Metrology, standardization and certification

Theme 7: Example of calculation of dimensional chain by means of maximum-minimum method

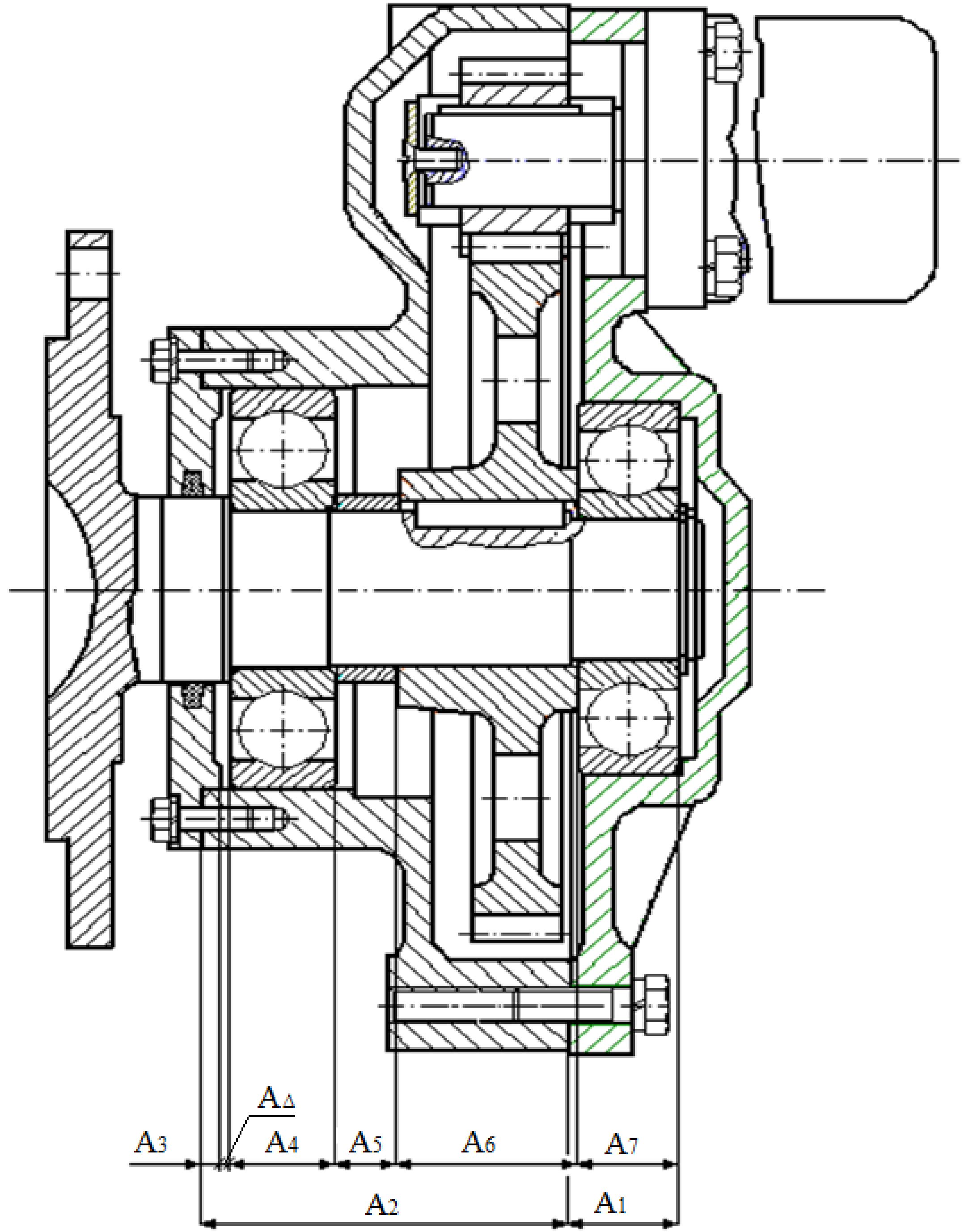
Lecture plan:

1. Formulation of the problem.
2. Determination of the grade of tolerance for component dimensions.
3. Checking of the equality and adjustment of tolerances.
4. Calculation of the coordinates of the middle of the tolerance zone for the resulting and all component dimensions except one.
5. Checking of the equalities.

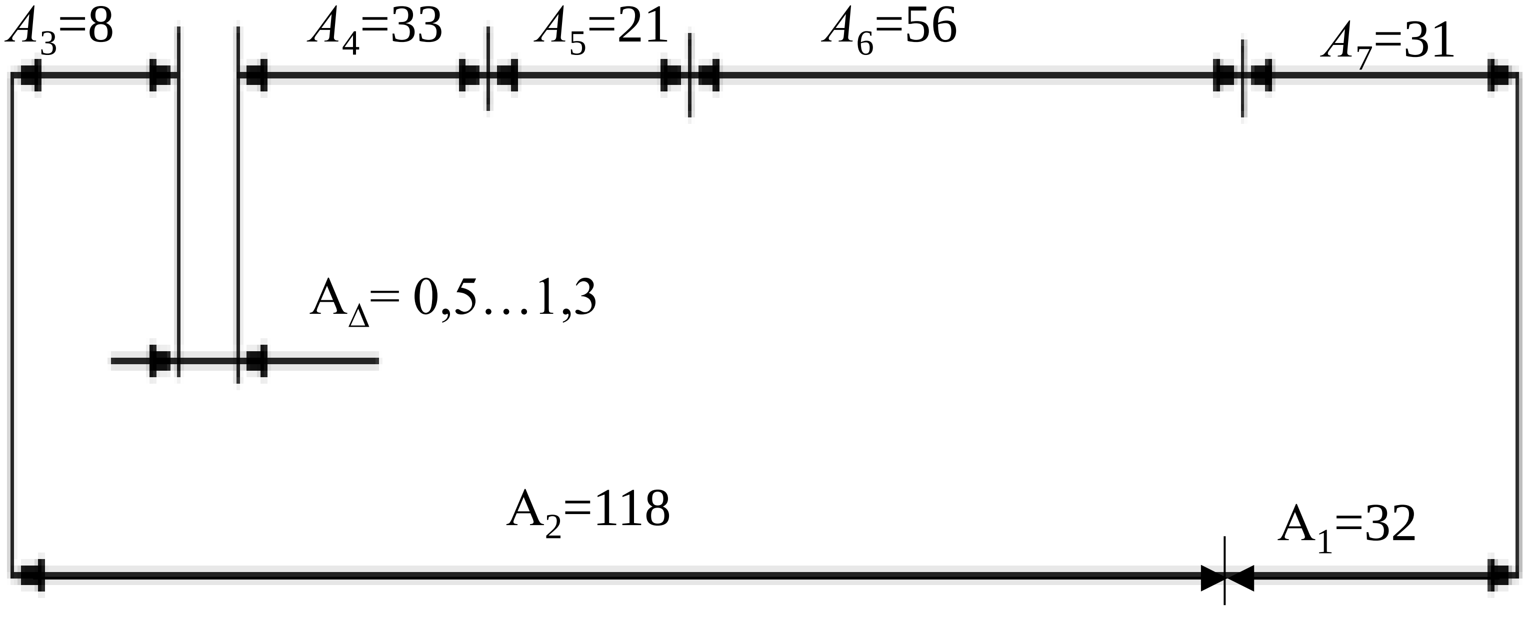
Formulation of the problem

Task: To determine the tolerances and deviations for component dimensions, if known their nominal dimensions, as well as the nominal dimension and tolerance of the resulting dimension $A\Delta$ = 0.5 ... 1.3 mm

Direct task (design stage)


AΔ
A3
A4
A5
A6
A7
A2
A1

Formulation of the problem



Determination of the grade of tolerance for the component dimensions

1. Dimensions A_4 and A_7 are the width of rolling bearings.
For A_4: D=140; d=65; B=33.   For A_7: D=130; d=60; B=31 [NSK CAT. No. E1102m, p. B12]
The tolerances on the width bearing ring are given in [NSK CAT. No. E1102m, p. A60 Table. 8.1.2].
Choose deviation from «Normal or 6» accuracy class: $A_4 = 33_{-0,150}$; $A_7 = 31_{-0,120}$.

2. Determine of the grade of tolerance for component dimensions:

TA = a · i.

$TA_\Delta = \Sigma\ TA_i = \Sigma\ a \cdot i$, as result: $\mathbf{a = TA_\Delta / \Sigma\ i}$

$$i = 0,45\sqrt[3]{A_i} + 0,001 \cdot A_i, \quad \mu\text{m}.$$

Determine the tolerance unit (i) for each size using the formula or choose value from the table 1.

Determination of the grade of tolerance for the component dimensions

Table 1

Range of sizes, mm	***i*, µm**
1… 3	0,55
3…6	0,73
6…10	0,90
10…18	1,08
18…30	1,31
30…50	1,56
50…80	1,80
80…120	2,17
120…180	2,52
180…250	2,90

$i_1 = 0,45\sqrt[3]{32} + 0,001 \cdot 32 = 1,461\ \mu m;$ $i_2 = 0,45\sqrt[3]{118} + 0,001 \cdot 118 = 2,325\ \mu\text{m};$

$i_3 = 0,45\sqrt[3]{8} + 0,001 \cdot 8 = 0,908\ \mu\text{m}.$ $i_5 = 0,45\sqrt[3]{21} + 0,001 \cdot 21 = 1,262\ \mu\text{m};$

$i_6 = 0,45\sqrt[3]{56} + 0,001 \cdot 56 = 1,777\ \mu\text{m}.$

For bearing [look ISO 286]:

i_4 = 150 / a(11)= 150/100 = 1,5 µm; i_7 = 120 / a(11) = 120/100 = 1,2 µm.

Determination of the grade of tolerance for the component dimensions

Determine the number of tolerance units "a" :

$a = 1000 \cdot (1{,}3-0{,}5) / (1.461 + 2.325 + 0.908 + 1.5 + 1.262 + 1.777 + 1.2) = 800 / 10.433 = 77.$

The resulting value is **a = 77** is between tabulated values **a = 64 (IT10)** and **a = 100 (IT11).** The nearest table value **a = 64**, which is set for 10 grade of tolerance [table 2], so the value of the tolerance of component dimensions is appointed as 10.

Table 2

Grade of tolerance (IT)	Number of tolerance units «a»
5	7
6	10
7	16
8	25
9	40
10	64
11	100
12	160
13	250
14	400
15	640

Checking of the equality and adjustment of tolerances

$TA_1 = 100$ µm; $TA_2 = 140$ µm; $TA_3 = 58$ µm; $TA_4 = 150$ µm; $TA_5 = 84$ µm; $TA_6 = 120$ µm; $TA_7 = 120$ µm.

Checking of the equality:

$$\mathbf{TA_{\Delta} = \Sigma\, TAi;}$$

$$1000 \cdot (1{,}3 - 0{,}5) = 100 + 140 + 58 + 150 + 84 + 120 + 120;$$

800 = 772 is not met (too low tolerances).

The equality is not met because the calculated value of the number of units of tolerance a=77 was rounded down to a=64, and tolerances are selected by grade of tolerance 10, corresponding to this indicator. As a result, assigned tolerances were too low. It is necessary to make a "willed" correction of the tolerances. Assign to the most sophisticated manufacturing units a less grade of tolerance. Or add to existing tolerance of one of the component dimensions the difference between (800 - 772 = 28 µm) and produce checking of the condition again. Tolerances on the width of the bearing rings are unchanged.

We add 28 mm to the tolerance for A_2 size, since this size is the most difficult to manufacture, then obtain: $TA_2 = 140 + 28 = 168$ µm.

Checking of the equality and adjustment of tolerances

Checking of the equality:

$$\mathbf{TA_\Delta = \Sigma TA_i}:$$

$$1000 \cdot (1,3 - 0,5) = 100+168+58+150+84+120+120;$$

$$800 = 800 \quad \text{is met.}$$

Then set the tolerances on all parts of the dimensional chain, depending on the type of size (external, internal or half open), except one A_5. It is recommended not to assign tolerance in the size of the part, which is the easiest to manufacture. Generally, tolerance is given in the "body" of the part, i.e, with the sign (-) for the shaft, and with a sign (+) for the hole and numerically equal to the tolerance. On the half-open sizes tolerances set symmetrically to the nominal size and numerically equal to half the value of tolerance with the sign (+), and half with the sign (-):

$$A_1 = 32 \pm 0,05; \; A_2 = 118_{-0,168}; \; A_3 = 8 \pm 0,029;$$

$$A_4 = 33_{-0,150}; \; A_6 = 56_{-0,120}; \; A_7 = 31_{-0,120}.$$

After this procedure, calculated nominal (basic) size of the resulting dimension:

$$A_{\Delta B} = \Sigma A_{IN(B)} - \Sigma A_{DE(B),}$$

$$A_{\Delta B} = (118+32) - (8+21+56+31+33) = 150 - 149 = 1 \text{ mm.}$$

$$A_{\Delta B} = 1 \text{ mm.}$$

Calculation of the coordinates of the middle of the tolerance zone for the resulting and all component dimensions except one

Set tolerances for A_Δ size, based on its size limits (A_Δ = 0.5 ... 1.3 mm)

$$A_\Delta = 1^{+0,3}_{-0,5}.$$

Then, to determine the coordinate for the middle of the tolerance zone for resulting dimension:

$C\Delta = [es(ES)\Delta + ei(EI)\Delta] / 2;$

$C\Delta = [0,3 + (–0,5)] / 2 = –0,1$

and coordinates of the midpoints of all tolerance zones for the component dimensions except one A5:

$Ci = [es(ES)i + ei(EI)i] / 2;$

$C1 = [0,5 + (–0,5)] / 2 = 0$ mm;

$C2 = [0 + (–0,168)] / 2 = –0,084$ mm;

$C3 = [0,29 + (–0,029)] / 2 = 0$ mm;

$C4 = [0 + (–0,150)] / 2 = –0,075$ mm;

$C6 = [0 + (–0,120)] / 2 = –0,060$ mm;

$C7 = [0 + (–0,120)] / 2 = –0,060$ mm.

Then we solve the equation with one unknown:

$C\Delta = \Sigma C\text{in} – \Sigma C\text{de};$

$C\Delta = (C1 + C2) – (C3 + C4 + C5 + C6 + C7)$

$–0,1 = [0 + (–0,084)] – [0 + (–0,075) + C5 + (–0,060) + (–0,60)]$

$C5 = 0,1 – 0,084 + 0,075 + 0,060 + 0,060$

$C5 = +0,211$ mm.

Set tolerance for A_5 size, based on the fact that the value of the tolerance of this component dimension is calculated earlier: TA_5 = 84 μm

$es(A_5) = C5 + TA_5/2;$ $ei(A_5) = C5 – TA_5/2.$

$es(A_5)$ $= +0,211 + 0,084/2 = +0,253$ мм; **$ei(A_5)$** $= +0,211 – 0,084/2 = +0,169$ mm.

$$A_5 = 21^{+0,253}_{+0,169}$$

Checking of the equalities

Because the A_5 size is external, so deviations should be assigned in the body of the part, i.e in (-). Therefore, A_5 size can be written as:

$$A_5 = 22^{-0{,}747}_{-0{,}831}$$

If the deviations and dimensional tolerances of the component dimensions are assigned correctly, the equalities must be satisfied:

$$A_{\Delta max} = \Sigma A_{in\_max} - \Sigma A_{de\_min};$$
$$A_{\Delta min} = \Sigma A_{in\_min} - \Sigma A_{de\_max}.$$

$A_{\Delta max}$=(32,050+118)–(7,971+32,850+21,169+55,880+30,880) = 1,3 mm;
$A_{\Delta min}$ = (31,950+117,832) – (8,029+33+21,253+56+31) = 0,5 mm.

Equalities are met.

Thank you for attention