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INNOVATIVE METHODS OF EXPANDING THE FUNCTIONAL CAPABILITIES OF THE SINGLE-SPINDLE LATHE

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Turret lathes, which are automated turret machines, are widely used in large-scale and mass production. The use of automatic machines in small-scale production, which has a significant specific weight in instrument construction, was considered inadvisable until recently due to the fact that their reconfiguration takes a lot of time.

Currently, thanks to the expansion of processing methods, which allow with minimal time consumption to go from the production of one part to the production of another part of the same group, automatic machines are increasingly used in small-scale production.

The introduction of innovative methods to expand the technological capabilities of machines should go not only by increasing the accuracy of processing, a wider use of the expansion of functionality can be realized by equipping with auxiliary devices that can perform operations that improve the production of parts. One of the ways to improve the productivity of the automatic lathe is to use shaped cutters, which allow you to process the part faster and with better quality, and with the help of developing a methodology for calculating and adjusting the cams.

The expansion of the technological capabilities of automatic machines should not only go by increasing the accuracy of processing, a wider use of the expansion of functional capabilities can be realized by equipping them with auxiliary devices that can perform such operations that improve production. One of the ways to improve the productivity of the automatic lathe is to use shaped cutters, which allow you to process the part faster and with better quality, and with the help of developing a methodology for calculating and adjusting the cams. Therefore, the topic of the article is relevant.

Keywords: *complex, functionality, machine, equipment, processing process, innovative methods, vibrations, efficiency.*

F. 1. Fig. 10. Ref. 20.

1. Problem formulation

Turret lathes belong to the group of lathes. Machines of this type are used for processing parts in serial production from bar material or artificial blanks. Depending on the type of workpieces, they are divided into rod and cartridge. Revolver machines do not have a rear headstock, but have a turret head into which various cutting tools (cutters, drills, countersinks, and reamers) are installed. The tool is mounted in the cutter holder of the transverse caliper. All cutting tools are installed in advance when setting up the machine, and in the process of processing, they are put into operation one by one. After each working stroke, the turret head is turned, and the working position is occupied by a new cutting tool [1-5].

According to the design of the turret, the machines are divided into machines with vertical, inclined and horizontal axes of rotation of the turret.

The advantage of lathe-turret machines in comparison with lathe-screw cutters is the possibility of reducing the main time as a result of the use of multi-cutter holders and simultaneous processing of the part with tools fixed in the turret head and in the cutter holder.

Relatively small costs of auxiliary time as a result of preliminary adjustment of the machine for processing with several tools, quick replacement of the tool by turning the turret head, automatic obtaining of



specified dimensions thanks to the possibility of using stops. Due to this, there is a significant increase in labor productivity.

2. Analysis of recent research and publications

Turret lathes are used in serial production to produce parts of a heavy configuration from artificial blanks or a bar. Based on these factors, machines are divided into cartridge and bar machines.

Single-spindle lathes and semi-automatic machines are classified as: automatic machines and semi-automatic machines.

An automatic machine is a machine in which all the main and auxiliary movements necessary for the cycle of workpiece processing are automated, including loading and dispensing of the processed part. The worker should only periodically load a batch of blanks or bars and periodically control the dimensions of the parts [1-20].

A semi-automatic machine is called a machine in which all the main and auxiliary movements that are part of the workpiece processing cycle are automated, but the installation of a new workpiece and the removal of the finished part, as well as the control of its dimensions, are carried out by the worker.

Single-spindle bar automatic machines are divided into: turning-revolver machines; style-distinctive; longitudinal turning

Shape-cutting machines are used for processing short blanks of small diameter and simple shape. They have two to four calipers that move only in the transverse direction and carry shaped and cutting cutters. Such machines are also made with a longitudinal caliper, which allows drilling holes along the axis of the workpiece.

Longitudinal turning machines are used for processing long and precise small-diameter parts from a bar or a coil of wire. The workpiece has a longitudinal feed, and the calipers (three or four of them) are either stationary or have a transverse feed. Drilling, countersinking, thread cutting is carried out with the help of special devices, shaped surfaces are processed by joint movements of the workpiece in the longitudinal direction, and the cutter - in the transverse direction.

*a**b**c*

Fig. 1. Single-spindle bar machines: a – lathe-revolver; b – style-distinctive; c – longitudinal turning.

Source: grouped by author based on [1, 9, 10]

Lathe-turret machine - a metal-cutting machine of the lathe group, equipped with a multi-position rotating turret head, carrying tools for processing external and internal surfaces by sharpening, boring, drilling, countersinking, rolling, rolling, etc.



Turret turning machines are designed for the production of parts from various steels and non-ferrous metals and alloys in grades 9-11. They are processed from cold-drawn calibrated round, square and hexagonal bar material. Unlike longitudinal turning machines, the spindle headstock of a lathe-turning machine does not have an axial movement.

Traditionally, lathe-turner machines were used in automated lines, where maximum productivity, accuracy and reliability of the equipment were required. As a rule, this is mass and large-scale production, where the equipment works in multi-shift mode with a limited range of processed parts.

Turret lathes, compared to universal lathes, have the following characteristic features:

- turret lathes do not have a lead screw and a tailstock, and instead of the latter there is a caliper with a turret head, in the sockets of which a cutting tool is installed, designed for sequential processing of parts. When installing special holders in one slot, several cutting tools can be fixed for simultaneous processing of the part

- the position of each of the tools is adjusted so that the dimensions of the surface of the parts processed by it correspond to those specified in the drawing

- lathes and turrets have adjustable cams designed to automatically turn off feeds at the end of each stroke of the calipers

- turret lathes are often used for simultaneous processing of parts with cutting tools, which are in the holders of the turret head and in the cutter holder of the transverse caliper, which significantly reduces machine time.

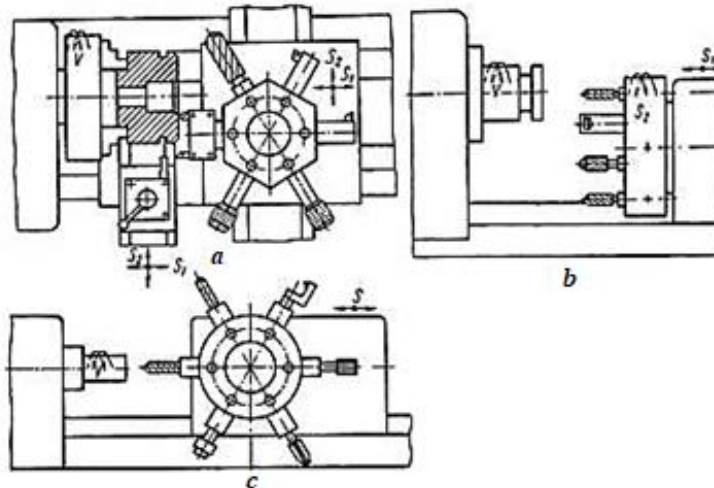
Turret lathes are used in serial production for processing parts from bars or from artificial blanks. All basic turning operations can be performed on these machines.

The use of lathes is considered rational if the technological process of processing the part requires the use of a large number of cutting tools.

The advantages of lathe-turret machines, in comparison with lathes, include:

- the possibility of reducing machine time due to the use of multi-cutter holders and simultaneous processing of the part with a tool installed on the turret head and transverse caliper;

- relatively small time spent due to the preliminary setting of the machine for processing the part with many tools.



**Fig. 2. Location of turret heads: a – with a vertical axis of rotation;
b – with a horizontal axis of rotation parallel to the axis of the spindle;
c – with the horizontal axis of rotation perpendicular to the axis of the spindle.**

Source: grouped by author based on [1, 9, 10]

In revolving machines, the main movement is the rotation of the spindle; feed movement - longitudinal s_1 and transverse s_2 movement of calipers, with cutting tools. In turret heads with a horizontal axis of rotation, parallel to the spindle axis, transverse feed is carried out by slow rotation of the turret head. In machines with a turret, which has a vertical axis of rotation, the transverse feed is carried out by a transverse caliper, and sometimes by moving a carriage with a turret in the transverse direction.

Auxiliary movements in turret machines are: turns (indexing) of the turret head for sequential introduction of various tools into work; feeding and clamping the bar; quick supply and removal of turret, transverse calipers, etc.



A distinctive feature of the structure of lathe-turret machines (Fig. 3) is the presence of a rotating, sometimes linearly movable turret head, in which the necessary sets of tools for processing are located in the necessary sequence. Such machines usually do not have a tailstock.



Fig. 3. Turret lathe

Source: grouped by author based on [1,9,10]

The location of the axis of rotation of the turret head 4 determines the layout of lathe-turret machines (Fig. 4): with a horizontal axis and a vertical axis of the turret head.

The calipers that inform the tool of the feed movement 3 and 5 move along the guides 6 of the bed, the spindle headstock 2 is mounted on the bed 7. The tray 10 is used to collect shavings. Control handles are located on aprons 8 and 9.

On a lathe-turret machine, you can immediately carry out processing with tools that are fixed in the transverse caliper 3 and in the turret head 4, which makes it possible to increase productivity with the help of parallel processing of planes with several tools. Increasing the profitability and productivity of the machines is facilitated by its initial setting for processing a given workpiece and further work on stops 11.

By shape, revolver heads are divided into prismatic and cylindrical (most often with six faces). After each working stroke, the turret rotates, and the next cutting tool or group of tools, which are located on a special mandrel, occupies the working position.

The main parameters of lathes and turret machines are the maximum diameter of the processed bar and the maximum diameter of the processed surface of the artificial workpiece above the caliper and above the bed. The main parameters also include the overall dimensions of the working area of the machine, which determine the maximum length of the processed part, and speed characteristics.

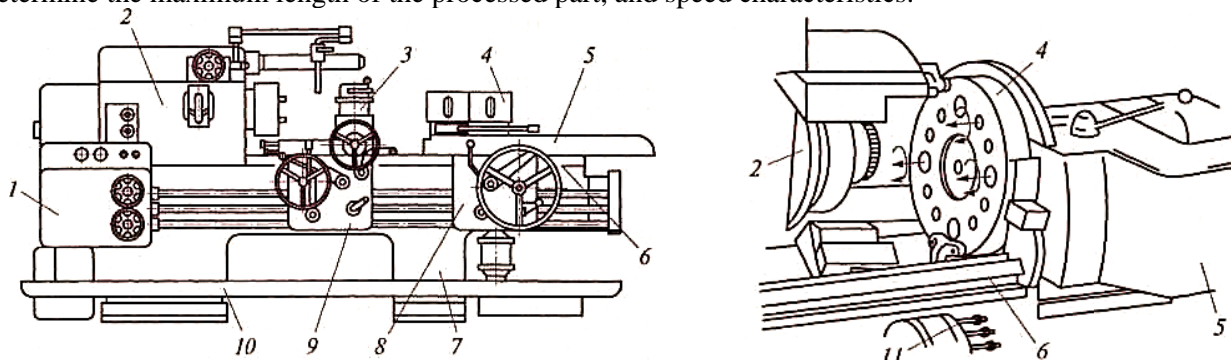


Fig. 4. Location diagram of a lathe-turner automatic machine: 1 – transmission box; 2 – spindle headstock; 3 – transverse caliper; 4 – revolver head; 5 – longitudinal caliper; 6 – guide; 7 – bed; 8, 9 – aprons of transverse and longitudinal calipers; 10 – pallet; 11 – emphasis.

Source: grouped by author based on [1, 9, 10]

The main movement of the lathe-turret machine is the feed movement: transverse and longitudinal (in machines with a horizontal axis of the turret head - circular due to the rotation of the head) movement of the calipers that feed the tool; movement of the spindle that feeds the workpiece.

The main components of a lathe-turret machine with a vertical axis of the turret head are largely the same in design as the components of lathes.



The spindle headstock of large and medium-sized machines has a built-in speed box, which provides a small adjustment range and a small number of steps of the spindle rotation frequency, compared to the same unit of a lathe. Only the spindle is installed in the spindle headstock of small machines. The speed of rotation of the spindle is adjusted with the help of a reducer, which is installed in the base of the machine and connected to the spindle by a belt transmission.

Gear box 1 is structurally simpler than the gear boxes of lathe-screw-cutting machines, since lathe-turret machines have a smaller range of adjustment of the rotation frequency and a smaller number of gear stages. In addition, there are no elements in the feed box that are required for cutting threads with a cutter using a lead screw.

A lathe-turret machine with manual control is considered a universal machine. On such a machine, you can make parts from a bar and from artificial blanks that are fixed in a chuck. The machine is equipped with a hydraulic drive for clamping and feeding the bar into collet chucks (with a bar tolerance of ± 1 mm). Artificial workpieces are clamped using a special chuck attached to the machine. Lathe-turret automatic machines were developed on the basis of lathe-turret machines.

Lathe-turret automatic machine, the scheme of which is presented in fig. 5, makes the processing of parts of a rather complex configuration.

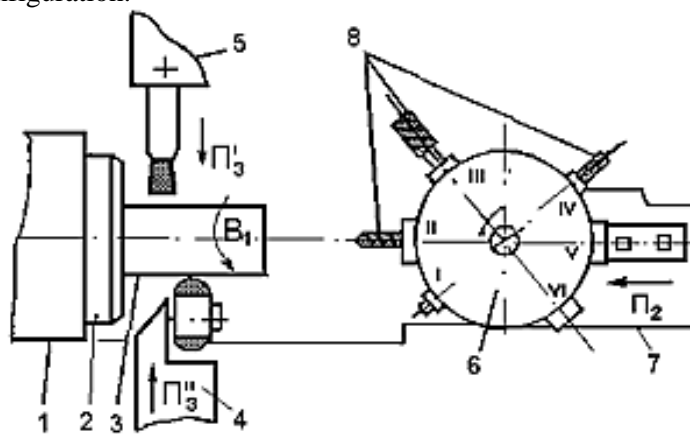


Fig. 5. Scheme of processing on a turning machine

Source: grouped by author based on [1, 9, 10]

The workpiece-bar 3 is fixed in the spindle 2 and receives the main rotational movement.

Turret head 6, fixed on a turret caliper 7. Tools 8 are placed in it in a certain sequence, starting from position I, where a stop limiting the feed of the rod is installed. The turret head, after the end of the operation, for example, drilling in position II, moves away from caliper to the right and turns by $1/6$ of a turn, driving another tool into the processing area, for example, a countersink in position III.

Caliper 7 provides longitudinal feed to tools 8.

The automatic machine has three, and in some models four, transverse calipers 4 and 5, which provide transverse clearance and cut-off.

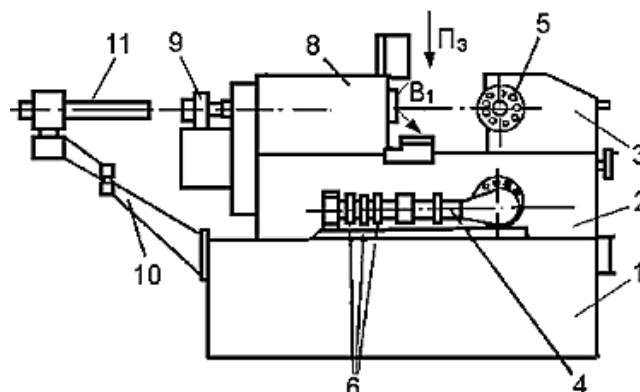


Fig. 6. The device of a lathe-revolver automatic machine

Source: grouped by author based on [1,9,10]



The device of a lathe-revolver automatic machine is shown in Fig. 6. Based on 1, which houses a gearbox with an electric motor. The cabinet with electrical equipment and units of the lubrication and cooling system are placed in the frame 2, along the guides of which the longitudinal turret support 3, which carries the turret head 5, moves. In the left part of the frame, there is a spindle headstock 8, in which the spindle with a collet clamp rotates.

Transverse calipers 7 and a rod feeding and clamping mechanism 9 are placed on the frame.

On the left side of the base 1, a bracket 10 and a supporting pipe 11 are fixed for placing the processed rod in it.

The camshaft 4 with cams 6 is located on the front wall of the bed, and the auxiliary shaft is mounted on the rear wall.

Lathe-turret single-spindle automatic machines of models 1D112 and 1D118 are designed for mass and serial production of parts from round, hexagonal and square calibrated bars. Machines can, with appropriate cutting modes, process various metals: from copper to hard steels. The machines are supplied in a universal version with a set of replaceable gears, collets and various holders.

3. Research purpose and tasks

The purpose of the article is to use innovative methods to expand the functionality of a single-spindle lathe-turning machine using shaped cutters and by developing a methodology for calculating and adjusting cams. To achieve the goal, it is necessary to solve the following tasks:

- conduct an analysis of known device designs and determine their advantages and disadvantages, which can be used to increase the efficiency of the machine;
- to propose a methodology for calculating shaped cutters;
- develop a methodology for calculating and adjusting cams;
- perform a technical and economic justification of the feasibility of expanding functional capabilities.

4. Results of the researches

Tool support. Technological processes of metal processing by removing shavings in order to give the parts specified shapes, sizes and quality of surface layers are carried out with cutting tools. Almost all turning operations can be performed on automatic lathes. The cutting tools are installed in the holders of the turret head and the transverse caliper. The combination of a transverse caliper with a turret head allows you to process several surfaces at the same time.

In the literature, technological recommendations for effective processing of parts are given, but the problem of improving such recommendations will always remain relevant, as new designs of cutting tools are developed, the technological capabilities of machine tools are expanded, and the requirements for the quality characteristics of the processed surface are increased. Accordingly, the existing technological recommendations lose their relevance and require further improvement. Taking as an example the processing of internal holes in a solid material by drilling with axial blade cutting tools, we established that the most labor-intensive processing by cutting consists of the technological transitions of drilling - 36%, milling - 26%, turning - 25%, all other types of processing together make up only 13% .

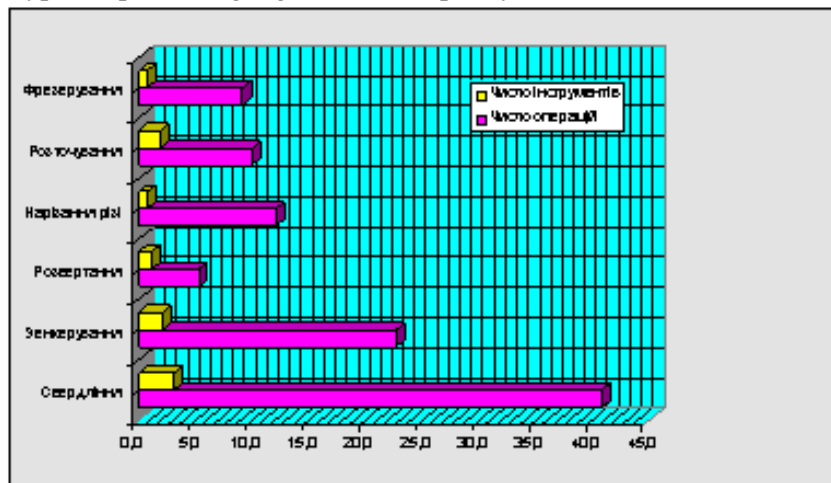


Fig. 7. Analysis of the labor intensity of technological transitions



The use of innovative methods to expand the functionality of the turning machine. To reduce labor intensity and increase the productivity of work on the automatic lathe, we used shaped cutters.

Shaped cutters are used for processing external, internal and end-shaped surfaces of bodies of rotation on lathes, semi-automatic and automatic machines, as well as for processing various shaped surfaces on planing machines. They have a number of advantages in comparison with ordinary cutters - high productivity, dimensional accuracy, identity of the shape of products that do not require high skill of the worker.

According to their design, shaped cutters are more complex than ordinary cutters of general use and are highly specialized, that is, they are designed for processing blanks of one profile. This is a relatively expensive tool and it is used mainly in large-scale and mass production.

However, recently, shaped cutters began to be used in small series and single production, especially when their use is due to technical necessity - it is impossible to obtain the required surface in another way.

Shaped cutters can be classified according to various features [6]: according to the tool material (hard alloy, high-speed cutting), according to the feed direction (radial, tangential), according to the location of the mounting base (cutters with a parallel arrangement of the base and the axis of the workpiece and with an inclined one), according to the structural form (flat and rod, prismatic and round) etc.

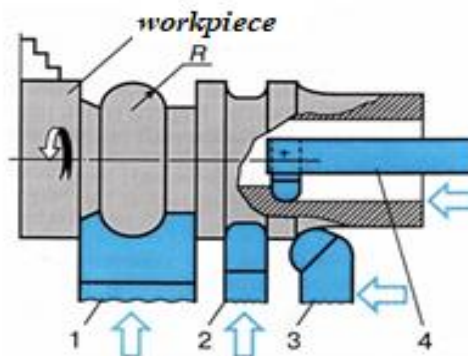


Fig. 8. Rod shaped cutters: 1 – complex profile; 2 – radial groove; 3 – external gallet; 4 – internal halt

The simplest design is a rod shaped cutter with a welded or soldered cutting plate (Fig. 9). Due to the complexity of the profile, shaped cutters are ground not on the back surface, but on the front. The disadvantages of rod cutters include a small amount of allowable resharpening.

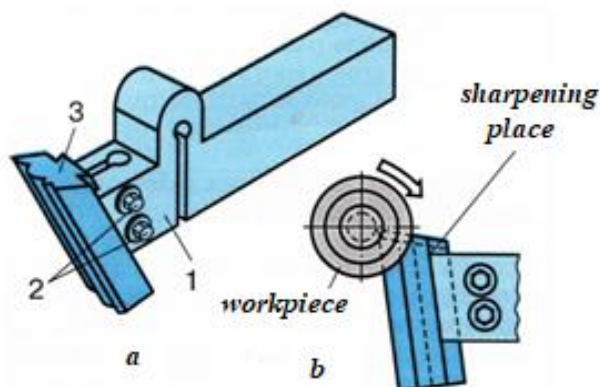


Fig. 9. Prismatic shaped cutter: a – assembled with a holder; b – installation diagram (1 – holder; 2 – screws; 3 – cutter)

A prismatic cutter can withstand a large number of resharpening operations (Fig. 9). The profile of its back surface corresponds to the given shape profile of the part. The cutter is fixed in a special holder with a dovetail shank, and in order to form a rear corner, the cutter is installed with an inclination towards the sole of the holder. Resharpening of the cutter is performed by grinding the front surface.

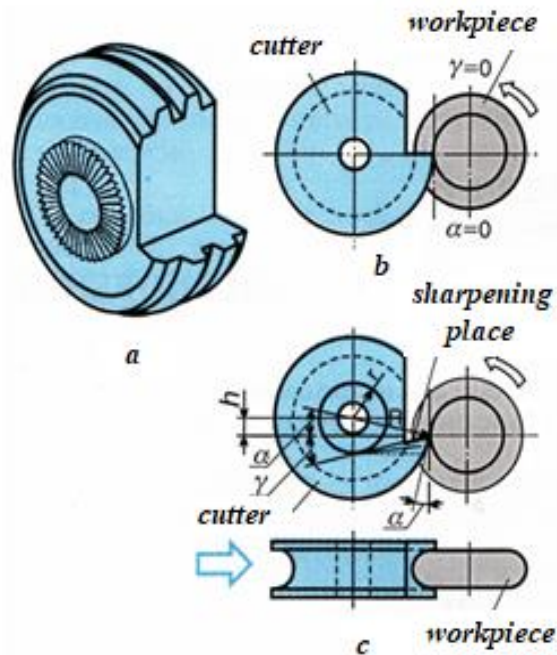


Fig. 10. Disc shaped cutter: a – construction; b – setting in the center of the workpiece ($\alpha=0$); c – setting higher than the center of the workpiece ($\alpha>0$)

Disc (round) cutters with a shaped outer surface have become widespread. A shaped cutting edge is formed at the intersection of the plane of the corner cutout with the outer surface. The cut is made below the center of the cutter, and the center of the cutter is set higher than the center of the workpiece (Fig. 10), which ensures positive values of the front and back angles. The front surface of the cutter is resharpened tangentially to the conventional circle, the radius of which

$$r = R \sin(\alpha + \gamma) \quad (1)$$

where – α is the specified rear angle; γ – is the given front angle.

After each resharpening of the front surface, the disc cutter is rotated on the axis of the holder, reinstalled in the center and fixed. The teeth on the end of the cutter and on the end of the holder prevent the cutter from twisting due to the forces arising during cutting [17-20].

To reduce the vibration of the workpiece when processing with a shaped cutter by the method of transverse transmission, the surface is pre-drilled with a through cutter, leaving a small allowance for final processing with a shaped cutter. Mode of turning with a shaped cutter: feed 0.02...0.1 mm/rev (before the end of the working stroke, the feed is reduced); cutting speed up to 30 m/min.

5. Conclusions

The analysis of the existing designs of automatic lathes and tooling showed that the existing designs need to be modernized. An analysis of the advantages and disadvantages of various designs of lathe-turning machines, a comparison of automatic and semi-automatic machines was carried out. The analysis of tooling showed that it is really beneficial to use shaped cutters, because it reduces the time of technological transitions, thereby improving production. Shaped cutters can be used expediently in productions of various series.

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ІННОВАЦІЙНІ МЕТОДИ РОЗШИРЕННЯ ФУНКЦІОНАЛЬНИХ МОЖЛИВОСТЕЙ ТОКАРНО-РЕВОЛЬВЕРНОГО ОДНОШПИНДЕЛЬНОГО АВТОМАТА

Токарно-револьверні автомати, що представляють собою автоматизовані револьверні верстати, отримали широке застосування у великосерійному і масовому виробництві.

Використання автоматів в дрібносерійному виробництві, що має значну питому вагу в приладобудуванні, до останнього часу вважалося не доцільним внаслідок того, що їх переналадження займає багато часу.

В даний час завдяки розширенню методів обробки, що дозволяють з мінімальною витратою часу переходити від виготовлення однієї деталі до виготовлення іншої деталі тієї ж групи, автомати отримують все більше застосування в дрібносерійному виробництві.

Впровадження інноваційних методів для розширення технологічних можливостей автоматів повинно йти не тільки шляхом збільшення точності обробки, більш широке використання розширення функціональних можливостей можна реалізувати за допомогою оснащення допоміжними



приспособуваннями, які можуть виконувати операції, які покращують виробництво деталей. Одним із шляхів покращення продуктивності токарного автомата є застосування фасонних різців, які дають змогу обробляти деталь швидше, так якісніше, та за допомогою розробки методики розрахунку та налаштування кулачків.

Розширення технологічних можливостей машин-автоматів повинно йти не тільки за рахунок підвищення точності обробки, більш широке використання розширення функціональних можливостей може бути реалізовано шляхом оснащення їх допоміжними пристроями, які можуть виконувати такі операції, які покращують виробництво. Одним із шляхів підвищення продуктивності токарного верстата є використання фасонних різців, які дозволяють швидше і якісніше обробляти деталь, а також за допомогою розробки методики розрахунку і регулювання кулачків. Тому тема статті є актуальною.

Ключові слова: комплекс, функціональні можливості, верстат, обладнання, процес обробки, інноваційні методи, вібрації, ефективність.

Ф. 1. Рис. 10. Лім. 20.

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