

# Synthesis of optimal dimensional structure of the technological processes of machining

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**Abstract.** In this paper we consider the question of the creation of optimal processes using a many criteria of optimality. In the synthesis of machining technologies must take into account a great many factors (economic, temporal, technical, dimensional accuracy etc.) that influence on the output quality parameters of the process and is not only essential but also quite complex in the definition. Among the criteria of optimality can be noted a minimum number of operations in the technological process, of technological mounting, of operation elements in each operation, of elements in the technological dimension chains; of a minimum values of machining allowances (a minimum values of allowance's tolerances) etc. Is shown the necessity of ranking optimality criteria, and that the first criteria to be considered are a criteria directly related to the accuracy of machining. In the synthesis of the technological process must be taken into account the results of the previous operation for the next operation.

## 1. Introduction

Creating of effective machining technology from a technical and economic point of view is a complex task. The constructive requirements about the details (the form and structure of surfaces, the sizes and its accuracy and roughness, the technical requirements etc.) considering first of all functional requirements are accepted. From the point of view of technology, the common characteristics of the piece and of the technological system are of great importance, in particular their dimensional structures. For this reason, the designer makes constructive improvements to the parts regarding their adaptability to manufacturing and brings constructive modifications to the parts without affecting their functionality. This constructive improvement often leads to shortening the time for technological preparation of manufacture and the machining time itself, the time factor being decisive for efficiency of the manufacturing.

## 2. Optimality of the machining technologies

The modern technologies are based on the use of CNC machine-tools and machining centers so the dimensional and information discontinuities inherent in multi-operational technologies are gradually disappearing. In these conditions the main direction for optimization is the technological process with a minimum number of operations, the technological operation with a minimum number of technological mountings and a minimum number of operation elements. In this sense, there are significant examples of technologies based on the principle of centralization of processing performed by machining centres. The machine tool undergoes programmed morphological and structural transformations with the possibility of realizing of the various mechanical machining, of the heat



treatments, and lately also of the processes from the field of additive manufacturing. The technologies developed for machining centres are considered optimal if they contain 1 or 2 technological mountings, 1 or 2 operations and many technological elements executed by through various processing methods.

In the methodology of technological processes planning emphasis is placed to the problems on the optimality of tolerances allocation for each technological element and to the problems on the optimization of machining datum selection [1, 2, 3].

It is known that the mechanical machining process is considered optimum, if in the structure of all technological dimensional chains the number of the technological sizes is minimal [4]. This condition is respected if for each constructive size corresponds, within the technological dimensional chain, the unique technological size, and in dimensional chains for machining allowances, each machining allowance is determined by two technological sizes or one technological size and one size on blank. Otherwise the accuracy of technological sizes must be higher.

Solving the linear dimensional chains is usually done by method of the maximum-minimum  $\omega_{\Delta} = \omega_A + \omega_B$ . Here,  $\Delta$  - closing element of chain,  $A$  and  $B$  - elements of chain. It is demonstrated that exact solutions can be obtained taking into account compensation of the errors  $\omega^{comp}$ , thus

$\omega_{\Delta} = \omega_A + \omega_B - 2 \cdot \omega_{AB}^{comp}$ . The dimensional analyse for diameter sizes of cylindrical surfaces (the calculation of the allowance, the intermediate size etc.) is made in accordance with relation  $\omega_{\Delta} = \omega_A - \omega_B$  which reflects the generalized error's compensation. It is worth mentioning that in the case of linear dimensional chains there are more manifestations of the error compensation phenomenon than in the case of diametrical chains. Therefore the dimensional chain's analysis can be done with relation of the type  $\omega_{\Delta} = \omega_A \pm \omega_B$  (here and further on - "+" by the maximum-minimum solutions and "-" by solutions with generalized error's compensation).

The general direction of creation of optimum technological processes is the similarity of the graphs of the constructive and technological dimensional links [5]. Any deviation from the similarity of the above mentioned graphs results in the increase of the required accuracy for the technological sizes and/or the increase of the values of the machining allowances. In both cases, the probability of additional operational elements increases and the technology's degree of optimality decreases. To demonstrate these statements, we will analyze a series of examples that reflect various graphs of the constructive dimensional links and various graphs of the technological dimensional links (various technology variants for various constructive variants).

Example 1 (figure 1). The all constructive sizes are given from constructive base - surface 0 and the technological sizes are given also from locating datum surface (LDS) 0.

Conditions for ensuring the size's accuracy are optimal because the accuracy of technological sizes is not greater than accuracy of constructive sizes:  $\omega_{A_i^i} \leq \omega_{A_c^i}$ ,  $\omega_{B_i^i} \leq \omega_{B_c^i}$ ,  $\omega_{C_i^i} \leq \omega_{C_c^i}$ ,  $\omega_{E_i^i} \leq \omega_{E_c^i}$ .

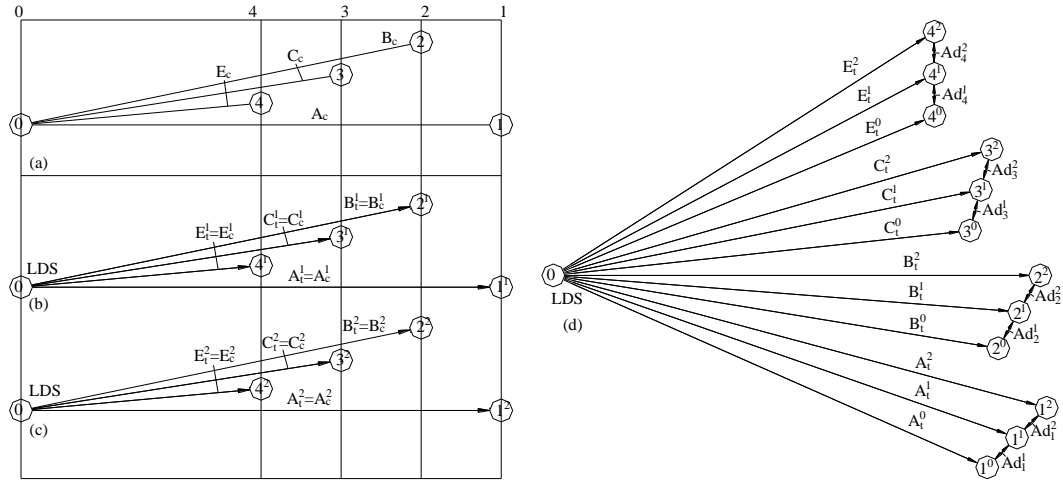
From figure 1(d) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_t^{i-1}} \pm \omega_{B_t^i})$ ,  $\omega_{Ad_3^1} = (\omega_{C_t^{i-1}} \pm \omega_{C_t^i})$ ,  $\omega_{Ad_4^1} = (\omega_{E_t^{i-1}} \pm \omega_{E_t^i})$ .

Example 2 (figure 2). A part of constructive sizes are given from constructive base - surface 0 and other part are given in chain from the surface 4. The technological sizes are given according to the same structure from locating datum surface 0 and from technological adjustment base (TAB) 4.

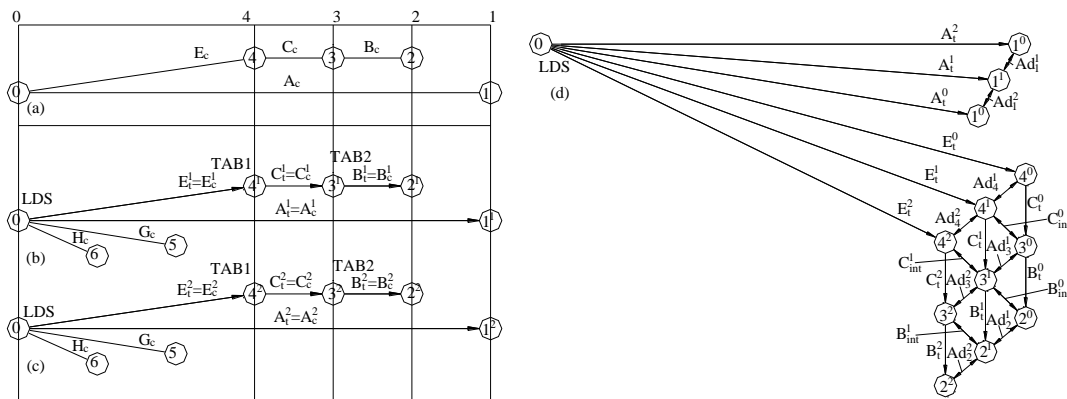
Conditions for ensuring the size's accuracy are optimal because the accuracy of technological sizes is not greater than accuracy of constructive sizes:  $\omega_{A_i^i} \leq \omega_{A_c^i}$ ,  $\omega_{B_i^i} \leq \omega_{B_c^i}$ ,  $\omega_{C_i^i} \leq \omega_{C_c^i}$ ,  $\omega_{E_i^i} \leq \omega_{E_c^i}$ .

From figure 2 (d) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_t^{i-1}} \pm \omega_{B_t^i}) + (\omega_{C_t^{i-1}} \pm \omega_{C_t^i}) + (\omega_{E_t^{i-1}} \pm \omega_{E_t^i})$ ,

$$\omega_{Ad_3^i} = (\omega_{C_{t-1}^i} \pm \omega_{C_t^i}) + (\omega_{E_{t-1}^i} \pm \omega_{E_t^i}), \omega_{Ad_4^i} = (\omega_{E_{t-1}^i} \pm \omega_{E_t^i}).$$



**Figure 1.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c) and machining allowances (d).



**Figure 2.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c) and machining allowances (d).

Example 3 (figure 3). One of constructive sizes is given from constructive base - surface 0 and the rest of the sizes are given from the surface 4. The machining is realized by technological sizes given from locating datum surface 0.

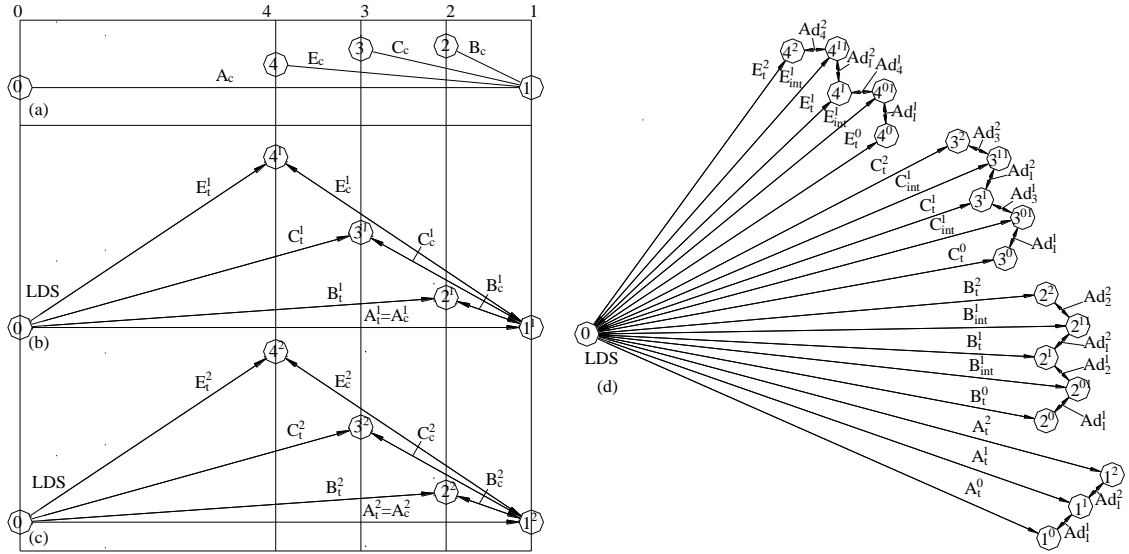
Conditions for ensuring the size's accuracy are not optimal because the accuracy of technological sizes is greater than the accuracy of constructive sizes:  $\omega_{A_t^i} \leq \omega_{A_c^i}$ ,  $\omega_{A_t^i} \pm \omega_{B_t^i} \leq \omega_{B_c^i}$ ,  $\omega_{A_t^i} \pm \omega_{C_t^i} \leq \omega_{C_c^i}$ ,

$$\omega_{A_t^i} \pm \omega_{E_t^i} \leq \omega_{E_c^i}.$$

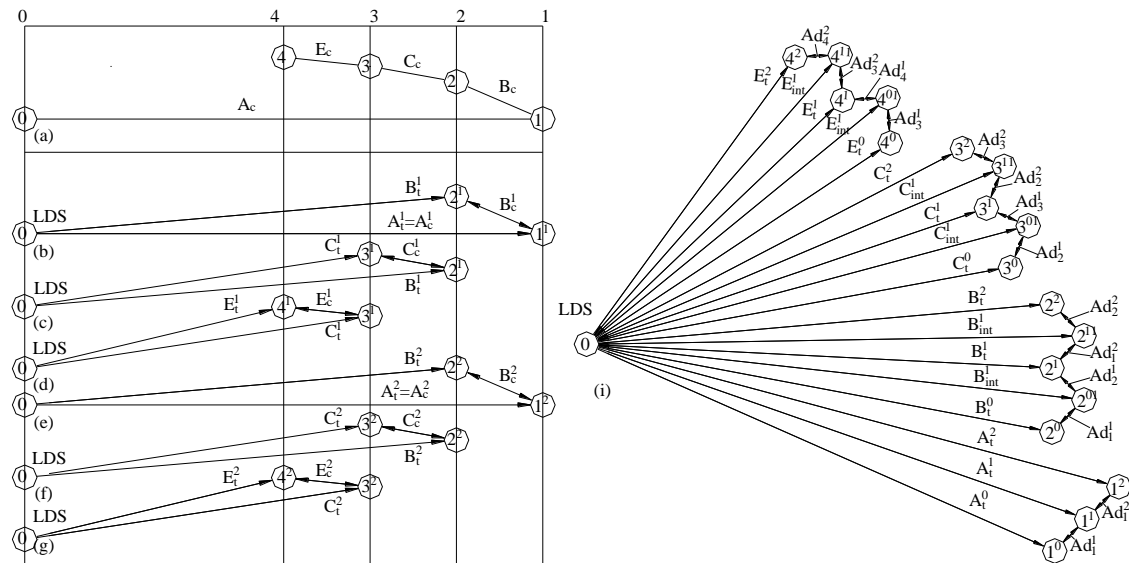
From figure 3 (d) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_{t-1}^i} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_{t-1}^i} \pm \omega_{B_t^i}) + (\omega_{A_{t-1}^i} \pm \omega_{A_t^i})$ ,

$$\omega_{Ad_3^i} = (\omega_{C_{t-1}^i} \pm \omega_{C_t^i}) + (\omega_{A_{t-1}^i} \pm \omega_{A_t^i}), \omega_{Ad_4^i} = (\omega_{E_{t-1}^i} \pm \omega_{E_t^i}) + (\omega_{A_{t-1}^i} \pm \omega_{A_t^i}).$$

Example 4 (figure 4). One of constructive sizes is given from constructive base - surface 0 and the rest of the sizes are given in chain from the surface 4. The machining is realized by technological sizes given from locating datum surface 0.



**Figure 3.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c) and machining allowances (d).



**Figure 4.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c, d, e, f, g) and machining allowances (i).

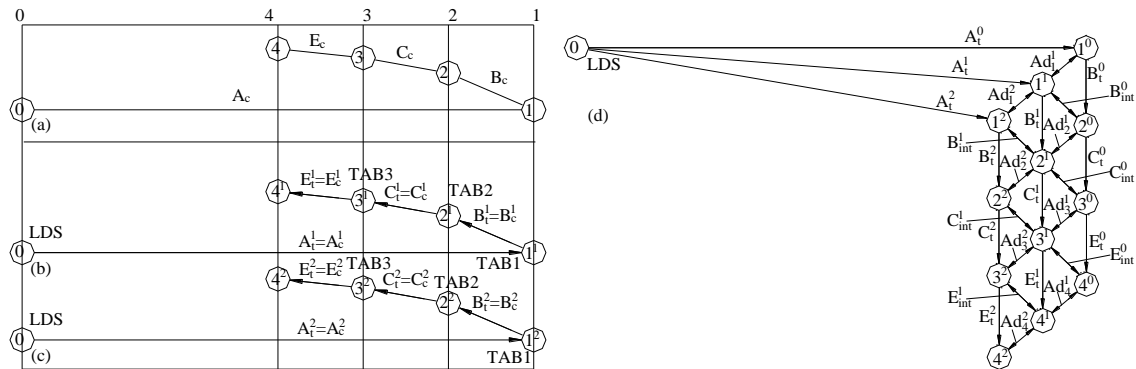
Conditions for ensuring the size's accuracy are not optimal because the accuracy of technological sizes is greater than the accuracy of constructive sizes:  $\omega_{A_i} \leq \omega_{A_c}$ ,  $\omega_{A_i} \pm \omega_{B_i} \leq \omega_{B_c}$ ,  $\omega_{B_i} \pm \omega_{C_i} \leq \omega_{C_c}$ ,

$$\omega_{C_i} \pm \omega_{E_i} \leq \omega_{E_c}.$$

From figure 4 (i) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_{t-1}^i} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_{t-1}^i} \pm \omega_{B_t^i}) + (\omega_{A_{t-1}^i} \pm \omega_{A_t^i})$ ,

$$\omega_{Ad_3^i} = (\omega_{C_{t-1}^i} \pm \omega_{C_t^i}) + (\omega_{B_{t-1}^i} \pm \omega_{B_t^i}), \quad \omega_{Ad_4^i} = (\omega_{E_{t-1}^i} \pm \omega_{E_t^i}) + (\omega_{C_{t-1}^i} \pm \omega_{C_t^i}).$$

Example 5 (figure 5). One of constructive sizes is given from constructive base - surface 0 and the rest of the sizes are given in chain from the surface 4. The machining is realized by technological sizes given from locating datum surface 0 and in chain from technological adjustment bases.



**Figure 5.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c) and machining allowances (d).

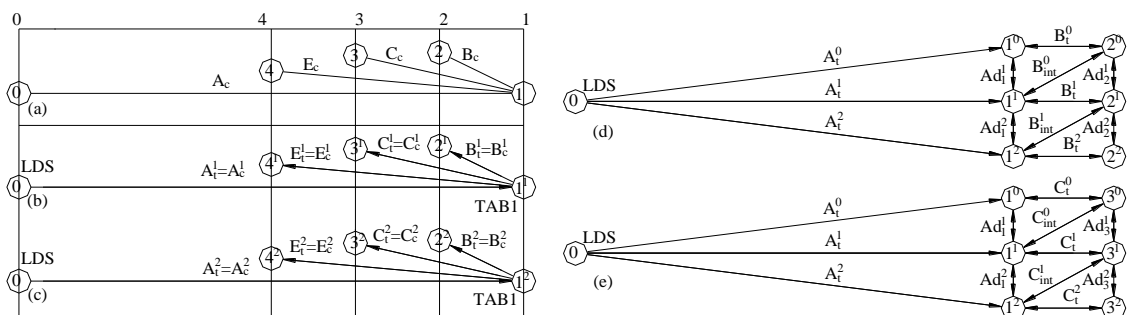
Conditions for ensuring the size's accuracy are optimal because the accuracy of technological sizes is not greater than accuracy of constructive sizes:  $\omega_{A_t^i} \leq \omega_{A_c^i}$ ,  $\omega_{B_t^i} \leq \omega_{B_c^i}$ ,  $\omega_{C_t^i} \leq \omega_{C_c^i}$ ,  $\omega_{E_t^i} \leq \omega_{E_c^i}$ .

From figure 5 (d) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_t^{i-1}} \pm \omega_{B_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,

$$\omega_{Ad_3^i} = (\omega_{C_t^{i-1}} \pm \omega_{C_t^i}) + (\omega_{B_t^{i-1}} \pm \omega_{B_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i}),$$

$$\omega_{Ad_4^i} = (\omega_{E_t^{i-1}} \pm \omega_{E_t^i}) + (\omega_{C_t^{i-1}} \pm \omega_{C_t^i}) + (\omega_{B_t^{i-1}} \pm \omega_{B_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i}).$$

Example 6 (figure 6). One of constructive sizes is given from constructive base - surface 0 and the rest of the sizes are given directly from the surface 4. The machining is realized by technological sizes given from locating datum surface 0 and from technological adjustment bases.



**Figure 6.** Example of the graphs of dimensional links for: constructive sizes (a), technological sizes (b, c) and machining allowances (d, e).

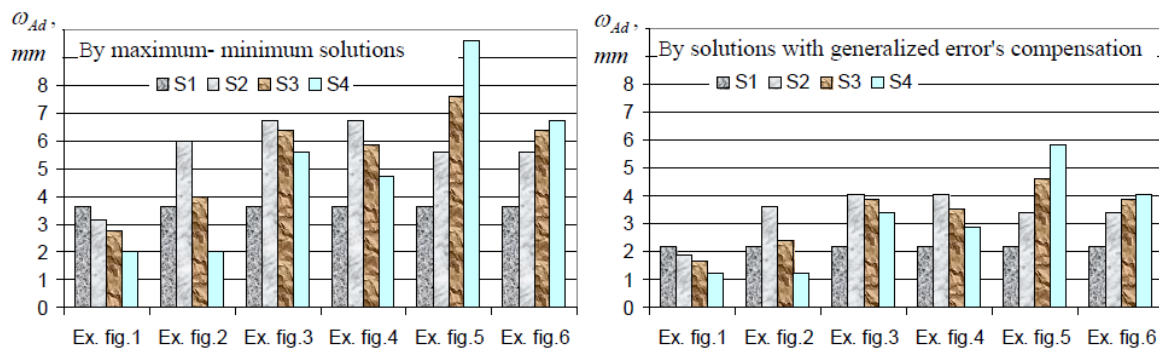
Conditions for ensuring the size's accuracy are optimal because the accuracy of technological sizes is not greater than accuracy of constructive sizes:  $\omega_{A_t^i} \leq \omega_{A_c^i}$ ,  $\omega_{B_t^i} \leq \omega_{B_c^i}$ ,  $\omega_{C_t^i} \leq \omega_{C_c^i}$ ,  $\omega_{E_t^i} \leq \omega_{E_c^i}$ .

From figure 6 (d, e) should be that the tolerances of machining allowances for surfaces 1, 2, 3 and 4 can be determined:  $\omega_{Ad_1^i} = (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,  $\omega_{Ad_2^i} = (\omega_{B_t^{i-1}} \pm \omega_{B_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i})$ ,

$$\omega_{Ad_3^i} = (\omega_{C_t^{i-1}} \pm \omega_{C_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i}), \quad \omega_{Ad_4^i} = (\omega_{E_t^{i-1}} \pm \omega_{E_t^i}) + (\omega_{A_t^{i-1}} \pm \omega_{A_t^i}).$$

The analysis of the graphs of dimensional links for machining allowances (figures 1 - 6) demonstrate that the tolerances of machining allowances are defined by the accuracy of the corresponding technological sizes at two consecutive stages of machining and by the accuracy of all similar pairs of sizes up to locating datum surface. In some cases, these values may be quite great.

The dimensional chains have been solved at the machining the front surfaces S1, S2, S3 and S4 with the positioning coordinates in relation to surface S0 respectively at 200, 150, 100 and 50 mm in all cases according to figures 1-6. The accuracy of the initial dimensions was taken at IT16 and the results obtained at IT13. The values of machining allowance's tolerances on the analyzed surfaces are given in figure 7. It can be seen that there are situations with fairly high values of the machining allowance's tolerances, consequently with fairly high values of the machining allowances.



**Figure 7.** The values of the machining allowances tolerance's for various constructive and technological variants according to figures 1 – 6.

### 3. Conclusions

The optimality of the machining technology is influenced by several factors and is assured at the general level by promoting the principle of processing's centralization. Structurally, optimality is ensured by the mutual approach of constructive and technological dimensional structures. In this process there are concurrent effects of increasing the accuracy of the technological sizes and of increasing the value of the machining allowances. Both factors must be taken into account at the same time. Solving the dimensional chains by the maximum-minimum method leads to exaggerated solutions regarding the accuracy of the technological sizes and the values of the machining allowances. Balanced solutions are obtained through the generalized method of error's compensation.

### 4. References

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