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# STUDIES ON CHOOSING THE OPTIMAL VARIANT OF WORKING PROCESS DEPENDING ON CUTTING DEPTH AND TOLERANCE

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**Keywords**: process optimization, technology, tolerance, depth of cut, minimal cost.
**Abstract**: In this paper we present a method for determining the optimal choice of processing a piece, the purpose being to minimize the cost function, as restrictions are linked to the value of cut depth and the tolerance value. The size of the processing addition will take into account the number of levels, from the surface of finished piece and reaching the semi-finished piece. The method follows the principle of optimization through the dynamic programming method and for its application is necessary attending several working steps.

## 1. PRELIMINARY NOTIONS

Processing on working machines is the main element of the technological process.
Towards obtaining the final piece, the semi-finished passes through a series of operations, which are a multiple choice question. In order to achieve the technological process are taken into account several factors such as:
- construction of the piece (size, mass, configuration);
- dimensional shape tolerance and its mutual arrangement;
- surface roughness;
- the working machine model;
- construction of the device, etc.

The construction of the optimal operation includes: optimizing the technological crossing on the processed surface of the work piece; forming optimal operation; editing technical documentation of the model. To determine the optimal variant of realization of the technological process is taken into account, among others, the number of passes for removing the processing addition for each individual operation.
In the processing with multiple passes, each anterior pass influences naturally the next one and ultimately affect the processing precision. For this reason, the variants of later transition execution can be discussed only after you have selected the defining parameters of the previous one.
One of the criteria to optimize the technological process could be the technological cost, which is given by:

$$C = \sum_{i=1}^{p} C_{pre\ i} \qquad (1)$$

where: $C_{pre\ i}$ is the cost for implementation of i operation;
p - number of passes.

To reach the optimal variant of the technological process are taken into account a number of factors which will have to meet certain conditions, which finally meet the minimum cost function:

$$\begin{cases} N_{pre} \le N_M \eta \\ F_z \le F_{Radm} \\ T \ge T_{sa} \end{cases}$$
$$\begin{cases} \Delta_{Ri} \le T_{det} \\ \Delta_{di} \le \Delta_{d\,det} \end{cases}$$
$$\begin{cases} s_k \le \{s_{Rz}\} \\ s_k \le \{s_{Ra}\} \end{cases} \tag{2}$$
$$n_i \in \{n_{i\,min}, n_{i\,max}\}$$
$$s_k \in \{s_{min}, s_{max}\}$$
$$C = \sum_{i=1}^{p} C_{pre\ i} \to \min \tag{3}$$

where: $N_{pre}$ is the tool power, used during cutting;
$N_M$ - the engine power of the working machine;
$F_z$ - the tangential component of the total cutting force;
$F_{Radm}$ –the admissible radial component of the total cutting force;
$T_{sa}$ - the admissible durability of cutting tool;
$\Delta_{Ri}$ – total processing error of the diameter at ***i*** crossing;
$T_d$ –diameter tolerance to be processed;
$\Delta_{di}$ – cylindricity deviation at ***i*** crossing;
$\Delta_{dadm}$ – the admissible deviation from cylindricity of the processed diameter;
$n_i$ – the piece speed at ***i*** crossing;
$n_{imin}$ – minimum speed of working machine;
$n_{imax}$ - maximum speed of working machine;
$s_k$ – the advance;
$s_{min}$ – the minimum advance of working machine;
$s_{max}$ - the maximum advance of working machine.

This classical method has some drawbacks (there is a significant number of calculations when we have a big number of areas which are to be processed) and for removing them is being used the dynamic programming method.

## 2. CHOOSING THE OPTIMAL VARIANT OF THE FABRICATION PROCESS DEPENDING ON THE DEPTH OF CUT AND TOLERANCE

The method of choosing the optimal technological process of fabricating an area requires the difference of the $a_{min}$ minimum addition on levels. Thus, the size of the addition (counting levels is done from the surface area of semi finished) and will be:
-for the first level: $l_1^n = t_{min}$
- for the second level: $l_2^n = t_{min} + \gamma$
- for the third level: $l_3^n = t_{min} + 2\gamma$
- for i level: $l_i^n = t_{min} + (i-1)\gamma$
- for m level: $l_m^n = t_{min} + (m-1)\gamma$ .
where: $t_{min}$ is the lowest depth of cut permitted in the processing;
γ - the step which is determined by the kinematic possibility of the working machine to shift the cutting tool or the semi-finished to the given constructive dimension.

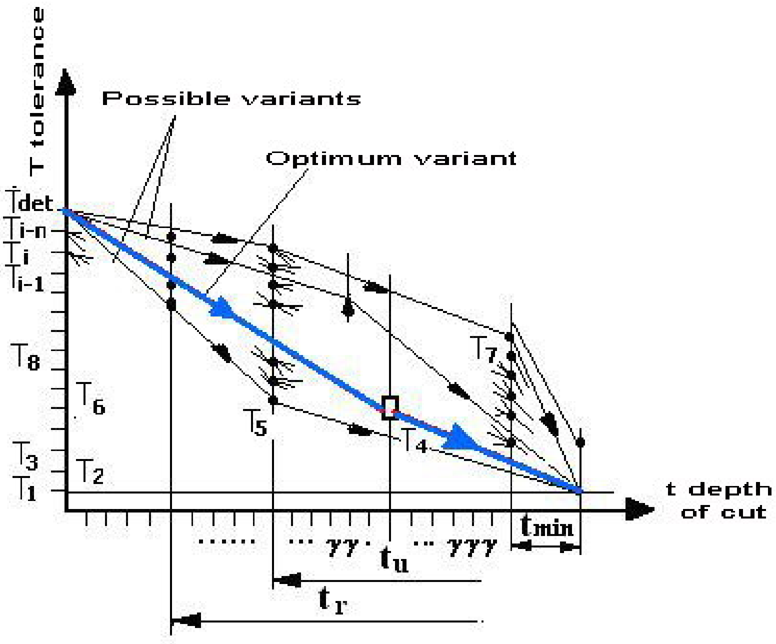


***Fig.1 Choosing the optimal variant of the fabrication process depending on the depth of cut and tolerance***

If we assume that the semi-finished in the manufacturing process can have a range of intermediate values of technological tolerances: $T_{sem}$, $T_1$, $T_2$ ...$T_i$...$T_{det}$,
then selecting the optimal variant of the technological process will be done from the first level in order to increase the number of levels, first level would correspond to the final processing transition of the area and to define this, it should be known the prior passage parameters. This is shown in Figure 1, from this figure it could be chosen the optimum processing variant, from many possible variations of processing (which are presented depending on the **depth of cut and tolerance**).
Since the total error processing dependence to technological factors of:

$$\Delta_{Ri} = f(t, s, v) \tag{4}$$

for the practical method of processing by cutting and knowing which are the parameters of the planned transition, it could be calculated the total processing error. If we do not have the data of the penultimate passage, we can assume that the processing error will occur after the issuing of it.
Following the optimization principle of dynamic programming method, for each of these sentences (meaning for each initial tolerances possible on the first level) must be chosen such variations so that in the final passage is obtained the optimal decision. Basic steps needed to calculate processing version of each level are shown in Figure 2.
Calculation of first-level variations and of any level processing by single pass differs of the general scheme in some features, but the steps sequence and formulas layout remain the same. Thus, at the level with m number at working with a single pass, the actual depth of cut is:

$$t_{real} = \alpha \cdot t_m , \tag{5}$$

where: ***α*** is a coefficient that depends on technological parameters of the system and on one of the possible initial tolerances $T_{m,i}$ (on the area) of the levels.

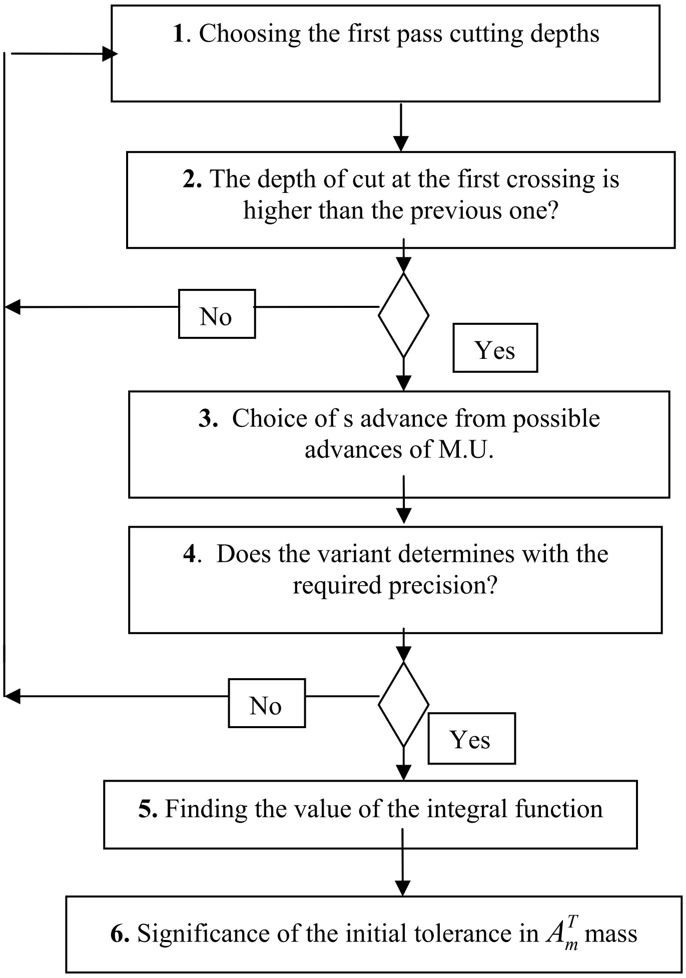


***Fig.2. The principle scheme of the steps for determining the optimal variant of processing.***

In this case, the advance should satisfy the condition, in relation to surface roughness of the piece:

$$s_{m,k} \leq \left[s_{Rz}, s_{Ra}\right] \tag{6}$$

If we have the total processing error $\Delta_R$ ,when selected parameters are less or equal to $\boldsymbol{T_{det}}$, then for this possibility, full function value is calculated: $f_m\left(t_m, T_{m,i}, s_{m,k}\right)$.
Minimum cost is given by the relation:

$$C_m\left(T_{m,i}\right) = \min\left\{f_m\left(t_m, T_{m,i}, s_{m,k}\right)\right\} \tag{7}$$

Starting from the advance of $A^{(s)}$, it will be determined the optimal variant processing of level with m number at the beginning of tolerance $T_{m,i}$.

In the case of multiple processing passes, the number of variants for comparison of the technological value will be determined by the parameters of the first passage (on semi-finished). To do this, follow the steps in figure 2:

**Step 1.** Choosing the cutting depth on the first pass is given by the relation:

$$t_r = \gamma q \tag{8}$$

Where: q belongs to the interval {1,2,…r-1} .

**Step 2.** Depth of cut at the first crossing is higher than the previous one? Choosing the value of q, we obtain: : ***$t_{real.r}$ =α$t_r$=α(γq)*** , the difference $t_r - t_{real.r}$ which shows the piece size of number r level after first crossing.

Since $(l_r - t_{real.r}) < l_r$ , we get the size $(l_r - t_{real.r})$ , that corresponds to the level with the lowest number u (u <r), for which the optimal treatment option already exists. If $\gamma q < t_u$ , then we go back to step 1 and choose another q.

**Step 3.** Choosing the s advance from the possible advances of M.U. The advance selection in phase with r number is made in such way that in the processing with a single pass, that, if $q = (r-1) + \frac{t_{\min}}{\gamma}$, then the advance amount will be determined after the cutting consumption, material hardness, cutting tools for the operation execution and other boundaries.

**Step 4.** Does it determine the variant with the required precision? Depending on the initial tolerance ***$T_{r,i}$***, on the c level with the r number, of selected parameters of the first passage (Step 1, Step 3), total processing error will be considered after the first pass $\Delta_{Ri}$ . If $\Delta_{Ri}$ belongs to the set $A_u^T$ , then we move to the next step. If $\Delta_R \notin A_u^T$ , then we return to step 3, checking all the values of the advance from $\boldsymbol{A^{(s)}}$ which satisfy the delimitation. If for all possible values of advance the error $\Delta_{Ri} \notin A_u^T$ , then we return to step 1.

**Step 5.** Finding the value of integral function $C_r(T_{r,i})$ after choosing the parameters of the first full shift, is calculated after the formula:

$$g_r\left[(1-T_i)l_r + T_i\gamma q; T_{r,i};\ s_{r,k}\right] + T_i C_u\left(T_{u,i}\right) \tag{9}$$

where:

$$T_i = \begin{cases} 0, & when\ \ q = u - 1 + \dfrac{t_{\min}}{\gamma} \\ 1 & -\ otherwise. \end{cases} \tag{10}$$

$C_u(T_{u,i})$ represents the optimal value of the integral function for the level with u number and at the beginning of tolerance $T_{u,i} = \Delta_R$ .

**Step 6**. Significance of the initial tolerance in $A_m^T$ mass. The initial tolerance $T_{r,i}$ , for which is calculated the value $C_r(T_{r,i})$ is within the $A_r^T$ mass. The calculation on the proposed scheme is repeated until obtaining conditions:

$$C_r(T_{r,i}) = \{g\left[(1-T)l_r + T\gamma q; T_{r,i};\ s_{r,k}\right] + T_i C_u\left(T_{u,i}\right)\} \tag{11}$$

Calculation on the proposed scheme is continued up to the conditions $T_{r,i} = T_{\det.}$ . As seen from the above, it occurs, during the design, the tolerances and deviations problem for the piece which follows to be processed.

## 3. CONCLUSIONS

For the appliance of the presented method was necessary to go through six working steps; they were presented as a calculation algorithm.

The method is based on the principle of optimization by dynamic programming method and it takes into account the calculation of the depth of cut, divided on several levels, and each of these levels are determined the tolerances; the optimal variant is chosen so that at the final passage it meet the condition $T_{r,i} = T_{\det.}$.

The presented method is difficult, especially on an industrial scale because it requires more computing relationships and many tabular data from literature, such as: the advance which takes into account the hardness of the material to be processed, cutting tools, etc..; surface roughness, processing time, etc.

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