Metrology, standardization and certification

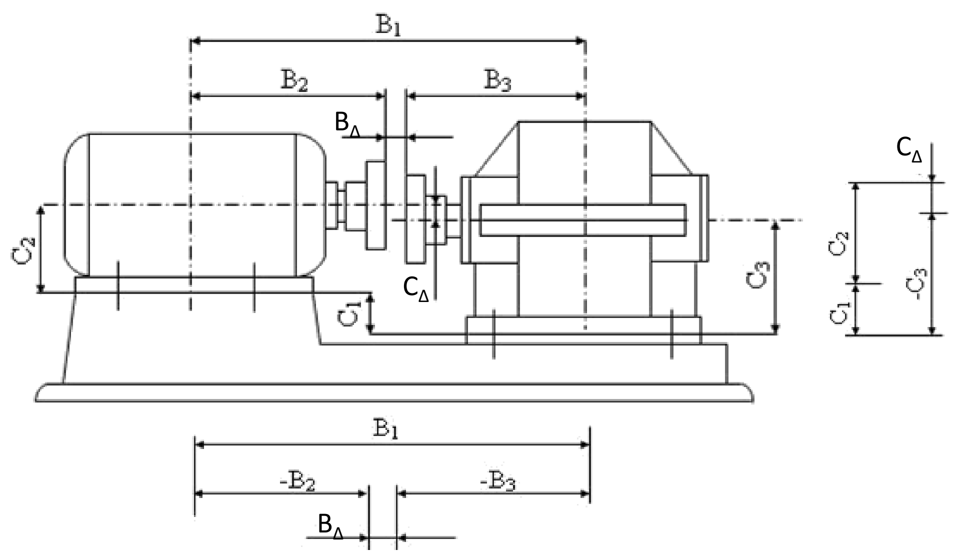
Theme 6: Calculation of dimensional chains

Lecture plan:

1. Tolerance analysis.
2. Basic concepts and methods of calculation.
3. Calculation of dimensional chain by maximum-minimum methods.

Tolerance analysis

Tolerance analysis is the term used to describe the study of accumulated variation in dimensions of components and assemblies. As every dimension is supposed to vary to some extent, i. e. tolerance, so when a set of components is assembled into a product, variation of the assembly dimension can be as high as the number of components involved. To ensure the required assembly parameters and prevent components from mutual interference or failure, the tolerance values for the components dimensions should be assigned wisely. For these purposes tolerance analysis methods are intended.

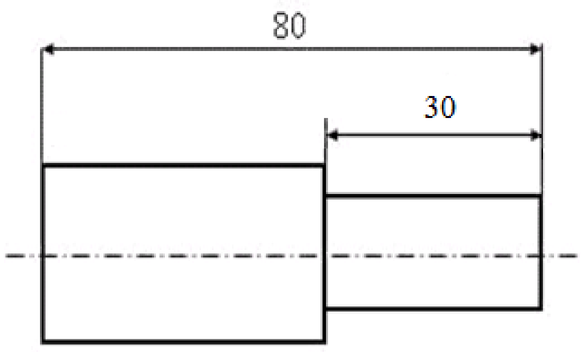


Assembly unit "engine-reducer" and schemes of dimension chains

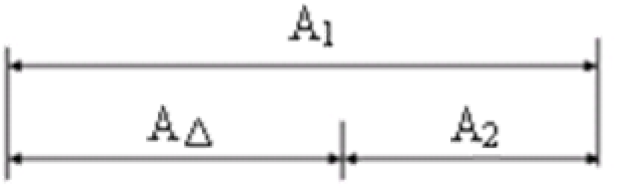
Basic concepts and methods of calculation

The sequence of dimensions that form a closed circuit is called as **dimension chain.** There are three types of the dimension chain: Linear, 2-D and 3-D.

We take into consideration a linear dimension chain.



Sketch of the detail



Dimension chain for the detail

Since the dimensions in a drawing never close a circuit into a chain, leaving the last dimension to be formed by itself during the assembly or machining process, the extra dimension is added to the dimensional sequence to make a loop. This extra dimension is called **resulting dimension** and is used to perform analysis.

The dimensions that constitute a chain are called **component dimensions,** and can be either **increasing** or **decreasing.**

In case of increasing the component dimension, the value of resulting dimension is increasing also. This component dimension is called **increasing dimension (A_1)**.

In case of increasing the component dimension, the value of resulting dimension is decreasing . This component dimension is called **decreasing dimension (A_2)**.

Basic concepts and methods of calculation

There are two types of tasks for the tolerance analysis:

1. **Direct task** (product design stage) consists in the calculation of the tolerances and limit of size for component dimension, with given basic sizes of the component dimension and the basic size and limit deviation of the resulting dimension .
2. **Inverse task** (product control stage) consists in the calculation of the basic size and limit deviations for the resulting dimension, with given basic sizes and limit deviations of the component dimensions.

According to GOST 16320-80 the following tolerance analysis methods are applied:

1. The complete interchangeability method (maximum-minimum method).
2. The incomplete interchangeability method (statistical method).
3. The method of group interchangeability.
4. The adjustment method.
5. The fitting method.

The complete interchangeability method

There are **two ways** of calculation the dimension chains.
First way is used then the sizes of the parts belong same dimensions range in the code tolerance system.

In this case the tolerances of component dimensions assign identical each other.
Value of each tolerance is calculated like a tolerance of the **resulting dimension** is divided into amount of **component dimensions** with out of **resulting dimension.**

$$\mathbf{TA_i = TA_\Delta / (m - 1)}$$

TA_i – tolerances of component dimensions ;
TA_Δ – tolerance of the resulting dimension ;
m – number of component dimensions.

After that the correction is performed. And the equality is verified.

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

Then the tolerances for all parts of the dimensional chain is set.
Generally, tolerances are given in the "body" parts, i.e, with the sign (-) for the shaft, and with a sign (+) for the holes and numerically equal the tolerance. For the half-open sizes the tolerances are set symmetrically to the nominal size and numerically equal to half the value of tolerance with the sign (+), and half with the sign (-).

The complete interchangeability method

Next the basic size of resulting dimension is calculated.

$$A_{\Delta B} = \Sigma A_{in(B)} - \Sigma A_{de(B)}$$

Finally the equalities are verified :

$$A_{\Delta}max = \Sigma A_{in}max - \Sigma A_{de}min \ ;$$
$$A_{\Delta}min = \Sigma A_{in}min - \Sigma A_{de}max,$$

If equalities are met, the calculation is over, otherwise it is necessary to continue the calculation.

It is necessary to determine the coordinates of the middle of the tolerance field for the resulting dimension:

$$C_{\Delta} = [\ es(ES)_{\Delta} + ei(EI)_{\Delta}] \ / \ 2 \ ,$$

and coordinates of the midpoints of tolerance fields of all component dimensions, except one:

$$Ci = [es(ES)_i + ei(EI)_i] \ / \ 2 \ .$$

Then the equation with one unknown is solved:

$$C_{\Delta} = \Sigma C_{in} - \Sigma C_{de}$$

and set the coordinate of the middle of the tolerance of the link, for which is not assigned a tolerance in the previous step calculation.

Finally, the correctness of the calculation is checked:

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

If equalities are met, then the task is solved correctly.

The complete interchangeability method

Second way is used then the sizes of the parts are not in a range of sizes. In this case you need to assign for all the dimensions the one grade of tolerances.

To determine the grade of tolerance is necessary to find the number of units of tolerance "a" characterizing a certain grade as:

$$\mathbf{TA = a \cdot i}$$

$$\mathbf{TA_{\Delta} = \Sigma TA_i = \Sigma\, a \cdot i,} \quad \text{then:}$$

$$\mathbf{a = TA_{\Delta} / \Sigma\, i\ ,}$$

i – unit of tolerance, μm;

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

Thus obtained, the number of unit of tolerance "a" in decision of particular task can be not match the value that is accepted in the standards for a grade of tolerance (see Tables 1 and 2). Nearest grade therefore is selected, in which the standard tolerances are appointed in accordance with the nominal sizes of component dimensions.

The complete interchangeability method

Then, the correction of tolerances for component dimensions is carried out.

If you chose a grade with more accuracy than turned on the calculation, the amount of tolerance units will be less than the tolerance of resulting dimension, and if was taken rougher grade, the amount of tolerance will be greater than the tolerance of resulting dimension.

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

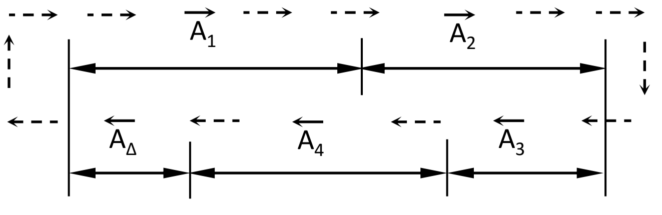
Range of size,mm	до 3	3…6	6…10	10…18	18…30	30…50	50…80	80…120	120…180	180…250
Value of tolerance units i, mm	0,55	0,73	0,90	1,08	1,31	1,56	1,80	2,17	2,52	2,90

The complete interchangeability method

For more complex in the manufacture of component dimensions are assigned large tolerances, and relatively simple - smaller. After adjustment is necessary to again carry out a verification calculation, i.e, make sure that the sum of the size tolerance of dimensional chain, is the resulting tolerance.

$$\mathbf{TA_{\Delta} = \Sigma TA_{i}}$$

Then, calculation is continuing in the same sequence as in the first way.



Scheme to detect the increasing and decreasing dimensions

Thank you for attention