Environment. Technology. Resources, Rezekne, Latvia
Proceedings of the 10th International Scientific and Practical Conference. Volume I, 125-127

Adaptive control of the indentation made by the drilling tool

Angel Lengerov
Technical University of Sofia, Branch Plovdiv, Faculty of Mechanical Engineering,
Address: Tsanko Diustabanov 25, Plovdiv, 4000, Bulgaria.

Abstract. **The objective of this study is to determine the advisability of introducing adaptive control of the indentation made by the drilling tool depending on the structural characteristics of the processed part. In the cases when the adaptive control is economically advisable, the selection of the technological cycle and the speed of moving of the tool can be achieved by the implementation of the respective algorithm for optimization of the dimensions fed for drilling.**

Keywords: **engage, adaptive, tool, drilling.**

I INTRODUCTION

Metal cutting machine tools with numerical control (CNC) are intended to provide a solution to the occurred in the modern machine engineering contradictions between the requirements for flexibility and the high degree of automation. In order to increase their efficiency and widen the scope of their implementation, it is necessary to assess in full their technical potential for technological operation optimization. One of the areas of cost minimization of the technological operations is related to the reduction of the idle strokes runtime (auxiliary strokes) that are required and accompany the operating strokes (main strokes).

II FORMULATION OF THE PROBLEM

The solution of this problem can be achieved by the introduction of adaptive control. The differences between the operating cycles of drilling holes with and without adaptive control are shown on Figure 1.

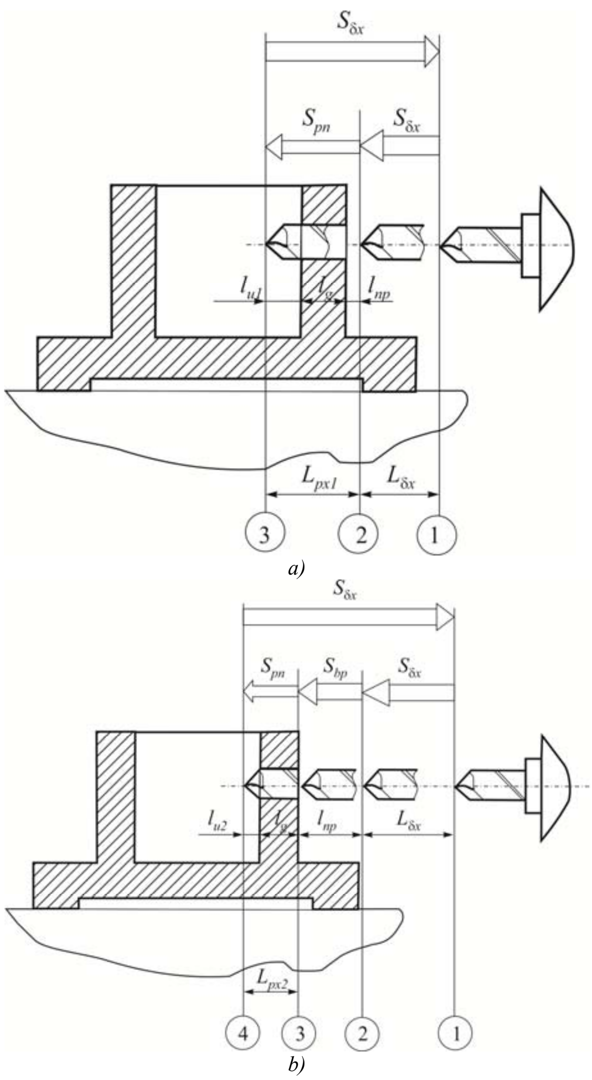

Fig. 1. Drilling operating cycle: a) without adaptive control; b) with adaptive control

ISSN 1691-5402

DOI: http://dx.doi.org/10.17770/etr2015vol1.623

In the case of the standard CNC (without adaptive control) processing is carried out by a program that provides:

- quick movement of the tool from p. 1 to p. 2;
- operating feeding movement from p.2 to p.3 and quick tool retraction from p. 3 to p.1.

In this case, the operating feeding stroke is defined as:

(1) $$L_{px1} = l_{np} + l_g + l_{u1}$$

Where L_{px1} is the length of the stroke in the case of drilling without adaptive control;

l_{np} - the distance required for the safe tool cutting;

l_g - the size of the processed surface;

l_{u1} - the exit distance of the tool in the case without adaptive control.

With the application of the dedicated adaptive control program, the programmable tool leading is achieved at fast pace from p. 1 to p.2 and afterwards the forward leading of the tool with maximum allowed feeding, while taking into account its resilience. This movement continues until reaching p. 3 which is not set in the programme. It corresponds to the point where the tool contacts the work piece. The contact is registered by the adaptive control system which sends a signal for stopping the accelerated feeding and for switch on of the operating tool feeding. The movement of the operating feeding continues to p. 4 which similarly to p.3 is not set in the programme, but it is determined by the adaptive control system. It corresponds to the point at which the tool in fact has left the processed material of the work piece. After reaching p. 4 the adaptive control system gives a command for quick tool retraction from p. 4 to p. 1. In this case, the stroke is determined by the formula:

(2) $$L_{px2} = l_g + l_{u2}$$

where L_{px2} is the stroke length in the adaptive control drilling;

l_{u2} - exit length of the tool in the adaptive control drilling.

III ANALYTICAL STUDY

The operating time cycle is expressed as follows:

(3) $$T_1 = \frac{L_{\delta x}}{S_{\delta x}} + \frac{L_{px1}}{L_{pn}},$$

(4) $$T_2 = \frac{L_{\delta x}}{S_{\delta x}} + \frac{L_{px2}}{S_{pn}} + \frac{l_{np}}{S_{bp}},.$$

where $L_{\delta x}$ is the distance of movement of the tool at rapid pace;

$S_{\delta x}$ - speed of rapid pace;

S_{pn} - speed of movement of operating feeding;

S_{bp} - speed of movement of rapid pitching-in.

The time reduction of the operating cycle with applied adaptive control is defined as:

(5) $$\Delta T = T_1 - T_2 .$$

After converting equations (1), (2), (3), (4) and substitution in equation (5), it looks as:

(6) $$\Delta T = \frac{l_{u1} - l_{u2}}{S_{pn}} + \frac{l_{np}}{S_{pn}}\left(1 - \frac{S_{pn}}{S_{bp}}\right).$$

If we assume that $l_{u1} - l_{u2} = l_{up} = \omega_z$, equation (6) is converted into

$$\Delta T = \frac{\omega_z}{S_{pn}}\left(2 - \frac{S_{pn}}{S_{bp}}\right),$$

where $\omega_z = \omega_{lb} + \omega_{lg}$ is the error of the linear dimensions of the work piece;

ω_{lb} - error of the dimensions of the supporting technological base to the end of the work piece;

ω_{lg} - error of the size of the processed surface.

The specific increase of the processing performance will be equal to:

(7) $$\frac{\Delta T}{T} = \frac{2\omega_z}{l_g}\left(1 - \frac{S_{pn}}{2S_{bp}}\right),$$

where $T = \frac{l_g}{S_{pn}}$ is the cutting time.

If we denote $\frac{\omega_z}{l_g} = k_1$ and $\frac{S_{pn}}{S_{bp}} = k_2$, the relationship (7) assumes the following form:

(8) $$\frac{\Delta T}{T} = k_1\left(2 - k_2\right).$$

On the grounds of (8) we assume the following:

1. With the increase of the pitch-in speed of the tool (reduction of k_2) the adaptive control effect increases, which is expressed in higher processing efficiency.
2. The adaptive control effect depends considerably on the size of the processed surface. With the increase of this size (reduction of k_1) the performance is reduced.

In order to achieve maximum effect of the adaptive control in specific working conditions, the speed of the feeding movement of pitching in S_{bp} has to be maximal, while taking into account the tool's resilience.

The maximum axial force that can withstand the drill when pitching into the processed surface is determined by [2] according to the following:

(9) $$P_{kp} = \frac{2\pi^2 E J_{\min}}{\left(1 + \frac{J_{\min}}{J_{\max}}\right) l^2},$$

where $J_{\min}$ and $J_{\max}$ are respectively the smallest and the biggest inertia moment along the cross section of the drill.

l - length of the taper drills.

The maximum allowed torque of the pitching drills

(10) $M_{kp} = W\tau_p$

where τ_p is the tangential pressure of destruction;

W - the polar moment of resistance of the drill.

To determine the moment of inertia and resistance of the spiral drill with satisfactory accuracy, the following equation can be applied [2]:

$J_{\min} = 0.0052d^4$, $J_{\max} = 0.027d^4$, $W = 0.047d^3$,

where d is the external diameter of the drill in mm;

For spiral drill made of tool steel, it is experimentally found out that $\tau_p = 620 \div 660\ N/mm^2$.

Under these conditions formula (9) and (10) assume the form:

$$P_{kp} = 18.10^3 d^4 / l^2, \qquad M_{kp} = 29.d^3 .$$

To determine the pitching-in feeding S_{bp} the empirical relations of the axial force can be used - P_0 and the torque moment M when drilling. The order models of the following type are widespread:

$$P_o = C_p.d^{q_p}.S^{y_p}.K_p \qquad M = C_m.d^{q_m}.S^{y_m}.K_m,$$

where C_m and C_p are constants defining the type of the work piece and the tool. If $P_0 = P_{kp}, M = M_{kp}$, we obtain two values of the pitching-in feeding:

$$S_{bp_1} = \left(\frac{P_{kp}}{C_p.d^{q_p}.K_p}\right)^{\frac{1}{y_p}}, \; S_{bp_2} = \left(\frac{M_{kp}}{C_m.d^{q_m}.K_m}\right)^{\frac{1}{y_m}}.$$

The pitching-in feeding of the tool into the processed work piece in the drilling operation is defined finally by the limitations of the metal cutting machine.

$$S_{bp} = \min\left(S_{bp1}, S_{bp2}\right) \text{ when}$$

$$S_{\max} \geq \min\left(S_{bp1}, S_{bp2}\right) \geq S_{\min}$$

$$S_{bp} = S_{\max} \text{ when } \min\left(S_{bp1}, S_{bp2}\right) > S_{\max},$$

where $S_{\min}$ and $S_{\max}$ are the minimum and maximum feeding that can be achieved by the metal cutting machine.

If $\min\left(S_{bp1}, S_{bp2}\right) < S_{\min}$ the processing on this machine is impossible.

IV CONCLUSION

On the grounds of the present analytical study on the application of the adaptive control of the pitching-in of the drilling tool, we can conclude that the processing optimization in terms of time is possible only by defining the feeding of each separate drill of the toolset of the machine. This is done in the course of the preparation of the control programme for the machine with CNC. The computational operations can be done be the respective developed computer software.

V REFERENCES

[1] Georgiev V., Lengerov, A. Adaptive control of the drilling process. AMTECH '95. Ruse, 1995, 6-15.

[2] Filipov G.V. Cutting tools. Machine building, Saint Petersburg, 1984, 13-17.