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AUTOMATED DIMENSIONING OF ASSEMBLY STRUCTURES OF MACHINE TOOLS BY USING COMPENSATORS

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Abstract. *The article presents the results of the obtained dependencies for determination of the dimensions and the number of compensators in assembling units of machine tools. An algorithm for automated dimensioning with non-adjustable compensators has been developed.*
The non-adjustable compensators are parts that are pre-fabricated with different dimensions. In the assembly process, that one is used providing the set size of the initial link in the particular configuration of the constituent links. The initial conditions for dimensioning the compensator are the results of the constructive design of the assembly with CAD products. As a result of this design, the nominal dimensions of all the parts of structural consideration are determined and under the condition to achieve the nominal size of the initial link. The tolerances and limiting dimensions of the parts, excluding those of the compensator, are chosen by the designer-constructor according to the functional purpose of the parts and the technological capabilities of the methods for their manufacture. This does not require limitations of the dimensional analysis but functional and cost-effective accuracy of the parts is taken into account. Dimensioning is done by applying a series of procedures, which are discussed in detail in the paper and the number of compensators by groups is determined. Based on the applied procedures is proposed an algorithm for sizing the units of machine with non-adjustable compensators. The tolerance for manufacturing the compensators shall be symmetrical in relation to the nominal dimension. On the basis of the dependencies obtained for the dimensions and the distribution of the compensators in groups, an algorithm and software for automated dimensioning of the structures with non-adjustable compensators can be created.
Keywords: *CAD, dimensional analysis, dimensional chains, mechanical engineering.*

Introduction

With the high precision of the closing link and a large number of constituent links, it is economically unfeasible to assemble the machine tools by methods of complete or incomplete interchangeability, and by selecting the details. In these cases of medium and large series production assembly with

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compensators is applied. A characteristic feature in the use of compensators is that there is an initial link that is different from the closing link. This is the dimension that has to be provided by the assembly process, by changing the compensator's dimensions. Compensators are variable structure elements with variable dimensions – distance bushings, springs, plastic deformable parts, screw pairs, etc.

Exposition

The focus of attention of this article is assembly with non-adjustable compensators. These are parts that are pre-fabricated with different dimensions. In the assembly process, that one is used providing the set size of the initial link in the particular configuration of the constituent links (Georgiev, Lengerov, & Rachev, 2014).

The initial conditions for dimensioning the compensator are the results of the constructive design of the assembly with CAD products. As a result of this design, the nominal dimensions of all the parts of structural consideration are determined and under the condition to achieve the nominal size of the initial link (Hadzhiyski, Kaldashev, & Ostrev, 2015). The tolerances and limiting dimensions of the parts, excluding those of the compensator, are chosen by the designer-constructor according to the functional purpose of the parts and the technological capabilities of the methods for their manufacture. This does not require limitations of the dimensional analysis but functional and cost-effective accuracy of the parts is taken into account.

A. Algorithm for dimensioning units with compensators

Dimensioning is done by applying the following procedures:

1. Construct the size chain of the unit and determine the transmission coefficients ξ_i of the constituent links, including the initial link.
2. Distraction ω_Σ is determined of the dimension of the compensator:

$$\omega_\Sigma = \sqrt{\sum_{i=1}^{n} T_i^2}\,, \qquad (1)$$

where T_i - the tolerance of the constituent link with a sequential number i,
n - number of constituent links.

3. The number K is determined for the compensation groups (K >1 integer):

$$K_{calc} = \frac{\omega_{\Sigma}}{T_{initial} + T_{k,tech}}, \quad (2)$$

where $T_{k,tech}$ - the tolerance for manufacturing the compensators which is selected for technological reasons. It should be as smaller as possible than the initial link's tolerance $T_{initial}$.

The number of groups K is determined in such a way that the calculated number K_{calc} is rounded to an integer. In practice, this means recalculating the tolerance for manufacturing the compensator, to preserve the ratio:

$$K = \frac{\omega_{\Sigma}}{T_{initial} + T_k}, \quad (K > 1 \text{ integer}).$$

4. Design and technology analysis is performed if the number of compensator groups is $K > 4$. To reduce to $K \leq 4$ it is necessary either to increase the tolerance of the initial link or to reduce the tolerance for manufacturing the compensators. Where this is inappropriate, the use of non-adjustable compensators should be avoided and a constructive solution should be sought with adjustable compensators.
5. Recalculation of the tolerance of the compensator:

$$T_k = T_{initial} - \frac{\omega_{\Sigma}}{K}, \quad (3).$$

6. The media of the fields of tolerance are selected EM_i of the constituent links.

The following variants are used:

- with axial dimensions:

$$EM_i = 0, \quad (4)$$

- with external and internal dimensions:

$$EM_i = 0,5T_i\xi_i. \quad (5)$$

7. Calculate the mean of the tolerance field of the closing link:

$$EM_{\Sigma} = \sum_{i=1}^{n} \xi_i EM_i + \xi_{initial} EM_{initial}. \quad (6)$$

8. Calculate the smallest dimensions of the compensator as the size of the first group:

$$A_{k,1} = A_{\Sigma} + EM_{\Sigma} - 0,5\omega_{\Sigma}. \quad (7)$$

9. Calculate the dimensions of the following compensator groups:

$$A_{k,j} = A_{k,1} + (j-1)(T_{initial} - T_k), \ (j = 2, 3, \ldots, K). \quad (8)$$

10. The tolerance for manufacturing the compensators shall be symmetrical in relation to the nominal dimension:

$$A_{k,j} = A_{k,j} \pm 0,5T_k. \quad (9)$$

B. Determining the number of compensators by groups

When organizing the manufacturing process, it is necessary to plan the manufacturing of the necessary quantities of compensators of any standard size to ensure the assembling of the product without interruption of the manufacturing process (Georgiev, Kuzmanov, Salapateva, & Lengerov, 2006). Due to the large number of dimensional chain constituent links, the hypothesis that the scattering of the dimensions of the closing link is subject to the normal distribution law can be assumed. In this case, the polygon of the normal distribution law is divided into *K* intervals and the percentage of each interval (standard dimension) from the total number *N* is determined of the products (compensators).

The number of compensators in each of the groups is determined by the expression:

$$N_j = N\left[\Phi(t_{j+1}) + \Phi(t_j)\right], \quad (10)$$

where N_j - the number of compensators in the group with sequence number *j*,

N - the total number of compensators (the items planned for production),

Φ(*t*) - table values of the normalized normal distribution function.

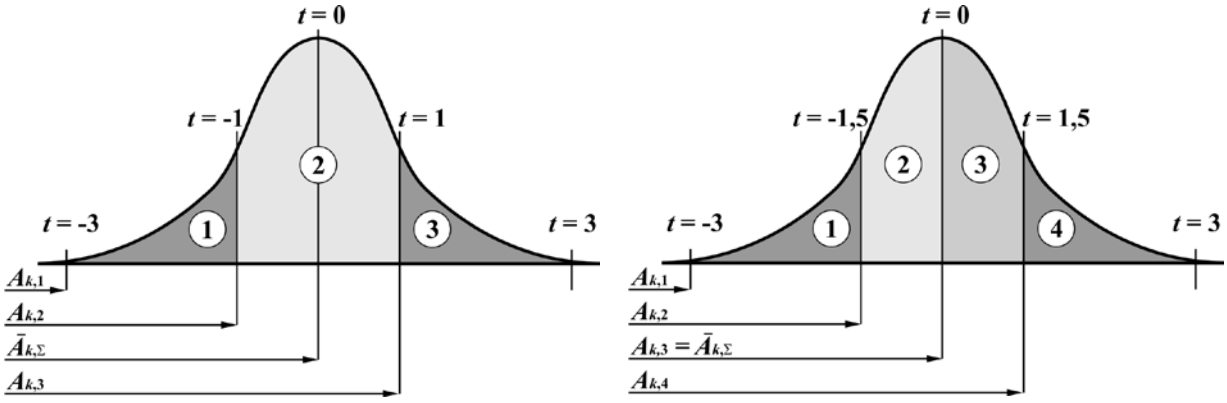
The parameters of the function Φ(*t*) are determined by the dimensions of the groups and the characteristics of the closing link:

$$t_j = \frac{A_{k,j} - \overline{A}_{\Sigma}}{\sigma_{\Sigma}}; \qquad t_{(j+1)} = \frac{A_{k,(j+1)} - \overline{A}_{\Sigma}}{\sigma_{\Sigma}}. \quad (11)$$

At: $\bar{A}_\Sigma = A_\Sigma + EM_\Sigma = A_{k,1} + 0,5\omega_\Sigma$ and $\sigma_\Sigma = \frac{\omega_\Sigma}{6}$ we obtain:

$$t_j = (j-1)\frac{6}{K} - 3. \qquad (12)$$

Figure 1 shows the distribution of the number of compensators by group, expressed as a percentage of the total number of items, $K = 3$ and $K = 4$.



a. $K = 3$; $N_1 = N_3 = 16\%$; $N_2 = 68\%$ *b*. $K = 4$; $N_1 = N_4 = 7\%$; $N_2 = N_3 = 43\%$

Figure 1 ***Distribution of the number of compensators in*** **3** ***and*** **4** ***groups***

The initial conditions for the algorithm's functioning are the data for: the initial link $A_{initial}$, $T_{initial}$, $EM_{initial}$; nominal dimensions A_i of the constituent links and A_Σ - of the closing link determined by the automated unit design; the tolerances chosen by the constructor T_i and mean deviations EM_i of the constituent links; the chosen tolerance $T_{k,tech}$ for manufacturing the compensators. The diagram of the algorithm is shown on Figure 2.

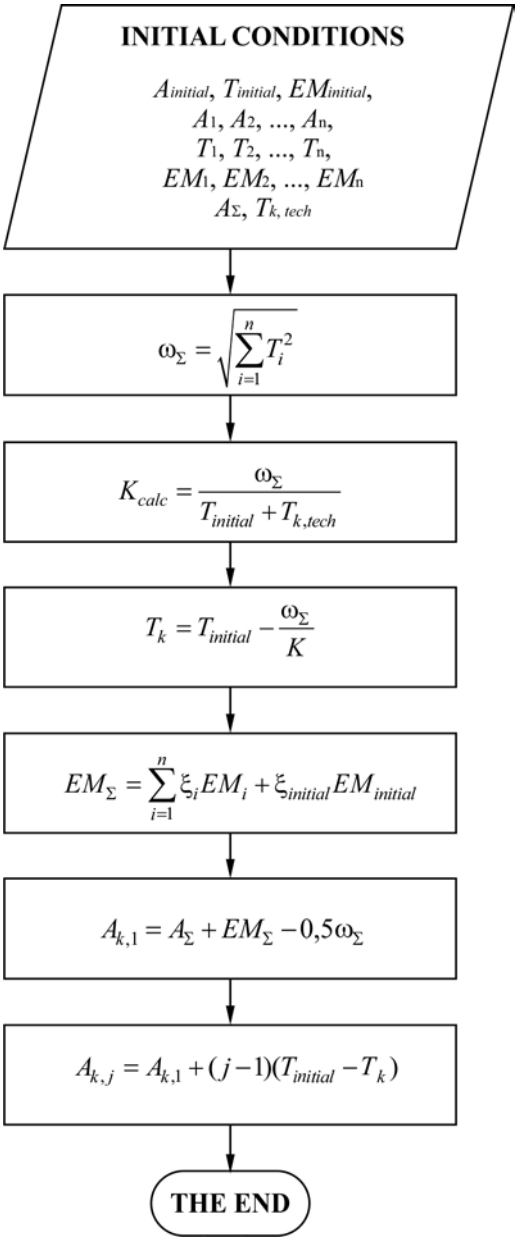


Figure 2 ***Algorithm for dimensioning units with non-adjustable compensators***

Conclusions

On the basis of the dependencies obtained for the dimensions and the distribution of the compensators in groups, an algorithm and specialized software for automated dimensioning of the structures of with non-adjustable compensators have been created.

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