The dimensional design of machining technologies

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The dimensional design of machining technologies

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Abstract. In the paper we analyze the mutual influence of constructive and technological dimensional links on conditions of formation of the machining accuracy sizes. It is shown, that the formation the sizes from technological locating datum surface demands higher accuracy of the technological sizes, but in this case, the machining allowances are more stable. At the formation the sizes by the means of transitions from technological locating datum surface to adjustment surface, the accuracy sizes is achieved without necessity of increase of an accuracy of the technological sizes, but thus, it is observed a growth of tolerances of the machining allowances and decreasing of the accuracy if some surface will not be machined. The dimensional optimality is not characterized only by the number of technological sizes, but it is necessary to take into account the growth (sometimes complicated) of the technological sizes accuracy (a case of formation of the sizes as closing link of dimensional chains).

1. Introduction.

Designing of technological process of a detail's manufacturing is very responsible stage of works. From quality of designing of technological processes, from their depth of study in many cases respects efficiency of the manufacture, size of initial costs, and also costs connected with elimination of mistakes depends. The dimensional analysis takes a special place during designing technology, concerning the stage of designing, and also the stage of technological designing [1-4].

The nature of the constructive dimensional links is defined by the designer who takes into account the technological features of machine tools, but not in detriment of their functionality. Therefore, carrying out of the dimensional analysis on a joint of these two phases it is very important with the purpose of improvement of dimensional adaptability to manufacturing of made details.

One of most complicated problems during the elaboration of the manufacturing process is the synthesis of dimensional structure. It is necessary to execute not only dimensional analysis of a developed manufacturing process but also to achieve on this basis the optimum dimensional structure.

The dimensional analysis of the manufacturing process is a methodology which offers the possibility: to establish these links at the elaboration stage of the manufacturing process, to establish the accuracy of machining, to choose correctly the machine tool's accuracy after the accuracy of machining, to establish the accuracy norms for the technological device, permits to trace out the narrow places, makes the manufacturing processes to be well-balanced. At the same time, the tackling of the dimensional analysis problems is done on the special positions, especially regarding the mechanism of the accuracy assurance [2, 3]. It treats, first of all, the effect of compensation of machining errors, which allows with the greater reliability to evaluate the machining accuracy considering the phenomenon of errors compensation.

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2. The optimality of the machining technologies.

One of criteria of optimality of the technologies has a structural nature. The manufacturing process is considered optimum, if in the structure of all technological dimensional chains, the number of the technological sizes is minimum [2]. This condition is respected if for each constructive size there corresponds within the technological dimensional chain the unique technological size (figure 1), 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 (figure 2). The last has two technological sizes formed at the other phase of a manufacturing process.

The minimum possible number of the technological sizes $N_{T_{MIN}}$ is determined from the relation $N_{T_{MIN}} = N_C + 2 \cdot N_{Ad}$, where N_C - number of the constructive sizes, N_{Ad} - number of machining

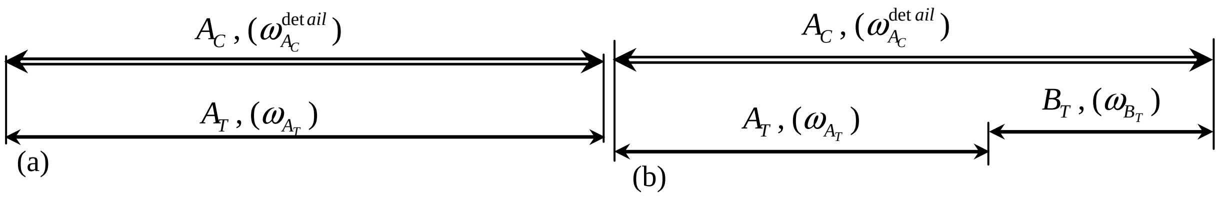

Figure 1. The constructive size is submitted: (a) - only by the technological size, $\omega_{A_C}^{\det ail} = \omega_{A_T}$; (b) - by the technological size and one (it is possible more) in already existing (historical) size, $\omega_{A_C}^{\det ail} = \omega_{A_T} + \omega_{B_T}$

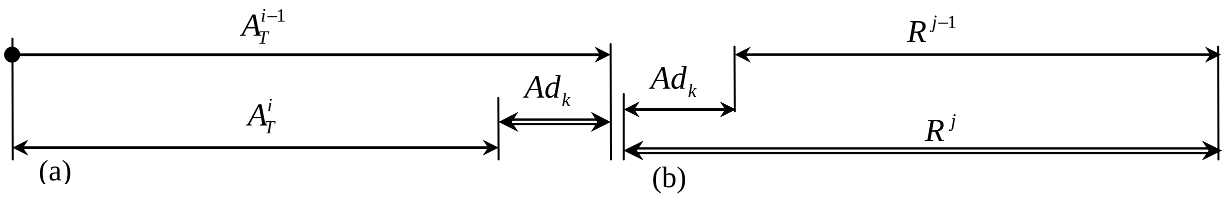

Figure 2. Two opportunities of transformation of the technological sizes: (a) - it is direct and under the control over technological base, $\omega_{Ad_k} = \omega_{Ad_T^{i-1}} + \omega_{A_T^i}$; (b) - it is not direct, as consequence of direct formation of other size, $\omega_{R^j} = \omega_{R^{j-1}} + \omega_{Ad_k}$.

allowances. The optimum manufacturing process becomes ideal, if each surface is processed only once, thus providing the final constructive size. It is necessary to note, that the dimensional optimality is not characterized only by the number N_T, but it is necessary to take into account the growth (sometimes complicated) of the technological sizes accuracy (a case of formation of the sizes as closing link of dimensional chains).

3. Interaction of the constructive and technological dimensional links.

During machining, the technological dimensional links are subordinated to constructive dimensional links, in a degree necessary for deriving on a detail the real sizes which are shaped within the limits of the appropriate tolerances. Thus it is insufficiently clear, the mechanism of formation of dimensional technological chain, the correlation of structures of dimensional constructive and technological links, the mechanism to form the favorable conditions of size’s accuracy assurance.

The setting-up size is formed as a closing link of the dimensional adjustment chain, the components and their structure depend on the way of adjustment. The adjustment size goes into, alongside with others, as a making link into the dimensional chain, closing size which is a technological size. Technological dimensional links reflect the technological opportunities of machine tools. In narrow sense, these technological opportunities are reduced to conditions of formation the linear, circular etc. distances - the sizes between a processed surface and technological locating datum surface or between two processed surfaces.

At its turn the technological sizes are links of a dimensional chain with the closing size – the derivative constructive size. The constructive sizes with the attributes (nominal, limit deviations) are present only on a drawing of a detail. The identical sizes on drawings of the blank during its transformation to a detail are derivatives constructive sizes and most frequently used as the closing sizes, substituted by the technological sizes.

It represents an interest to evaluate the conditions of accuracy sizes formation depending on structures of dimensional constructive and technological links. There were analyzed examples of details machining with different constructive dimensional links (figure 3) with a formation of the sizes from technological locating datum surface and from adjustment surfaces.

The formation of the sizes from technological locating datum surface is submitted on figure 4.

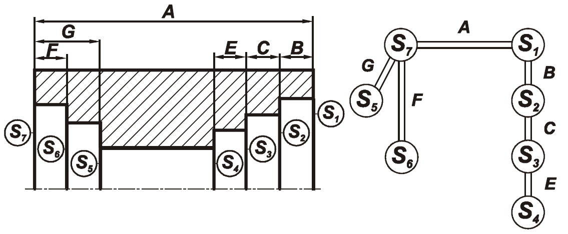

Figure 3. Example of constructive variants of mashined details and the appropriate structures of the dimensional technological links

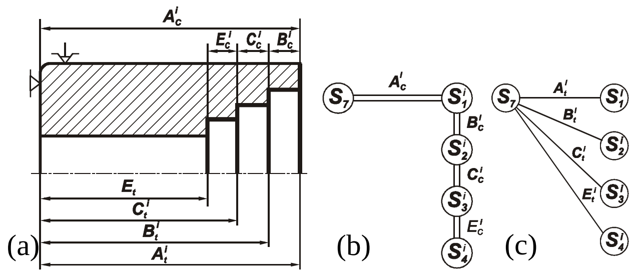

Figure 4. Formation of the sizes from technological locating datum surface. (a) - the operational sketch, (b) - constructive dimensional links, (c) - technological dimensional links

Drawing up of dimensional chains consists: in the choice of the derivative constructive size from the scheme of constructive links as closing; in definition of that technological size by means of which it will be assured (from the scheme of technological dimensional links); in the choice of the other technological sizes already generated to close the dimensional chain. At a stage i of machining the derivative constructive size A_c^i coincides with the technological size A_t^i, therefore the dimensional chain contains only two links and the technological accuracy of the machine tool is transferred to a detail lost-free (figure 5 a). For the size B_c^i (as for the sizes C_c^i and E_c^i with identical dimensional links) the dimensional chain powers up three links (figure 5 b). In a ratio of tolerances ω it is possible to write: $\omega_{A_t^i} \leq \omega_{A_c^i}$; $\omega_{B_t^i} + \omega_{A_t^i} \leq \omega_{B_c^i}$; $\omega_{C_t^i} + \omega_{B_t^i} \leq \omega_{C_c^i}$; $\omega_{E_t^i} + \omega_{C_t^i} \leq \omega_{E_c^i}$

Obtained inequalities specify necessity to establish the accuracy parameters $\omega_{A_t^i}, \omega_{B_t^i}, \omega_{C_t^i}$ and $\omega_{E_t^i}$ of the technological sizes A_t^i, B_t^i, C_t^i and E_t^i, and at the same time to reach the accuracy of the derivative constructive sizes it is necessary to execute the technological sizes with the greater accuracy.

At repeated machining all surfaces at a stage $i+1$ under the same scheme inequalities such as (1) will be fair. From processed surfaces S_1, S_2, S_3 and S_4 the machining allowances are deleted and their tolerances identified by the accuracy of the same technological sizes at two sequential stages (figure 6). After machining of surface S_1 the size B_c possess the value B_c^{int} with tolerance $\omega_{B_c^{\text{int}}} = \omega_{A_t^{i+1}} + \omega_{B_t^i}$. It is visible, that the accuracy increased by value $\omega_{A_t^i} - \omega_{A_t^{i+1}}$ (figure 7). Thus the sizes C_c and E_c , do not vary. At machining the surfaces S_1 and S_2 the tolerance of the size B_c^{i+1} possess the value $\omega_{B_c^{i+1}} = \omega_{A_t^{i+1}} + \omega_{B_t^{i+1}}$ also the accuracy of the size is a little improved C_c - $\omega_{C_c^{\text{int}}} = \omega_{B_t^{i+1}} + \omega_{C_t^i}$. In conclusion, for the sequential machining of surfaces we shall receive:

$$S_1: \quad \omega_{A_t^{i+1}} \le \omega_{A_c^{i+1}}, \quad \omega_{Ad_1^{i+1}} = (\omega_{A_t^i} + \omega_{A_t^{i+1}}), \quad \omega_{B_c^{\text{int}}} = \omega_{A_t^{i+1}} + \omega_{B_t^i}$$

$$S_1, S_2: \quad \omega_{B_t^{i+1}} + \omega_{A_t^{i+1}} \le \omega_{B_c^{i+1}}, \quad \omega_{Ad_2^{i+1}} = (\omega_{B_t^i} + \omega_{B_t^{i+1}}), \quad \omega_{C_c^{\text{int}}} = \omega_{B_t^{i+1}} + \omega_{C_t^i}$$

$$S_1 \ldots S_3: \quad \omega_{C_t^{i+1}} + \omega_{B_t^{i+1}} \le \omega_{C_c^{i+1}}, \quad \omega_{Ad_3^{i+1}} = (\omega_{C_t^i} + \omega_{C_t^{i+1}}), \quad \omega_{E_c^{\text{int}}} = \omega_{C_t^{i+1}} + \omega_{E_t^i}$$

$$S_1 \ldots S_4: \quad \omega_{E_t^{i+1}} + \omega_{C_t^{i+1}} \le \omega_{E_c^{i+1}}, \quad \omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}}), \quad \omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}})$$

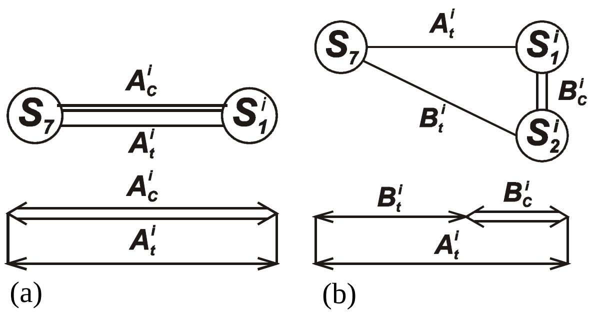

Figure 5. Dimensional chains for the sizes A_c^i (a) and B_c^i (b)

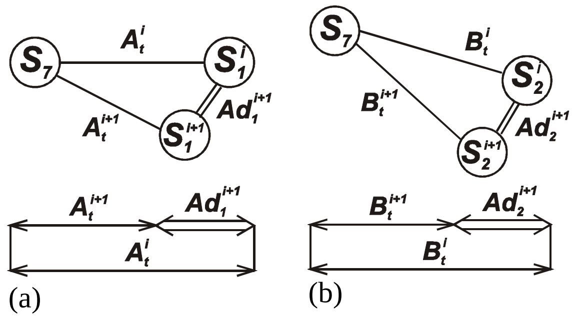

Figure 6. The dimensional chains for intermediate machining allowances

The machining of detail with formation the sizes from adjustment surfaces is submitted on figure 8. The adjustment surfaces for the sizes B_c, C_c and E_c correspond sequentially to a surface S_1, S_2 and S_3. It is visible, that schemes of constructive and technological dimensional links completely coincide. As a consequence, the dimensional chain for all derivative constructive sizes are powered up with only two links and a technological accuracy of the machine tool are transferred to a detail lost-free: $\omega_{A_t^i} \le \omega_{A_c^i}$; $\omega_{B_t^i} \le \omega_{B_c^i}$; $\omega_{C_t^i} \le \omega_{C_c^i}$; $\omega_{E_t^i} \le \omega_{E_c^i}$.

For a machining stage $i+1$, under the same scheme inequalities are identical and fair. At machining a surface S_1 the machining allowances Ad_1 is deleted, the size A_c passes in a condition A_c^{i+1} (figure 6 a), the size B_c passes in an intermediate condition B_c^{int}. The machining of the surface S_2 with the elimination of the machining allowances Ad_2 provokes the transition of the size B_c from the condition B_c^{int} to a condition B_c^{i+1}, and the size C_c passes in an intermediate condition C_c^{int}.

The solving of the dimensional chains taking in the consideration the sequential machining of

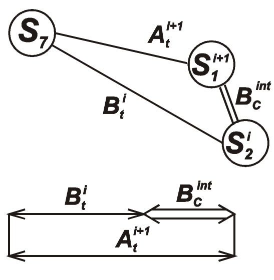

Figure 7. The dimensional chains for intermediate sizes

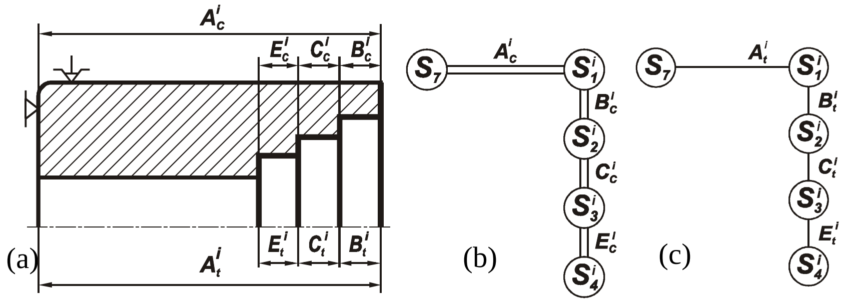

Figure 8. Formation of the sizes from adjustment surfaces. (a) - the operational sketch, (b) - constructive dimensional link, (c) - technological dimensional links

surfaces we shall receive:

S_1:

$$\begin{aligned}
&\omega_{A_t^{i+1}} \le \omega_{A_c^{i+1}} \\
&\omega_{Ad_1^{i+1}} = (\omega_{A_t^i} + \omega_{A_t^{i+1}}) \\
&\omega_{B_c^{\text{int}}} = \omega_{B_t^i} + \omega_{Ad_1^{i+1}} \\
&\omega_{B_c^{\text{int}}} = \omega_{B_t^i} + (\omega_{A_t^i} + \omega_{A_t^{i+1}})
\end{aligned}$$

S_1, S_2:

$$\begin{aligned}
&\omega_{B_t^{i+1}} \le \omega_{B_c^{i+1}} \\
&\omega_{Ad_2^{i+1}} = \omega_{B_t^{i+1}} + \omega_{B_c^{\text{int}}} \\
&\omega_{Ad_2^{i+1}} = (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) \\
&\omega_{Ad_2^{i+1}} = (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + \omega_{Ad_1^{i+1}} \\
&\omega_{C_c^{\text{int}}} = \omega_{C_t^i} + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + (\omega_{A_t^i} + \omega_{A_t^{i+1}})
\end{aligned}$$

$S_1 \ldots S_3$:

$$\begin{aligned}
&\omega_{C_t^{i+1}} \le \omega_{C_c^{i+1}} \\
&\omega_{Ad_3^{i+1}} = \omega_{C_t^{i+1}} + \omega_{C_c^{\text{int}}} \\
&\omega_{Ad_3^{i+1}} = (\omega_{C_t^i} + \omega_{C_t^{i+1}}) + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) \\
&\omega_{Ad_3^{i+1}} = (\omega_{C_t^i} + \omega_{C_t^{i+1}}) + \omega_{Ad_2^{i+1}} \\
&\omega_{E_c^{\text{int}}} = \omega_{E_t^i} + \omega_{Ad_3^{i+1}} \\
&\omega_{E_c^{\text{int}}} = \omega_{E_t^i} + (\omega_{C_t^i} + \omega_{C_t^{i+1}}) + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + (\omega_{A_t^i} + \omega_{A_t^{i+1}})
\end{aligned}$$

$S_1, \ldots S_4$:

$$\begin{aligned}
&\omega_{E_t^{i+1}} \le \omega_{E_c^{i+1}} \\
&\omega_{Ad_4^{i+1}} = \omega_{E_t^i} + \omega_{E_c^{\text{int}}} \\
&\omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}}) + (\omega_{C_t^i} + \omega_{C_t^{i+1}}) + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) \\
&\omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}}) + \omega_{Ad_3^{i+1}}
\end{aligned}$$

As the surfaces are formed sequentially from each other, the phenomenon of error's compensation operates. Then it is possible to write: $\omega_{A_t^i} \le \omega_{A_c^i}$; $\omega_{B_t^i} \le \omega_{B_c^i} + 2\omega_{1^i 2^i}^{comp}$; $\omega_{C_t^i} \le \omega_{C_c^i} + 2\omega_{2^i 3^i}^{comp}$; $\omega_{E_t^i} \le \omega_{E_c^i} + 2\omega_{3^i 4^i}^{comp}$. For a machining stage $i+1$, under the same scheme inequalities are identical and fair. The solving of the dimensional chains taking in the consideration the sequential machining of surfaces and the phenomenon of error's compensation we shall receive:

S_1:

$$\begin{aligned}
&\omega_{A_t^{i+1}} \le \omega_{A_c^{i+1}} \\
&\omega_{Ad_1^{i+1}} = (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega_{1^i 1^{i+1}}^{comp} \\
&\omega_{B_c^{\text{int}}} = \omega_{B_t^i} + \omega_{Ad_1^{i+1}} \\
&\omega_{B_c^{\text{int}}} = \omega_{B_t^i} - 2\omega_{1^i 2^i}^{cmp} + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega_{1^i 1^{i+1}}^{comp}
\end{aligned}$$

S_1, S_2:

$$\begin{aligned}
&\omega_{B_t^{i+1}} \le \omega_{B_c^{i+1}} + 2\omega_{1^{i+1} 2^{i+1}}^{comp} \\
&\omega_{Ad_2^{i+1}} = (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega_{2^i 2^{i+1}}^{comp} + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega_{1^i 1^{i+1}}^{comp} \\
&\omega_{Ad_2^{i+1}} = (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega_{2^i 2^{i+1}}^{comp} + \omega_{Ad_1^{i+1}} \\
&\omega_{C_c^{\text{int}}} = \omega_{C_t^i} - 2\omega_{2^i 3^i}^{cmp} + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega_{2^i 2^{i+1}}^{cmp} + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega_{1^i 1^{i+1}}^{cmp}
\end{aligned}$$

$$S_1 \dots S_3: \quad \omega_{C_t^{i+1}} \le \omega_{C_c^{i+1}} + 2\omega^{comp}_{2^{i+1}3^{i+1}}$$

$$\omega_{Ad_3^{i+1}} = (\omega_{C_t^i} + \omega_{C_t^{i+1}}) - 2\omega^{comp}_{3^i 3^{i+1}} + (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega^{comp}_{2^i 2^{i+1}} +$$
$$+ (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega^{comp}_{1^i 1^{i+1}}$$

$$\omega_{Ad_3^{i+1}} = (\omega_{C_t^i} + \omega_{C_t^{i+1}}) - 2\omega^{comp}_{3^i 3^{i+1}} + \omega_{Ad_2^{i+1}}$$

$$\omega_{E_c^{\text{int}}} = \omega_{E_t^i} - 2\omega^{comp}_{3^i 4^i} + (\omega_{C_t^i} + \omega_{C_t^{i+1}}) - 2\omega^{comp}_{3^i 3^{i+1}} +$$
$$+ (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega^{comp}_{2^i 2^{i+1}} + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega^{comp}_{1^i 1^{i+1}}$$

$$S_1, \dots S_4: \quad \omega_{E_t^{i+1}} \le \omega_{E_c^{i+1}} + 2\omega^{comp}_{3^{i+1}4^{i+1}}$$

$$\omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}}) - 2\omega^{comp}_{4^i 4^{i+1}} + (\omega_{C_t^i} + \omega_{C_t^{i+1}}) - 2\omega^{comp}_{3^i 3^{i+1}} +$$
$$+ (\omega_{B_t^i} + \omega_{B_t^{i+1}}) - 2\omega^{comp}_{2^i 2^{i+1}} + (\omega_{A_t^i} + \omega_{A_t^{i+1}}) - 2\omega^{comp}_{3^i 3^{i+1}}$$

$$\omega_{Ad_4^{i+1}} = (\omega_{E_t^i} + \omega_{E_t^{i+1}}) - 2\omega^{comp}_{4^i 4^{i+1}} + \omega_{Ad_3^{i+1}}$$

4. Conclusions.

The schemes of machining with a formation of sizes from technological locating datum surface are characterized by unfavorable conditions of accuracy formation for constructive sizes, but the machining allowances are more stable.

The schemes of machining with substitution of technological locating datum surface by adjustment surfaces are characterized by favorable conditions for accuracy formation of the constructive sizes as dimensional links power up only on two elements. The machining allowances are instable because their tolerance depends on multiples change of bases, and lowering of the accuracy if the line-up of repeated machining is broken off. The machining allowances also depends on the number of operation elements.

To develop of optimal dimensional technologies the following optimality criteria to be considered: the number of the technological sizes is minimum and equal to the number of design sizes; in the dimensional chains in which the machining allowance is the closing link the number of units should be equal to 3; the amount of machining allowances should be minimal, and the value of each of them shall not result in additional operation element; the number of operation elements to assure the accuracy of each surface should be as low as possible.

References

[1] Kuznetsov P M 2014 Operativnaâ razrabotka sistem tehnologičeskogo proektirovaniâ v mašinostroitel’nom proizvodstve. *Tehnologiâ mašinostroeniâ*. Moskva. **5**, 40 – 43

[2] Mokrushin Y A and Shamin V Y 2013 Necessity of improving technological process planning in machine building. *University proceedings. Volga region. Engineering sciences. Machine sciences and building.* **1**, 123 – 130

[3] Rahmilevich E G 2013 Avtomatizaciâ rasčetov količestvennyh pokazatelei tehnologičnosti s ispol’zovaniem konstryktorsko - tehnologičeskoi parametrizacii. *Tehnologiâ mašinostroeniâ.* Moskva. **1**, 53 – 56

[4] González Contreras F 2012. An improved tolerance charting technique using an analysis of setup capability. *The International Journal of Advanced Manufacturing Technology*, Volume **62**, Issue **9 – 12**, Springer, 1205 - 1218