40 – 50	+320	+180	+130														
50 – 65	+340	+190	+140	–	+100	+60	–	+30	–	+10	0		+13	+18	+28	–2+***Δ***	–
65 – 80	+360	+200	+150														
80 – 100	+380	+220	+170	–	+120	+72	–	+36	–	+12	0		+16	+22	+34	–3+***Δ***	–
100–120	+410	+240	+180														
120–140	+460	+260	+200	–	+145	+85	–	+43	–	+14	0		+18	+26	+41	–3+***Δ***	–
140–160	+520	+280	+210														
160–180	+580	+310	+230														
180–200	+660	+340	+240	–	+170	+100	–	+50	–	+15	0		+22	+30	+47	–4+***Δ***	–
200–225	+740	+380	+260														
225–250	+820	+420	+280														
250–280	+920	+480	+300	–	+190	+110	–	+56	–	+17	0		+25	+36	+55	–4+***Δ***	–
280–315	+1050	+540	+330														
315–355	+1200	+600	+360	–	+210	+125	–	+62	–	+18	0		+29	+39	+60	–4+***Δ***	–
355–400	+1350	+680	+400														
400–450	+1500	+760	+440	–	+230	+135	–	+68	–	+20	0		+33	+43	+66	–5+***Δ***	–
450–500	+1650	+840	+480														

Note. * Symmetric deviations ± ***IT***/2 for J_S of accuracy grades from 7 to 11 can be rounded off, if the ***IT*** value is odd. Substitution is performed with the nearest smaller even number.

Table A.1.3, continued

Letter symbol	Upper deviation ***ES***										
	M		N		P to ZC	***Δ******					
Accuracy grade	Up to 8	Above 8	Up to 8	Above 8	Up to 7	3	4	5	6	7	8
Up to 3	–2	–2	–4	–4	Deviations equal to deviations of accuracy grades above 7 with adding ***Δ***	0					
3 – 6	–4+***Δ***	–4	–8+***Δ***	0		1	1.5	1	3	4	6
6 – 10	–6+***Δ***	–6	–10+***Δ***	0		1	1.5	2	3	6	7
10 – 14	–7+***Δ***	–7	–12+***Δ***	0		1	2	3	3	7	9
14 – 18											
18 – 24	–8+***Δ***	–8	–15+***Δ***	0		1.5	2	3	4	8	12
24 – 30											
30 – 40	–9+***Δ***	–9	–17+***Δ***	0		1.5	3	4	5	9	14
40 – 50											
50 – 65	–11+***Δ***	–11	–20+***Δ***	0		2	3	5	6	11	16
65 – 80											
80 – 100	–13+***Δ***	–13	–23+***Δ***	0		2	4	5	7	13	19
100–120											
120–140	–15+***Δ***	–15	–27+***Δ***	0		3	4	6	7	15	23
140–160											
160–180											
180–200	–17+***Δ***	–17	–31+***Δ***	0		3	4	6	9	17	26
200–225											
225–250											
250–280	–20** +***Δ***	–20	–34+***Δ***	0		4	4	7	9	20	29
280–315											
315–355	–21+***Δ***	–21	–37+***Δ***	0		4	5	7	11	21	32
355–400											
400–450	–23+***Δ***	–23	–40+***Δ***	0		5	5	7	13	23	34
450–500											

Notes: ** Particular case: for M6, K8 ***ES*** = –9 (but not –11) for dimensions of 250 to 315 mm.
*** For ***ES*** calculations of K, M, N up to accuracy grade 8 and of P to ZC up to accuracy grade 7 the values ***Δ*** are selected from the right-hand columns. For example, for P7 from 18 to 30 mm ***Δ*** = 8, hence ***ES*** = –14.

Table A.1.3, continued

Letter symbol	Upper deviation ***ES***											
	P	R	S	T	U	V	X	Y	Z	ZA	ZB	ZC
Accuracy grade	Above 7											
Up to 3	–6	–10	–14	–	–18	–	–20	–	–26	–32	–40	–60
3 – 6	–12	–15	–19	–	–23	–	–28	–	–35	–42	–50	–80
6 – 10	–15	–19	–23	–	–28	–	–34	–	–42	–52	–67	–97
10 – 14	–18	–23	–28	–	–33	–	–40	–	–50	–64	–90	–130
14 – 18						–39	–45	–	–60	–77	–108	–150
18 – 24	–22	–28	–35	–	–41	–47	–54	–63	–73	–98	–136	–188
24 – 30				–41	–48	–55	–44	–75	–88	–118	–160	–218
30 – 40	–26	–34	–43	–48	–60	–68	–80	–94	–112	–148	–200	–274
40 – 50				–54	–70	–81	–97	–114	–136	–180	–242	–325
50 – 65	–32	–41	–53	–66	–87	–102	–122	–144	–172	–226	–300	–405
65 – 80		–43	–59	–75	–102	–120	–146	–174	–210	–274	–360	–480
80 – 100	–37	–51	–71	–91	–124	–146	–178	–214	–258	–335	–445	–585
100–120		–54	–79	–104	–144	–172	–210	–254	–310	–400	–525	–690
120–140	–43	–63	–92	–122	–170	–202	–248	–300	–365	–470	–620	–800
140–160		–65	–100	–134	–190	–228	–280	–340	–415	–535	–700	–900
160–180		–68	–108	–146	–210	–252	–310	–380	–465	–600	–780	–1000
180–200	–50	–77	–122	–166	–236	–284	–350	–425	–520	–670	–880	–1150
200–225		–80	–130	–180	–258	–310	–385	–470	–575	–740	–960	–1250
225–250		–84	–140	–196	–284	–340	–425	–520	–640	–820	–1050	–1350
250–280	–56	–94	–158	–218	–315	–385	–475	–580	–710	–920	–1200	–1550
280–315		–98	–170	–240	–350	–425	–525	–650	–790	–1000	–1300	–1700
315–355	–62	–108	–190	–268	–390	–475	–590	–730	–900	–1500	–1500	–1900
355–400		–114	–208	–294	–435	–530	–660	–820	–1000	–1300	–1650	–2100
400–450	–68	–126	–232	–330	–490	–595	–740	–920	–1100	–1450	–1850	–2400
450–500		–132	–252	–360	–540	–660	–820	–1000	–1250	–1600	–2100	–2600

Appendix 2

GOST 25347-82. Basic norms of interchangeability. USTF. Tolerance bands and recommended fits (fragment)

Table A.2.1. Tolerance bands of shafts for nominal dimensions from 1 to 500 mm

Accuracy grade 6

Dimension interval, mm, above – up to, including	Tolerance bands										
	f6	g6	h6	js6	k6	m6	n6	p6	r6	s6	t6
	Limit deviations, micrometer										
From 1 up to 3	–6 –12	–2 –8	0 –6	+3.0 –3.0	+6 0	+8 +2	+10 +4	+12 +6	+16 +10	+20 +14	–
Above 3 up to 6	–10 –18	–4 –12	0 –8	+4.0 –4.0	+9 +1	+12 +4	+16 +8	+20 +12	+23 +15	+27 +19	–
6 – 10	–13 –12	–5 –14	0 –9	+4.5 –4.5	+10 +1	+15 +6	+19 +10	+24 +15	+28 +19	+32 +23	–
10 – 14	–16 –27	–6 –17	0 –11	+5.5 –5.5	+12 +1	+18 +7	+23 +12	+29 +18	+34 +23	+39 +28	–
14 – 18											
18 – 24	–20 –33	–7 –20	0 –13	+6.5 –6.5	+15 +2	+21 +8	+28 +15	+35 +22	+41 +28	+48 +35	–
24 – 30											+54 +41
30 – 40	–25 –41	–9 –25	0 –16	+8.0 –8.0	+18 +2	+25 +9	+33 +17	+42 +26	+50 +34	+59 +43	+64 +48
40 – 50											+70 +54
50 – 65	–30 –49	–10 –29	0 –19	+9.5 –9.5	+21 +2	+30 +11	+39 +20	+51 +32	+60 +41	+72 +53	+85 +66
65 – 80									+62 +43	+78 +59	+94 +75
80 – 100	–36 –58	–12 –34	0 –22	+11.0 –11.0	+25 +3	+35 +13	+45 +23	+59 +37	+73 +51	+93 +71	+113 +91
100 – 120									+76 +54	+101 +79	+126 +104
120 – 140	–43 –68	–14 –39	0 –25	+12.5 –12.5	+28 +3	+40 +15	+52 +27	+68 +43	+88 +63	+117 +92	+147 +122
140 – 160									+90 +65	+125 +100	+159 +134
160 – 180									+93 +68	+133 +108	+171 +146
180 – 200	–50 –79	–15 –44	0 –29	+14.5 –14.5	+33 +4	+46 +17	+60 +31	+79 +50	+106 +77	+151 +122	+195 +166
200 – 225									+109 +80	+159 +130	+209 +180
225 – 250									+113 +84	+169 +140	+225 +196
250 – 280	–56 –88	–17 –49	0 –32	+16.0 –16.0	+36 +4	+52 +20	+66 +34	+88 +56	+126 +94	+190 +158	+250 +218
280 – 315									+130 +98	+202 +170	+272 +240
315 – 355	–62 –98	–18 –54	0 –36	+18.0 –18.0	+40 +4	+57 +21	+73 +37	+98 +62	+144 +108	+226 +190	+304 +268
355 – 400									+150 +114	+244 +208	+330 +294

Dimension interval, mm, above – up to, including	Tolerance bands								
	e7	f7	h7	js7	k7	m7	n7	s7	u7
	Limit deviations, micrometer								
From 1 up to 3	–14 –24	–6 –16	0 –10	+5 –5	+10 0	–	+14 +4	+ 24 +14	+28 +18
Above 3 up to 6	–20 –32	–10 –22	0 –12	+6 –6	+13 +1	+16 +4	+20 +8	+31 +19	+35 +23
6 – 10	–25 –40	–13 –28	0 –15	+7 –7	+16 +1	+21 +6	+25 +10	+38 +23	+43 +28
10 – 14	–32 –50	–16 –34	0 –18	+9 –9	+19 +1	25 +7	+30 +12	+46 +28	+51 +33
14 – 18									
18 – 24	–40 –61	–20 –41	0 –21	+10 –10	+23 +2	+29 +8	+36 +15	+56 +35	+62 +41
24 – 30									+69 +48
30 – 40	–50 –75	–25 –50	0 –25	+12 –12	+27 +2	+34 +9	+42 +17	+68 +43	+85 +60
40 – 50									+95 +70
50 – 65	–60 –90	–30 –60	0 –30	+15 –15	+32 +2	+41 +11	+50 +20	+83 +53	+117 +87
65 – 80								+89 +59	+132 +102
80 – 100	–72 –107	–36 –71	0 –35	+17 –17	+38 +3	+48 +13	+58 +23	+106 +71	+159 +124
100 – 120								+114 +79	+179 +144
120 – 140	–85 –125	–43 –83	0 –40	+20 –20	+43 +3	+55 +15	+67 +27	+132 +92	+210 +170
140 – 160								+140 +100	+230 +190
160 – 180								+148 +108	+250 +210
180 – 200	–100 –146	–50 –96	0 –46	+23 –23	+50 +4	+63 +17	+77 +31	+168 +122	+282 +236
200 – 225								+176 +130	+304 +258
225 – 250								+186 +140	+330 +284
250 – 280	–110 –162	–56 –108	0 –52	+26 –26	+56 +4	+72 +20	+86 +34	+210 +158	+367 +315
280 – 315								+222 +170	+402 +350
315 – 355	–125 –182	–62 –119	0 –57	+28 –28	+61 +4	+78 +21	+94 +37	+247 +190	+447 +390
355 – 400								+265 +208	+492 +435

Dimension interval, mm, above – up to, including	Tolerance bands													
	c8	d8	e8	f8	h8	j_S8^x	u8	x8	z8	d9	e9	f9	h9	j_S9^x
	Limit deviations, micrometer													
From 1 up to 3	–60 –74	–20 –34	–14 –28	–6 –20	0 –14	+7 –7	+32 +18	+34 +20	+40 +26	–20 –45	–14 –39	–6 –31	0 –25	+12 –12
Above 3 up to 6	–70 –88	–30 –48	–20 –38	–10 –28	0 –18	+9 –9	+41 +23	+46 +28	+53 +35	–30 –60	–20 –50	–10 –40	0 –30	+15 –15
6 – 10	–80 –102	–40 –62	–25 –47	–13 –35	0 –22	+11 –11	+50 +28	+56 +34	+64 +42	–40 –76	–25 –61	–13 –49	0 –36	+18 –18
10 – 14	–95 –122	–50 –77	–32 –59	–16 –43	0 –27	+13 –13	+60 +33	+67 +40	+77 +50	–50 –93	–32 –75	–16 –59	0 –43	+21 –21
14 – 18								+72 +45	+87 +60					
18 – 24	–110 –143	–65 –98	–40 –73	–20 –53	0 –33	+16 –16	+74 +41	+87 +54	+106 +73	–65 –117	–40 –92	–20 –72	0 –52	+26 –26
24 – 30							+81 +48	+97 +64	+121 +88					
30 – 40	–120 –159	–80 –119	–50 –89	–25 –64	0 –39	+19 –19	+99 +60	+119 +80	+151 +112	–80 –142	–50 –112	–25 –87	0 –62	+31 –31
40 – 50	–130 –169						+109 +70	+136 +97	+175 +136					
50 – 65	–140 –186	–100 –146	–60 –106	–30 –76	0 –46	+23 –23	+133 +87	+168 +122	+218 +172	–100 –174	–60 –134	–30 –104	0 –74	+37 –37
65 – 80	–150 –196						+148 +102	+192 +146	+256 +210					
80 – 100	–170 –224	–120 –174	–72 –126	–36 –90	0 –54	+27 –27	+178 +124	+232 +178	+312 +258	–120 –207	–72 –159	–36 –123	0 –87	+43 –43
100 – 120	–180 –234						+198 +144	+264 +210	+364 +310					
120 – 140	–200 –263	–145 –208	–85 –148	–43 –106	0 –63	+31 –31	+233 +170	+311 +248	+428 +365	–145 –245	–85 –185	–43 –143	0 –100	+50 –50
140 – 160	–210 –273						+253 +190	+343 +280	+478 +415					
160 – 180	–230 –293						+273 +210	+373 +310	+528 +465					
180 – 200	–240 –312	–170 –242	–100 –172	–50 –122	0 –72	+36 –36	+308 +236	+422 +350	+592 +520	–170 –285	–100 –215	–50 –165	0 –115	+57 –57
200 – 225	–260 –332						+330 +258	+457 +385	+647 +575					
225 – 250	–280 –352						+366 +284	+497 +425	+712 +640					
250 – 280	–300 –381	–190 –271	–110 –191	–56 –137	0 –81	+40 –40	+396 +315	+556 +475	+791 +710	–190 –320	–110 –240	–56 –186	0 –130	+65 –65
280 – 315	–330 –411						+431 +350	+606 +525	+871 +790					

Accuracy grades from 10 to 12 **_Table A.2.1_, continued**

Dimension interval, mm, above – up to, including	Tolerance bands											
	d10	h10	j_S10^x	a11	b11	c11	d11	h11	j_S11^x	b12	h12	j_S12^x
	Limit deviations, micrometer											
From 1 up to 3	–20 –60	0 –40	+20 –20	–270 –330	–140 –200	–60 –120	–20 –80	0 –60	+30 –30	–140 –240	0 –100	+50 –50
Above 3 up to 6	–30 –78	0 –48	+24 –24	–270 –345	–140 –215	–70 –145	–30 –105	0 –75	+37 –37	–140 –260	0 –120	+60 –60
6 – 10	–40 –98	0 –58	+29 –29	–280 –370	–150 –240	–80 –170	–40 –130	0 –90	+45 –45	–150 –300	0 –150	+75 –75
10 – 14 14 – 18	–50 –120	0 –70	+35 –35	–290 –400	–150 –260	–95 –205	–50 –160	0 –110	+55 –55	–150 –330	0 –180	+90 –90
18 – 24 24 – 30	–65 –149	0 –84	+42 –42	–300 –430	–160 –290	–110 –240	–65 –195	0 –130	+65 –65	–160 –370	0 –210	+105 –105
30 – 40	–80 –180	0 –100	+50 –50	–310 –470	–170 –330	–120 –280	–80 –240	0 –160	+80 –80	–170 –420	0 –250	+125 –125
40 – 50				–320 –480	–180 –340	–130 –290				–180 –430		
50 – 65	–100 –220	0 –120	+60 –60	–340 –530	–190 –380	–140 –330	–100 –290	0 –190	+95 –95	–190 –490	0 –300	+150 –150
65 – 80				–360 –550	–200 –390	–150 –340				–200 –500		
80 – 100	–120 –260	0 –140	+70 –70	–380 –600	–220 –440	–170 –390	–120 –340	0 –220	+110 –110	–220 –570	0 –350	+175 –175
100 – 120				–410 –630	–240 –460	–180 –400				–240 –590		
120 – 140	–145 –305	0 –160	+80 –80	–460 –710	–260 –610	–200 –450	–145 –395	0 –250	+125 –125	–260 –660	0 –400	+200 –200
140 – 160				–520 –770	–280 –530	–210 –460				–280 –680		
160 – 180				–580 –830	–310 –560	–230 –480				–310 –710		
180 – 200	–170 –355	0 –185	+92 –92	–660 –950	–340 –630	–240 –530	–170 –460	0 –290	+145 –145	–340 –800	0 –460	+230 –230
200 – 225				–740 –1030	–380 –670	–260 –550				–380 –840		
225 – 250				–820 –1110	–420 –710	–280 –570				–420 –880		
250 – 280	–190 –400	0 –210	–105 –105	–920 –1240	–480 –800	–300 –620	–190 –510	0 –320	+160 –160	–480 –1000	0 –520	+260 –260
280 – 315				–1050 –1370	–540 –860	–330 –650				–540 –1060		
315 – 355	–210 –440	0 –230	–115 –115	–1200 –1560	–600 –960	–360 –720	–210 –570	0 –360	+180 –180	–600 –1170	0 –570	+285 –285
355 – 400				–1350 –1710	–680 –1040	–400 –760				–680 –1250		

Dimension interval, mm, above – up to, including	Tolerance bands									
	$h13^x$	j_s13^x	$h14^x$	j_s14^x	$h15^x$	j_s15^x	$h16^x$	j_s16^x	$h17^x$	j_s17^x
	Limit deviations, micrometer									
From 1 up to 3	0 –140	+70 –70	0 –250	+125 –125	0 –400	+200 –200	0 –600	+300 –300	0 –1000	+500 –500
Above 3 up to 6	0 –180	+90 –90	0 –300	+150 –150	0 –480	+240 –240	0 –750	+375 –375	0 –1200	+600 –600
6 – 10	0 –220	+110 –110	0 –360	+180 –180	0 –580	+290 –290	0 –900	+450 –450	0 –1500	+750 –750
10 – 14 14 – 18	0 –270	+135 –135	0 –430	+215 +215	0 –700	+350 –350	0 –1100	+550 –550	0 –1800	+900 –900
18 – 24 24 – 30	0 –330	+165 –165	0 –520	+260 –260	0 –840	+420 –420	0 –1300	+650 –650	0 –2100	+1050 –1050
30 – 40 40 – 50	0 –390	+195 –195	0 –620	+310 –310	0 –1000	+500 –500	0 –1600	+800 –800	0 –2500	+1250 –1250
50 – 65 65 – 80	0 –460	+230 –230	0 –740	+370 –370	0 –1200	+600 –600	0 –1900	+950 –950	0 –3000	+1500 –1500
80 – 100 100 – 120	0 –540	+270 –270	0 –870	+435 –435	0 –1400	+700 –700	0 –2200	+1100 –1100	0 –3500	+1750 –1750
120 – 140 140 – 160 160 – 180	0 –630	+315 –315	0 –1000	+500 –500	0 –1600	+800 –800	0 –2500	+1250 –1250	0 –4000	+2000 –2000
180 – 200 200 – 225 225 – 250	0 –720	+360 –360	0 –1150	+575 –575	0 –1850	+925 –925	0 –2900	+1450 –1450	0 –4600	+2300 –2300
250 – 280 280 – 315	0 –810	+405 –405	0 –1300	+650 –650	0 –2100	+1050 –1050	0 –3200	+1600 –1600	0 –5200	+2600 –2600
315 – 355 355 – 400	0 –890	+445 –445	0 –1400	+700 –700	0 –2300	+1150 –1150	0 –3600	+1800 –1800	0 –5700	+2850 –2850
400 – 450 450 – 500	0 –970	+485 –485	0 –1550	+775 –775	0 –2500	+1250 –1250	0 –4000	+2000 –2000	0 –6300	+3150 –3150

Notes:

1. □ – preferred tolerance bands (their designations are given in the rectangular frames).
2. ^{x} – tolerance bands are not assigned for fits, as a rule.

Table A2.2. Tolerance bands of holes for nominal dimensions from 1 to 500 mm

Accuracy grades 5 and 6

Dimension interval, mm, above – up to, including	Tolerance bands												
	G5	H5	J_S5	K5	M5	N5	G6	H6	J_S6	K6	M6	N6	P6
	Limit deviations, micrometer												
From 1 up to 3	+6 +2	+4 0	+2.0 –2.0	0 –4	–2 –6	–4 –8	+8 +2	+6 0	+3.0 –3.0	0 –6	–2 –8	–4 –10	–6 –12
Above 3 up to 6	+9 +4	+5 0	+2.5 –2.5	0 –5	–3 –8	–7 –12	+12 +4	+8 0	+4.0 –4.0	+2 –6	–1 –9	–5 –13	–9 –17
6 – 10	+11 +5	+6 0	+3.0 –3.0	+1 –5	–4 –10	–8 –14	+14 +5	+9 0	+4.5 –4.5	+2 –7	–3 –12	–7 –16	–12 –21
10 – 14 14 – 18	+14 +6	+8 0	+4.0 –4.0	+2 –6	–4 –12	–9 –17	+17 +6	+11 0	+5.5 –5.5	+2 –9	–4 –15	–9 –20	–15 –26
18 – 24 24 – 30	+16 +7	+9 0	+4.5 –4.5	+1 –8	–5 –14	–12 –21	+20 +7	+13 0	+6.5 –6.5	+2 –11	–4 –17	–11 –24	–18 –31
30 – 40 40 – 50	+20 +9	+11 0	+5.5 –5.5	+2 –9	–5 –16	–13 –24	+25 +9	+16 0	+8.0 –8.0	+3 –13	–4 –20	–12 –28	–21 –37
50 – 65 65 – 80	+23 +10	+13 0	+6.5 –6.5	+3 –10	–6 –19	–15 –28	+29 +10	+19 0	+9.5 –9.5	+4 –15	–5 –24	–14 –33	–26 –45
80 – 100 100 – 120	+27 +12	+15 0	+7.5 –7.5	+2 –13	–8 –23	–18 –33	+34 +12	+22 0	+11.0 –11.0	+4 –18	–6 –28	–16 –38	–30 –52
120 – 140 140 – 160 160 – 180	+32 +14	+18 0	+9.0 –9.0	+3 –15	–9 –27	–21 –39	+39 +14	+25 0	+12.5 –12.5	+4 –21	–8 –33	–20 –45	–36 –61
180 – 200 200 – 225 225 – 250	+35 +15	+20 0	+10.0 –10.0	+2 –18	–11 –31	–25 –45	+44 +15	+29 0	+14.5 –14.5	+5 –24	–8 –37	–22 –51	–41 –70
250 – 280 280 – 315	+40 +17	+23 0	+11.5 –11.5	+3 –20	–13 –36	–27 –50	+49 +17	+32 0	+16.0 –16.0	+5 –27	–9 –41	–25 –57	–47 –79
315 – 355 355 – 400	+43 +18	+25 0	+12.5 –12.5	+3 –22	–14 –39	–30 –55	+54 +18	+36 0	+18.0 –18.0	+7 –29	–10 –46	–26 –62	–51 –87
400 – 450 450 – 500	+47 +20	+27 0	+13.5 –13.5	+2 –25	–16 –43	–33 –60	+60 +20	+40 0	+20.0 –20.0	+8 –32	–10 –50	–27 –67	–55 –95

Dimension interval, mm, above – up to, including	F7	G7	H7	J_S7	K7	M7	N7	P7	R7	S7	T7
	Limit deviations, micrometer										
From 1 up to 3	+16 +6	+12 +2	+10 0	+5 –5	0 –10	–2 –12	–4 –14	–6 –16	–10 –20	–14 –24	–
Above 3 up to 6	+22 +10	+16 +4	+12 0	+6 –6	+3 –9	0 –12	–4 –16	–8 –20	–11 –23	–15 –27	–
6 – 10	+28 +13	+20 +5	+15 0	+7 –7	+5 –10	0 –15	–4 –19	–9 –24	–13 –28	–17 –32	–
10 – 14 14 – 18	+34 +16	+24 +6	+18 0	+9 –9	+6 –12	0 –18	–5 –23	–11 –29	–16 –34	–21 –39	–
18 – 24	+41 +20	+28 +7	+21 0	+10 –10	+6 –15	0 –21	–7 –28	–14 –35	–20 –41	–27 –48	–
24 – 30											–33 –54
30 – 40	+50 +25	+34 +9	+25 0	+12 –12	+7 –18	0 –25	–8 –33	–17 –42	–25 –50	–34 –59	–39 –64
40 – 50											–45 –70
50 – 65	+60 +30	+40 +10	+30 0	+15 –15	+9 –21	0 –30	–9 –39	–21 –51	–30 –60	–42 –72	–55 –85
65 – 80									–32 –62	–48 –78	–64 –94
80 – 100	+71 +36	+47 +12	+35 0	+17 –17	+10 –25	0 –35	–10 –45	–24 –59	–38 –73	–58 –93	–78 –113
100 – 120									–41 –76	–66 –101	–91 –126
120 – 140	+83 +43	+54 +14	+40 0	+20 –20	+12 –28	0 –40	–12 –52	–28 –68	–48 –88	–77 –117	–107 –147
140 – 160									–50 –90	–85 –125	–119 –159
160 – 180									–53 –93	–93 –133	–131 –171
180 – 200	+96 +50	+61 +15	+46 0	+23 –23	+13 –33	0 –46	–14 –60	–33 –79	–60 –106	–105 –151	–149 –195
200 – 225									–63 –109	–113 –159	–163 –209
225 – 250									–67 –113	–123 –169	–179 –225
250 – 280	+108 +56	+69 +17	+52 0	+26 –26	+16 –36	0 –52	–14 –66	–36 –88	–74 –126	–138 –190	–198 –250
280 – 315									–78 –130	–150 –202	–220 –272
315 – 355	+119 +62	+75 +18	+57 0	+28 –28	+17 –40	0 –57	–16 –73	–41 –98	–87 –144	–169 –226	–247 –304
355 – 400									–93 –150	–187 –244	–273 –330

Dimension interval, mm, above – up to, including	Tolerance bands													
	D8	E8	F8	H8	Js8	K8	M8	N8	U8	D9	E9	F9	H9	Js9[x]
	Limit deviations, micrometer													
From 1 up to 3	+34 +20	+28 +14	+20 +6	+14 0	+7 –7	0 –14	–	–4 –18	–18 –32	+45 +20	+39 +14	+31 +6	+25 0	+12 –12
Above 3 up to 6	+48 +30	+38 +20	+28 +10	+18 0	+9 –9	+5 –13	+2 –16	–2 –20	–23 –41	+60 +30	+50 +20	+40 +10	+30 0	+15 –15
6 – 10	+62 +40	+47 +25	+35 +13	+22 0	+11 –11	+6 –16	+1 –21	–3 –25	–28 –50	+76 +40	+61 +25	+49 +13	+36 0	+18 –18
10 – 14	+77 +50	+59 +32	+43 +16	+27 0	+13 –13	+8 –19	+2 –25	–3 –30	–33 –60	+93 +50	+75 +32	+59 +16	+43 0	+21 –21
14 – 18														
18 – 24	+98 +65	+73 +40	+53 +20	+33 0	+16 –16	+10 –23	+4 –29	–3 –36	–41 –74	+117 +65	+92 +40	+72 +20	+52 0	+26 –26
24 – 30									–48 –81					
30 – 40	+119 +80	+89 +50	+64 +25	+39 0	+19 –19	+12 –27	+5 –34	–3 –42	–60 –99	+142 +80	+112 +50	+87 +25	+62 0	+31 –31
40 – 50									–70 –109					
50 – 65	+146 +100	+106 +60	+76 +30	+46 0	+23 –23	+14 –32	+5 –41	–4 –50	–87 –133	+174 +100	+134 +60	+104 +30	+74 0	+37 –37
65 – 80									–102 –148					
80 – 100	+174 +120	+126 +72	+90 +36	+54 0	+27 –27	+16 –38	+6 –48	–4 –58	–124 –178	+207 +120	159 +72	+123 +36	+87 0	+43 –43
100 – 120									–144 –198					
120 – 140	+208 +145	+148 +85	+106 +43	+63 0	+31 –31	+20 –43	+8 –55	–4 –67	–170 –233	+245 +145	+185 +85	+143 +43	+100 0	+50 –50
140 – 160									–190 –253					
160 – 180									–210 –273					
180 – 200	+242 +170	+172 +100	+122 +50	+72 0	+36 –36	+22 –50	+9 –63	–5 –77	–236 –308	+285 +170	+215 +100	+165 +50	+115 0	+57 –57
200 – 225									–258 –330					
225 – 250									–284 –356					
250 – 280	+271 +190	+191 +110	+137 +56	+81 0	+40 40	+25 –56	+9 –72	–5 –86	–315 –396	+320 +190	+240 +110	+186 +56	+130 0	+65 –65
280 – 315									–350 –431					
315 – 355	+299 +210	+214 +125	+151 +62	+89 0	+44 –44	+28 –61	+11 –78	–5 –94	–390 –479	+350 +210	+265 +125	+202 +62	+140 0	+70 –70
355 – 400									–435 –524					

Dimension interval, mm, above – up to, including	D10	H10	J_S10^x	A11	B11	C11	D11	H11	J_S11^x	B12	H12	J_S12^x
	Limit deviations, micrometer											
From 1 up to 3	+60 +20	+40 0	+20 –20	+330 +270	+200 +140	+120 +60	+80 +20	+60 0	+30 –30	+240 +140	+100 0	+50 –50
Above 3 up to 6	+78 +30	+48 0	+24 –24	+345 +270	+215 +140	+145 +70	+105 +30	+75 0	+37 –37	+260 +140	+120 0	+60 –60
6 – 10	+98 +40	+58 0	+29 –29	+370 +280	+240 +150	+170 +80	+130 +40	+90 0	+45 –45	+300 +150	+150 0	+75 –75
10 – 14	+120 +50	+70 0	+35 –35	+400 +290	+260 +150	+205 +95	+160 +50	+110 0	+55 –55	+330 +150	+180 0	+90 –90
14 – 18												
18 – 24	+149 +65	+84 0	+42 –42	+430 +300	+290 +160	+240 +110	+195 +65	+130 0	+65 –65	+370 +160	+210 0	+105 –105
24 – 30												
30 – 40	+180 +80	+100 0	+50 –50	+470 +310	+330 +170	+280 +120	+240 +80	+160 0	+80 –80	+420 +170	+250 0	+125 –125
40 – 50				+480 +320	+340 +180	+290 +130				+430 +180		
50 – 65	+220 +100	+120 0	+60 –60	+530 +340	+380 +190	+330 +140	+290 +100	+190 0	+95 –95	+490 +190	+300 0	+150 –150
65 – 80				+550 +360	+390 +200	+340 +150				+500 +200		
80 – 100	+260 +120	+140 0	+70 –70	+600 +380	+440 +220	+390 +170	+340 +120	+220 0	+110 –110	+570 +220	+350 0	+175 –175
100 – 120				+630 +410	+460 +240	+400 +180				+590 +240		
120 – 140	+305 +145	+160 0	+80 –80	+710 +460	+510 +260	+450 +200	+395 +145	+250 0	+125 –125	+660 +260	+400 0	+200 –200
140 – 160				+770 +520	+530 +280	+460 +210				+680 +280		
160 – 180				+830 +580	+560 +310	+480 +230				+710 +310		
180 – 200	+355 +170	+185 0	+92 –92	+950 +660	+630 +340	+530 +240	+460 +170	+290 0	+145 –145	+800 +340	+460 0	+230 –230
200 – 225				+1030 +740	+670 +380	+550 +260				+840 +380		
225 – 250				+1110 +820	+710 +420	+570 +280				+880 +420		
250 – 280	+400 +190	+210 0	+105 –105	+1240 +920	+800 +480	+620 +300	+510 +190	+320 0	+160 –160	+1000 +480	+520 0	+260 –260
280 – 315				+1370 +1050	+860 +540	+650 +330				+1060 +540		
315 – 355	+440 +210	+230 0	+115 –115	+1560 +1200	+960 +600	+720 +360	+570 +210	+360 0	+180 –180	+1170 +600	+570 0	+285 –285
355 – 400				+1710 +1350	+1040 +680	+760 +400				+1250 +680		

Dimension interval, mm, above – up to, including	Tolerance bands									
	H13^x	J_S13^x	H14^x	J_S14^x	H15^x	J_S15^x	H16^x	J_S16^x	H17^x	J_S17^x
	Limit deviations, micrometer									
From 1 up to 3	+140 0	+70 –70	+250 0	+125 –125	+400 0	+200 –200	+600 0	+300 –300	+1000 0	+500 –500
Above 3 up to 6	+180 0	+90 –90	+300 0	+150 –150	+480 0	+240 –240	+750 0	+375 –375	+1200 0	+600 –600
6 – 10	+220 0	+110 –110	+360 0	+180 –180	+580 0	+290 –290	+900 0	+450 –450	+1500 0	+750 –750
10 – 14 14 – 18	+270 0	+135 –135	+430 0	+215 –215	+700 0	+350 –350	+1100 0	+550 –550	+1800 0	+900 –900
18 – 24 24 – 30	+330 0	+165 –165	+520 0	+260 –260	+840 0	+420 –420	+1300 0	+650 –650	+2100 0	+1050 –1050
30 – 40 40 – 50	+390 0	+195 –195	+620 0	+310 –310	+1000 0	+500 –500	+1600 0	+800 –800	+2500 0	+1250 –1250
50 – 65 65 – 80	+460 0	+230 –230	+740 0	+370 –370	+1200 0	+600 –600	+1900 0	+950 –950	+3000 0	+1500 –1500
80 – 100 100 – 120	+540 0	+270 –270	+870 0	+435 –435	+1400 0	+700 –700	+2200 0	+1100 –1100	+3500 0	+1750 –1750
120 – 140 140 – 160 160 – 180	+630 0	+315 –315	+1000 0	+500 –500	+1600 0	+800 –800	+2500 0	+1250 –1250	+4000 0	+2000 –2000
180 – 200 200 – 225 225 – 250	+720 0	+360 –360	+1150 0	+575 –575	+1850 0	+925 –925	+2900 0	+1450 –1450	+4600 0	+2300 –2300
250 – 280 280 – 315	+810 0	+405 –405	+1300 0	+650 –650	+2100 0	+1050 –1050	+3200 0	+1600 –1600	+5200 0	+2600 –2600
315 – 355 355 – 400	+890 0	+445 –445	+1400 0	+700 –700	+2300 0	+1150 –1150	+3600 0	+1800 –1800	+5700 0	+2850 –2850
400 – 450 450 – 500	+970 0	+485 –485	+1550 0	+775 –775	+2500 0	+1250 –1250	+4000 0	+2000 –2000	+6300 0	+3150 –3150

Notes:

1. ☐ – preferred tolerance bands (their designations are given in the rectangular frames)
2. ^{x} – tolerance bands are not assigned for fits, as a rule.

Table A.2.3. Recommended fits in system of hole at nominal dimensions from 1 to 500 mm

Basic holes	Basic deviations of shafts																			
	a	b	c	d	e	f	g	h	js	k	m	n	p	r	s	t	u	v	x	z
	Fits																			
H5							H5/g4	H5/h4	H5/js4	H5/k4	H5/m4	H5/n4								
H6						H6/f6	H6/g5	H6/h5	H6/js5	H6/k5	H6/m5	H6/n5	H6/p5	H6/r5	H6/s5					
H7			H7/c8	H7/d8	H7/e7; **H7/e8**	**H7/f7**	**H7/g6**	**H7/h6**	**H7/js6**	**H7/k6**	H7/m6	**H7/n6**	**H7/p6**	**H7/r6**	**H7/s6**; H7/s7	H7/t6	H7/u7			
H8			H8/c8	H8/d8	**H8/e8**	H8/f7; H8/f8		**H8/h7**; **H8/h8**	H8/js7	H8/k7	H8/m7	H8/n7			H8/s7		H8/u8		H8/x8	H8/z8
				H8/d9	H8/e9	H8/f9		H8/h9												
H9				**H9/d9**	H9/e8; H9/e9	H9/f8; H9/f9		H9/h8; H9/h9												
H10				H10/d10				H10/h9; H10/h10												
H11	H11/a11	H11/b11	H11/c11	**H11/d11**				**H11/h11**												
H12		H12/b12						H12/h12												

Note. ☐ – preferred fits.

Table A.2.4. Recommended fits in system of shaft at nominal dimensions from 1 to 500 mm

Basic shafts	Basic deviations of holes																
	A	B	C	D	E	F	G	H	Js	K	M	N	P	R	S	T	U
	Fits																
h4							$\frac{G5}{h4}$	$\frac{H5}{h4}$	$\frac{Js5}{h4}$	$\frac{K5}{h4}$	$\frac{M5}{h4}$	$\frac{N5}{h4}$					
h5						$\frac{F6}{h5}$	$\frac{G6}{h5}$	$\frac{H6}{h5}$	$\frac{Js6}{h5}$	$\frac{K6}{h5}$	$\frac{M6}{h5}$	$\frac{N6}{h5}$	$\frac{P6}{h5}$				
h6				$\frac{D8}{h6}$	$\frac{E8}{h6}$	$\frac{F7}{h6}$; $\boxed{\frac{F8}{h6}}$	$\frac{G7}{h6}$	$\boxed{\frac{H7}{h6}}$	$\boxed{\frac{Js7}{h6}}$	$\boxed{\frac{K7}{h6}}$	$\frac{M7}{h6}$	$\boxed{\frac{N7}{h6}}$	$\boxed{\frac{P7}{h6}}$	$\frac{R7}{h6}$	$\frac{S7}{h6}$	$\frac{T7}{h6}$	
h7				$\frac{D8}{h7}$	$\frac{E8}{h7}$	$\frac{F8}{h7}$		$\boxed{\frac{H8}{h7}}$	$\frac{Js8}{h7}$	$\frac{K8}{h7}$	$\frac{M8}{h7}$	$\frac{N8}{h7}$					$\frac{U8}{h7}$
h8				$\frac{D8}{h8}$; $\frac{D9}{h8}$	$\frac{E8}{h8}$; $\boxed{\frac{E9}{h8}}$	$\frac{F8}{h8}$; $\frac{F9}{h8}$		$\boxed{\frac{H8}{h8}}$; $\frac{H9}{h8}$									
h9				$\frac{D9}{h9}$; $\frac{D10}{h9}$	$\frac{E9}{h9}$	$\frac{F9}{h9}$		$\frac{H8}{h9}$; $\frac{H9}{h9}$; $\frac{H10}{h9}$									
h10				$\frac{D10}{h10}$				$\frac{H10}{h10}$									
h11	$\frac{A11}{h11}$	$\frac{B11}{h11}$	$\frac{C11}{h11}$	$\frac{D11}{h11}$				$\boxed{\frac{H11}{h11}}$									
h12		$\frac{B12}{h12}$						$\frac{H12}{h12}$									

Note. $\boxed{}$ – preferred fits.

Appendix 3

GOST 24853-81. Plain gauges for dimensions of up to 500 mm. Tolerances

(fragment)

A.3.1. Designations

D, ***d*** – nominal dimension of part
D_{min}, d_{min} – minimum limit dimension of part
D_{max}, d_{max} – maximum limit dimension of part
T – tolerance of part
H – tolerance for manufacture of work gauges hole
H_1 – tolerance for manufacture of work gauges for shaft
H_P – tolerance for manufacture of reference gauge for snap gauge
Z – deviation of tolerance band middle for manufacture of go-gauge for hole relative to minimum limit dimension of part
Z_1 – deviation of tolerance band middle for manufacture of go-gauge for shaft relative to maximum limit dimension of part
Y – permissible exceeding of dimension of worn go-gauge for hole over limit of part tolerance band
Y_1 – permissible exceeding of dimension of worn go-gauge for shaft over limit of part tolerance band

A.3.2. Diagrams of gauges tolerance bands

Gauge tolerance bands and deviations relative to tolerance bands of parts for holes of accuracy grades from 6 to 17 are shown in Fig. A.3.1.

Gauge tolerance bands and deviations relative to tolerance bands of parts for shafts of accuracy grades from 6 to 17 are shown in Fig. A.3.2.

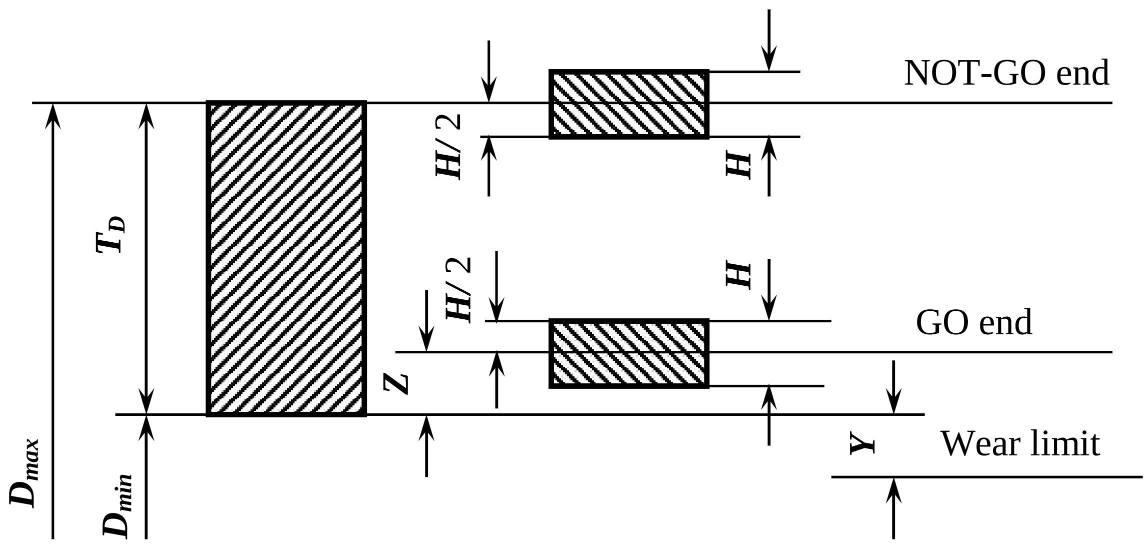


Fig. A.3.1. Tolerance bands of gauges for hole part

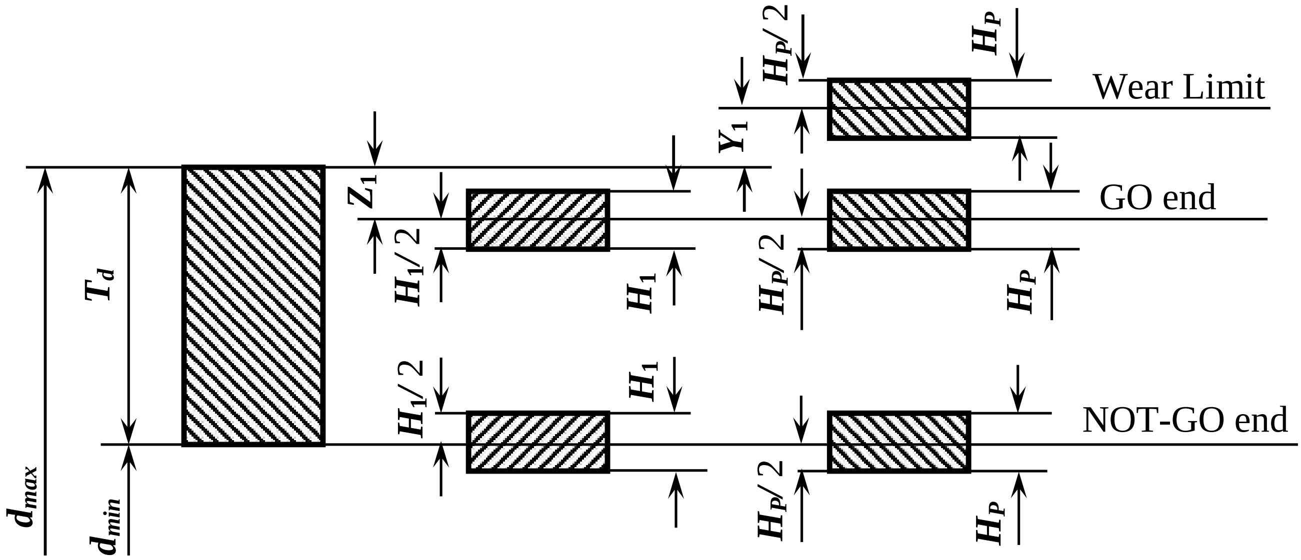


Fig. A.3.2. Tolerance bands of gauges for shaft part

A.3.3. Formulas for determination of executive dimensions of gauges

Table A.3.1

Gauge		Nominal dimension of part, mm			
		Up to 180			
		Work gauge		Reference gauge	
		Nominal dimension	Deviations	Nominal dimension	Deviations
For hole	GO new	$D_{min} + Z$	ï $\frac{H}{2}$	–	–
	GO worn	$D_{min} - Y$	–	–	–
	NOT-GO	D_{max}	ï $\frac{H}{2}$	–	–
For shaft	GO new	$d_{max} - Z_1$	ï $\frac{H_1}{2}$	$d_{max} - Z_1$	$\pm\frac{H_P}{2}$
	GO worn	$d_{max} + Y_1$	–	$d_{max} + Y_1$	$\pm\frac{H_P}{2}$
	NOT-GO	d_{min}	ï $\frac{H_1}{2}$	d_{min}	$\pm\frac{H_P}{2}$

Note. When calculating the executive dimensions of gauges it is necessary to apply the following rule for rounding-off:

- Rounding-off work gauges nominal dimensions (the maximum for holes and the minimum for shafts) for parts of 15 to 17 accuracy grades should be performed till round micrometer;
- For parts of 6 to 14 accuracy grades and for all reference gauges the gauge executive

dimensions should be rounded off till the values divisible by 0.5 µm with keeping the same value of gauge tolerance;
- Executive dimensions, which end in 0.25 and 0.75 µm, are rounded off to the values divisible by 0.5 µm with decrease of manufacture tolerance for a part.

A.3.4. Tolerances and deviations of gauges

Table A.3.2

Dimensions are in micrometers

Accuracy grade of part	Designation	Dimension interval, mm, above – up to, including									Tolerance for gauge form
		Up to 3	3 – 6	6 – 10	10 – 18	18 – 30	30 – 50	50 – 80	80 – 120	120 – 180	
6	Z	1	1.5	1.5	2	2	2.5	2.5	3	4	
	Y	1	1	1	1.5	1.5	2	2	3	3	
	Z_1	1.5	2	2	2.5	3	3.5	4	5	6	
	Y_1	1.5	1.5	1.5	2	3	3	3	4	4	
	H	1.2	1.5	1.5	2	2.5	2.5	3	4	5	IT1
	H_1	2	2.5	2.5	3	4	4	5	6	8	IT2
	H_P	0.8	1	1	1.2	1.5	1.5	2	2.5	3.5	IT1
7	Z, Z_1	1.5	2	2	2.5	3	3.5	4	5	6	
	Y, Y_1	1.5	1.5	1.5	2	3	3	3	4	4	
	H, H_1	2	2.5	2.5	3	4	4	5	6	8	IT2
	H_P	0.8	1	1	1.2	1.5	1.5	2	2	3.5	IT1
8	Z, Z_1	2	3	3	4	5	6	7	8	9	
	Y, Y_1	3	3	3	4	4	5	5	6	6	
	H	2	2.5	2.5	3	4	4	5	6	8	IT2
	H_1	3	4	4	5	6	7	8	10	12	IT3
	H_P	1.2	1.5	1.5	2	2.5	2.5	3	4	5	IT1
9, 10	Z, Z_1	5	6	7	8	9	11	13	15	18	
	Y, Y_1	0	0	0	0	0	0	0	0	0	
	H	2	2.5	2.5	3	4	4	5	6	8	IT2
	H_1	3	4	4	5	6	7	8	10	12	IT3
	H_P	1.2	1.5	1.5	2	2.5	2.5	3	4	5	IT1
11, 12	Z, Z_1	10	12	14	16	19	22	25	28	32	
	Y, Y_1	0	0	0	0	0	0	0	0	0	
	H, H_1	4	5	6	8	9	11	13	15	18	IT4
	H_P	1.2	1.5	1.5	2	2.5	2.5	3	4	5	IT1
13, 14	Z, Z_1	20	24	28	32	36	42	48	54	60	
	Y, Y_1	0	0	0	0	0	0	0	0	0	
	H, H_1	10	12	15	18	21	25	30	35	40	IT5
	H_P	2	2.5	2.5	3	4	4	5	6	8	IT2

Appendix 4

RECOMMENDATIONS
for selection of tolerances for form deviations and roughness for work surfaces of fixed gauges

Table A.4.1. Tolerances for form deviations of fixed gauges

Dimension intervals, mm		Accuracy grade of checked part								
		6		7		8–10		11–12		6–12
		Tolerance of gauge								
		H	***H_1***	***H***	***H_1***	***H***	***H_1***	***H***	***H_1***	***H_P***
		Tolerance of gauge form, micrometre								
Above	Up to	***IT1***	***IT2***				***IT3***	***IT4***		***IT1***
	3	0.8	1.2				2	3		0.8
3 –	10	1	1.5				2.5	4		1
10 –	18	1.2	2				3	5		1.2
18 –	30	1.5	2.5				4	6		1.5
30 –	50							7		
50 –	80	2	3				5	8		2
80 –	120	2.5	4				6	10		2.5
120 –	180	3.5	5				8	12		3.5

Table A.4.2. Numerical values of roughness parameter ***Ra*** for work surfaces of gauges

Gauge	Accuracy grade of checked part	***R_a***, micrometre, for dimensions	
		From 0.1 up to 100 mm	Above 100 up to 360 mm
- plug GO; NOT-GO	6	0.04	0.08
	7 ÷ 9	0.08	0.16
	10 ÷ 12	0.16	
	13 and above	0.32	0.32
- snap GO; NOT-GO	6 ÷ 9	0.08	0.16
	10 ÷ 12	0.16	
	13 and above	0.32	0.32
Reference plugs R-GO, R-W, R-NOT-GO	6 ÷ 9	0.04	0.08
	10 and above	0.08	0.16

Appendix 5

Numerical values of Laplace integral function *Φ₀(z)* and *t(z)* normalised function

$$\Phi_0(z) = \frac{1}{\sqrt{2\pi}} \int_0^z e^{-\frac{z^2}{2}} dz; \qquad t(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$$

z	*t(z)*	*Φ₀(z)*	*z*	*t(z)*	*Φ₀(z)*	*z*	*t(z)*	*Φ₀(z)*
0.00	0.39894	0.0000	**0.29**	0.3825	0.1141	**0.58**	0.3372	0.2190
0.01	0.39892	0.0040	**0.30**	0.3814	0.1179	**0.59**	0.3352	0.2224
0.02	0.39886	0.0080	**0.31**	0.3802	0.1217	**0.60**	0.3332	0.2257
0.03	0.39876	0.0120	**0.32**	0.3790	0.1255	**0.61**	0.3312	0.2291
0.04	0.39862	0.0160	**0.33**	0.3778	0.1293	**0.62**	0.3292	0.2324
0.05	0.39844	0.0199	**0.34**	0.3765	0.1331	**0.63**	0.3271	0.2257
0.06	0.39822	0.0239	**0.35**	0.3752	0.1368	**0.64**	0.3251	0.2389
0.07	0.39797	0.0279	**0.36**	0.3739	0.1406	**0.65**	0.3230	0.2422
0.08	0.39767	0.0319	**0.37**	0.3725	0.1443	**0.66**	0.3209	0.2454
0.09	0.39733	0.0359	**0.38**	0.3712	0.1480	**0.67**	0.3187	0.2486
0.10	0.3970	0.0398	**0.39**	0.3697	0.1517	**0.68**	0.3166	0.2517
0.11	0.3965	0.0438	**0.40**	0.3683	0.1554	**0.69**	0.3144	0.2549
0.12	0.3961	0.0478	**0.41**	0.3668	0.1591	**0.70**	0.3123	0.2580
0.13	0.3956	0.0517	**0.42**	0.3653	0.1628	**0.71**	0.3101	0.2611
0.14	0.3951	0.0557	**0.43**	0.3637	0.1664	**0.72**	0.3079	0.2642
0.15	0.3949	0.0596	**0.44**	0.3621	0.1700	**0.73**	0.3056	0.2673
0.16	0.3939	0.0636	**0.45**	0.3605	0.1736	**0.74**	0.3034	0.2703
0.17	0.3932	0.0675	**0.46**	0.3589	0.1772	**0.75**	0.3011	0.2734
0.18	0.3925	0.0714	**0.47**	0.3572	0.1808	**0.76**	0.2989	0.2764
0.19	0.3918	0.0753	**0.48**	0.3555	0.1844	**0.77**	0.2966	0.2794
0.20	0.3910	0.0793	**0.49**	0.3538	0.1879	**0.78**	0.2943	0.2823
0.21	0.3902	0.0832	**0.50**	0.3521	0.1915	**0.79**	0.2920	0.2852
0.22	0.3894	0.0871	**0.51**	0.3503	0.1950	**0.80**	0.2897	0.2881
0.23	0.3885	0.0910	**0.52**	0.3485	0.1985	**0.81**	0.2874	0.2910
0.24	0.3876	0.0948	**0.53**	0.3467	0.2019	**0.82**	0.2850	0.2939
0.25	0.3867	0.0987	**0.54**	0.3448	0.2054	**0.83**	0.2827	0.2967
0.26	0.3857	0.1026	**0.55**	0.3429	0.2088	**0.84**	0.2803	0.2995
0.27	0.3847	0.1064	**0.56**	0.3410	0.2123	**0.85**	0.2780	0.3023
0.28	0.3836	0.1103	**0.57**	0.3391	0.2157	**0.86**	0.2756	0.3051

Appendix 5, continued

z	$t(z)$	$\Phi_0(z)$	z	$t(z)$	$\Phi_0(z)$	z	$t(z)$	$\Phi_0(z)$
0.87	0.2732	0.3078	**1.19**	0.1965	0.3830	**1.51**	0.1276	0.4345
0.88	0.2709	0.3106	**1.20**	0.1942	0.3849	**1.52**	0.1257	0.4357
0.89	0.2685	0.3133	**1.21**	0.1919	0.3869	**1.53**	0.1238	0.4370
0.90	0.2661	0.3159	**1.22**	0.1895	0.3888	**1.54**	0.1219	0.4382
0.91	0.2639	0.3186	**1.23**	0.1872	0.3907	**1.55**	0.1200	0.4394
0.92	0.2613	0.3212	**1.24**	0.1849	0.3925	**1.56**	0.1182	0.4406
0.93	0.2589	0.3238	**1.25**	0.1826	0.3944	**1.57**	0.1163	0.4418
0.94	0.2565	0.3264	**1.26**	0.1804	0.3962	**1.58**	0.1145	0.4429
0.95	0.2541	0.3289	**1.27**	0.1781	0.3980	**1.59**	0.1127	0.4441
0.96	0.2516	0.3315	**1.28**	0.1758	0.3997	**1.60**	0.1109	0.4452
0.97	0.2492	0.3340	**1.29**	0.1736	0.4015	**1.61**	0.1092	0.4463
0.98	0.2468	0.3365	**1.30**	0.1714	0.4032	**1.62**	0.1074	0.4474
0.99	0.2444	0.3389	**1.31**	0.1691	0.4049	**1.63**	0.1057	0.4484
1.00	0.2420	0.3413	**1.32**	0.1669	0.4066	**1.64**	0.1040	0.4495
1.01	0.2396	0.3438	**1.33**	0.1647	0.4082	**1.65**	0.1023	0.4505
1.02	0.2371	0.3461	**1.34**	0.1626	0.4099	**1.66**	0.1006	0.4515
1.03	0.2347	0.3485	**1.35**	0.1604	0.4115	**1.67**	0.0989	0.4525
1.04	0.2323	0.3508	**1.36**	0.1582	0.4131	**1.68**	0.0973	0.4535
1.05	0.2299	0.3531	**1.37**	0.1561	0.4147	**1.69**	0.0957	0.4545
1.06	0.2275	0.3554	**1.38**	0.1539	0.4162	**1.70**	0.0940	0.4554
1.07	0.2251	0.3577	**1.39**	0.1518	0.4177	**1.71**	0.0925	0.4561
1.08	0.2227	0.3599	**1.40**	0.1497	0.4192	**1.72**	0.0909	0.4573
1.09	0.2203	0.3621	**1.41**	0.1476	0.4207	**1.73**	0.0893	0.4582
1.10	0.2179	0.3643	**1.42**	0.1456	0.4222	**1.74**	0.0878	0.4591
1.11	0.2155	0.3665	**1.43**	0.1435	0.4236	**1.75**	0.0863	0.4599
1.12	0.2131	0.3686	**1.44**	0.1415	0.4251	**1.76**	0.0848	0.4608
1.13	0.2108	0.3708	**1.45**	0.1394	0.4265	**1.77**	0.0833	0.4616
1.14	0.2083	0.3729	**1.46**	0.1374	0.4279	**1.78**	0.0818	0.4625
1.15	0.2059	0.3794	**1.47**	0.1354	0.4292	**1.79**	0.0804	0.4633
1.16	0.2036	0.3770	**1.48**	0.1334	0.4306	**1.80**	0.0790	0.4641
1.17	0.2012	0.3790	**1.49**	0.1315	0.4319	**1.81**	0.0775	0.4649
1.18	0.1989	0.3810	**1.50**	0.1295	0.4332	**1.82**	0.0761	0.4656

Appendix 5, continued

z	*t(z)*	*Φ₀(z)*	*z*	*t(z)*	*Φ₀(z)*	*z*	*t(z)*	*Φ₀(z)*
1.83	0.0748	0.4664	**2.16**	0.0387	0.4846	**2.66**	0.0116	0.4961
1.84	0.0734	0.4671	**2.18**	0.0371	0.4854	**2.68**	0.0110	0.4963
1.85	0.0721	0.4678	**2.20**	0.0355	0.4861	**2.70**	0.0104	0.4965
1.86	0.0707	0.4686	**2.22**	0.0339	0.4868	**2.72**	0.0099	0.4967
1.87	0.0694	0.4693	**2.24**	0.0325	0.4875	**2.74**	0.0093	0.4969
1.88	0.0691	0.4699	**2.26**	0.0310	0.4881	**2.76**	0.0088	0.4971
1.89	0.0669	0.4706	**2.28**	0.0297	0.4887	**2.78**	0.0084	0.4973
1.90	0.0656	0.4713	**2.30**	0.0283	0.4893	**2.80**	0.0079	0.4974
1.91	0.0644	0.4719	**2.32**	0.0270	0.4898	**2.82**	0.0075	0.4976
1.92	0.0632	0.4726	**2.34**	0.0258	0.4904	**2.84**	0.0071	0.4977
1.93	0.0620	0.4732	**2.36**	0.0246	0.4909	**2.86**	0.0067	0.4979
1.94	0.0608	0.4738	**2.38**	0.0235	0.4913	**2.88**	0.0063	0.4980
1.95	0.0596	0.4744	**2.40**	0.0224	0.4918	**2.90**	0.0060	0.4981
1.96	0.0584	0.4750	**2.42**	0.0213	0.4922	**2.92**	0.0056	0.4982
1.97	0.0573	0.4756	**2.44**	0.0203	0.4927	**2.94**	0.0053	0.4984
1.98	0.0562	0.4761	**2.46**	0.0194	0.4931	**2.96**	0.0050	0.4985
1.99	0.0551	0.4767	**2.48**	0.0184	0.4934	**2.98**	0.0047	0.4986
2.00	0.0540	0.4772	**2.50**	0.0175	0.4938	**3.00**	0.0044	0.49865
2.02	0.519	0.4783	**2.52**	0.0167	0.4941	**3.20**	0.0024	0.49931
2.04	0.0498	0.4793	**2.54**	0.0158	0.4945	**3.40**	0.0012	0.49966
2.06	0.0478	0.4803	**2.56**	0.0151	0.4948	**3.60**	0.0006	0.499841
2.08	0.0459	0.4812	**2.58**	0.0143	0.4951	**3.80**	0.0003	0.499928
2.10	0.0440	0.4821	**2.60**	0.0136	0.4953	**4.00**	0.00013	0.499968
2.12	0.0422	0.4830	**2.62**	0.0129	0.4956	**4.50**	0.000016	0.499997
2.14	0.0404	0.4838	**2.64**	0.0122	0.4959	**5.00**	0.0000015	0.499997

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