UDC 621.865.8

# THE RESEARCH OF CONDITIONS OF CHANGING GRIPS POSITIONS IN THE WORKING AREA OF THE MACHINE TOOL

**Mazhara Vitalii Anatoliiovych,**
**Artiukhov Anatolii Mukolaiovych**
Ph.D., associate professors
**Moskalenko Vasylii Mukolaiovych,**
**Tenenyka Svitlana Andriivna**
Professor’s assistants
Central Ukrainian National Technical University
Kropyvnytskyi, Ukraine

**Abstract:** This article proposes the use of calculation and layout schemes of robotic complexes, on the basis of which it is possible to determine the actual value of the robot's service time for technological equipment. Also, the conditions for changing grips in places in the working area of the machine were analyzed and formulas were determined for calculating the required amount of free space in different directions.

**Keywords:** two-grip industrial robot, change of grippers, robotic complex, two-grip devices, productivity

The productivity of the robotic complex largely depends on the idle time of the machine (uninterrupted working time of the industrial robot). This time is affected by the possibility of changing grippers directly in the working area of the machine. Limitations of the specified area by the clamping device, the back wall, guides and the tool head complicate the flow of this process, so the analysis of this possibility is an urgent problem, the solution of which can increase the productivity of the flexible modules.

When determining the artificial processing time of a part on robotic systems (RTC), there are values that characterize the technological operation and the features of the machine (main time, time to open the barrier, time to clamp the part, etc.). In total, they make up uncapped working time. The time of moving the cutting tool ($t_{ct}$) to form the zone of change of grips in places depends both on the size of the part installed on the machine, and on the features of the design of the robot and its functioning in the cycle. The working time of an industrial robot for machine maintenance ($t_{r(m)}$) depends on the features of RTC execution, and therefore, together with $t_{ct}$ will significantly affect the productivity of the complex, since these components increase the uninterrupted working time of the industrial robot (IR).

The first step in solving the given problem should be consideration of the trajectory (cyclogram) of movement and the general formula of the components of the industrial robot's working time at the machine's working position when using different types of gripping devices.

The scheme of this process when using a lathe and a gantry industrial robot is shown in Fig. 1, a, and the trajectory of movements carried out by grippers, in fig. 1, b. According to these conditions, the formula for the working time of an industrial robot (IR) at the working position of the machine will be:

$$t_{r(m)} = t_{mvp} + t_c + t_{lm} + t_{ch} + t_{lm} + t_c + t_{rwp} = t_{mwp} + 2t_c + 2t_{lm} + t_{ch} + t_{rwp}$$

where $t_{r(m)}$ is the working time of the IR at the working position of the machine; $t_{mwp}$ – the time of moving the IR to the working position; $t_{rwp}$ – the time of removal of the IR from the working position; $t_c$ – time for clamping (unclamping) the part; $t_{lm}$ - time for local movements (introduction, removal of the part from the chuck); $t_{ch}$ - time to change hobbies. [1]

Having performed similar calculations for other typical versions of two-grip devices, it is possible to compare them and determine the optimal performance of the two-grip device for certain operating conditions of the robotic complex.

The given data allow us to perform an initial comparative analysis of typical two-grip devices that are used for loading and unloading machines with a change of grips in places in the working area.

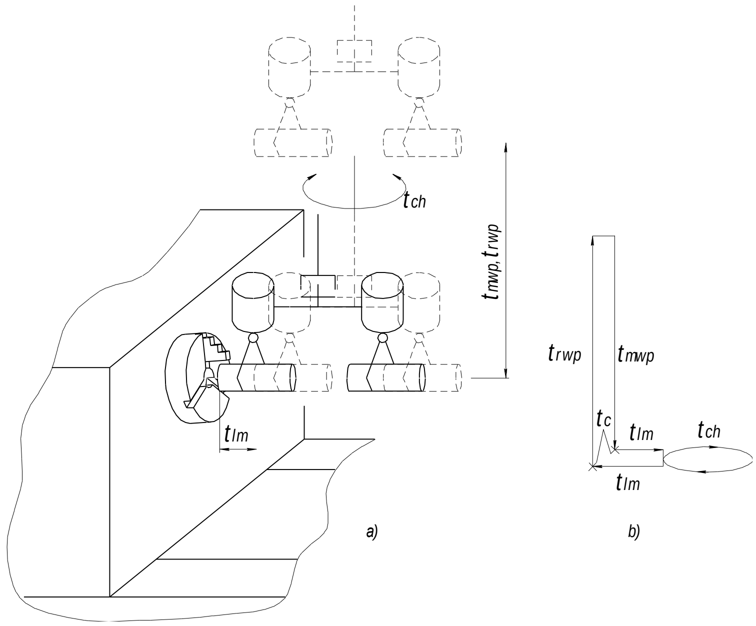


**Fig. 1. The maintenance of the working position of the machine tool**

In the case when the grippers are changed in places outside the working area of the machine, two more movements are added to the cycle of movements and the time formula for removing and inserting the grippers into the working area, which increases the working time of the industrial worker at the machine position and, accordingly, the idle time of the technological equipment. A more complete assessment can be made not only by the number of movements, but also by the actual value of time for their execution.

Having determined the general formula of the components of the working time of an industrial robot at the position of the machine, you can proceed to establishing the actual value of the given time. To do this, it is necessary to create a more specific calculation and composition scheme of the RTC, where the coordinates of the placement of the parts transported by the robot in all positions, and the coordinates of the base surfaces will be indicated.

The solution to this issue is considered on the example of a complex that includes a lathe and a portal-mounted two-grip industrial robot (Fig. 2, a). The blanks and processed parts are placed on the feeding and receiving auxiliary devices located on the side of the machine. According to this scheme, variants of two-grip robots are selected, for which the formulas of the non-overlapped working time of the IR at the working position of the machine are determined. In these formulas, the amount of time depends on the amount of linear and angular movements of the moving links of the industrial robot ($X_i$ , $Z_i$ , $\varphi_i$ ) and on the speed of these movements ($V_v$ , $V_h$, $\omega$). [2]

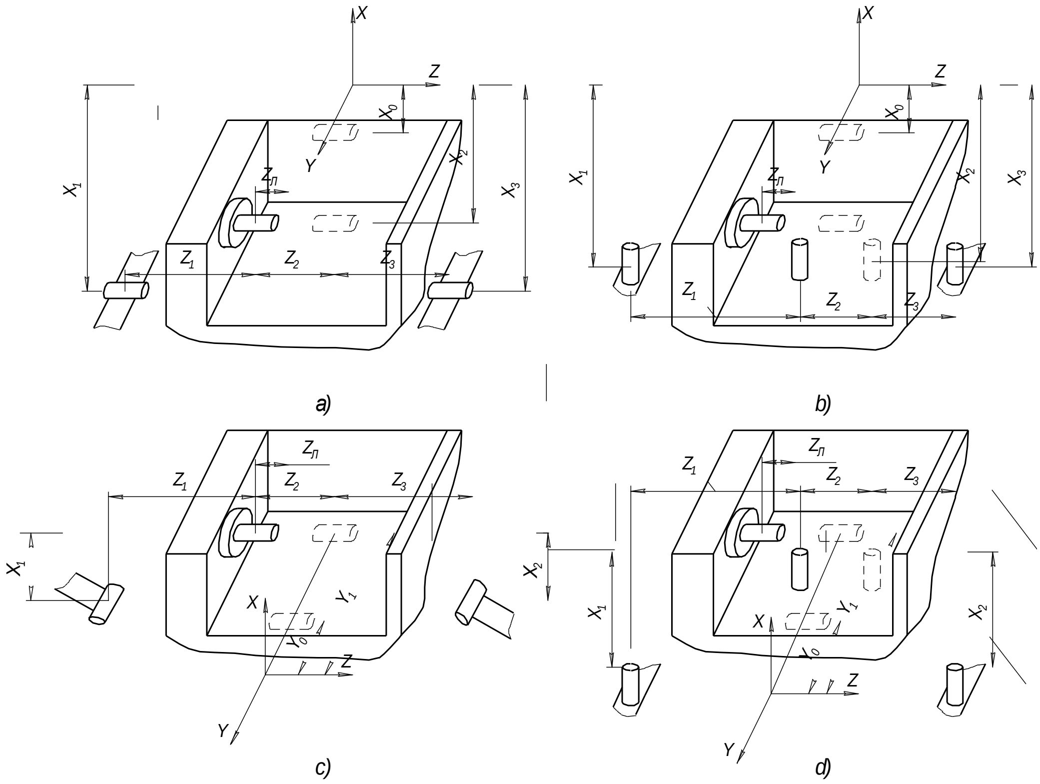


**Fig. 2. Calculation and layout schemes of various versions of robotic complexes**

Therefore, the formula for determining the non-overlapping time for a lathe RTC serviced by a gantry robot with a two-grip device (Fig. 1) according to the calculation and layout scheme (Fig. 2, a) will look like this:

$$t_{pn} = \frac{2(X_2 - X_0)}{V_v} + \frac{2Z_l}{V_h} + \frac{\varphi}{\omega} + t_c + t_{uc};$$

where $X_2$ , $X_0$ are values of linear movements in the vertical direction; $Z_l$ is the amount of linear movement in the horizontal direction; $V_v$ , $V_h$ – speed of movement in vertical and horizontal directions; φ, ω – respectively, magnitude and speed of angular movements; $t_c$ , $t_{uc}$ – respectively, the time for clamping and unclamping the part.

This formula for the working time of an industrial robot at a working position is minimal, since it is provided that the grippers already occupy the most appropriate positions in front of the working area of the machine. The presence of such schemes and formulas allows to more clearly present the time for maintenance of technological equipment with two-pass work of various design execution.

When determining the unobstructed time of operation of the RTC, it is necessary to take into account the time of removal of the tool head ($t_{rt}$) to create a space in which the process of changing grippers takes place. [1] This value depends on the features of the two-grip device and the dimensions of the parts (length – l, diameter – d). The time of movement of the cutting tool is determined by the formula:

$$t_{rt} = \frac{H_Z}{V_Z} \cdot K;$$

where $H_z$ is the amount of free space in the working area of the machine, which must be ensured by the removal of the cutting tool; K is a coefficient that takes into account the full tool removal path and a part of the tool lead path (K=1.5); $V_z$ is the speed of accelerated movement of the machine tool caliper.

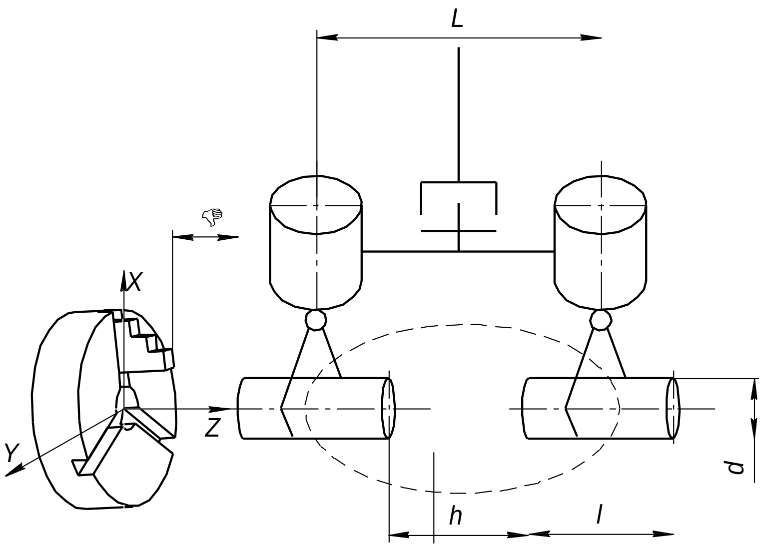


**Fig. 3. Calculation scheme for determining the required space in the working area of the machine tool**

Let's analyze the possibility of changing the grippers in places of the two-grip portal IR in the working space of the CNC lathe (Fig. 1).

So, the size of the free space in the direction of the Z axis depends on the length of the part being processed - l, its diameter - d, the distance between the parts - h and the technological quantity - Δ, which is necessary to remove the part from the clamping device of the machine tool:

$$H_Z = \Delta + 2 \cdot \sqrt{(\frac{1}{2}d)^2 + (l + \frac{1}{2}h)^2}.$$

The maximum distance in the direction of the X axis is determined by the height of the centers of the machine and is limited by its guides. It should be at least half the diameter of the processed part d:

$$H_{-X} = \frac{1}{2}d.$$

The distance required by the grippers in the Y direction depends on the length of the part – l, the diameter – d and the distance – h/2, and is defined as:

$$H_{-Y} = \sqrt{(\frac{1}{2}d)^2 + (l + \frac{1}{2}h)^2}.$$

The complex dependence of the removal time of the tool head on the studied parameters (diameter and length of the part) can be presented in the form of a graph (Fig. 4). For its construction, a number of constant values were introduced, in particular, the value of local displacement, for the output and input of the part into the chuck Δ = 50 мм, the distance between the parts h = 20 мм. The range of changing the length of the part is from 20 to 400 мм. The diameter varied from 10 to 200 mm.

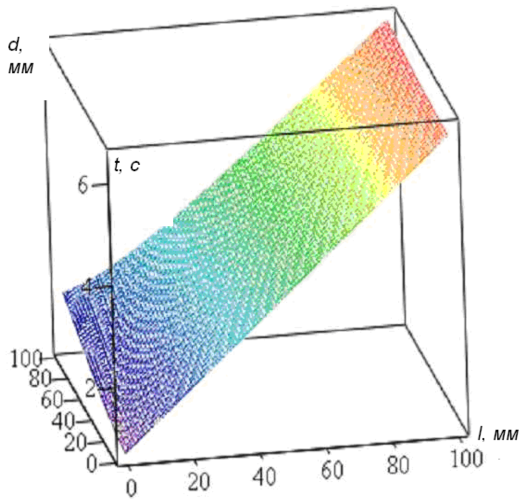


**Fig. 4. Dependence of the removal time of the cutting head on the overall dimensions of the part**

The presence of such dependencies makes it possible to more thoroughly represent the influence of the sizes of the transported parts and schemes of two-grip devices on the value of the idle time of the machine from the time of removal of the tool ($t_{ct}$).

**Conclusions.**

1. It is proposed to use RTC calculation and layout schemes, on the basis of which it is possible to determine the actual value of the robot's service time for technological equipment.

2. The conditions for changing grippers in places in the working area of the machine tool were analyzed and formulas were determined for calculating the required amount of free space in different directions for typical schemes of two-grip devices and the sizes of transported parts.

3. The influence of the dimensions of the processed parts and schemes of two-grip devices on the additional idle time of the machine, which is associated with the feeding and withdrawal of the cutting tool, was studied. Thus, in the interval of the ratio of the length of the part to the diameter ($l / d = 0.2...4.0$) for various schemes of two-grip devices, the downtime varies within 1.05 - 1.7 times.

Solving these issues will allow to increase the productivity of the RTC by reducing the downtime of the equipment due to the possibility of carrying out the process of changing grippers directly in the working area of the machine.

## REFERENCES

1. Pavlenko I. I. Robotic technological complexes: monograph / I. I. Pavlenko, V. A. Mazhara; under the editorship I. I. Pavlenko. – Kropyvnytskyi: KOD, 2019. – 382 p.

2. Pavlenko I.I. Industrial robots and RTC. Monograph. – Kropyvnytskyi: Publisher V.F. Lysenko. 2016. – 492 p.

3. Pavlenko I.I., Godunko M.O. Robotic gripping devices. Tutorial. – Kirovohrad: Lysenko V.F. 2014. – 368 p.