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AUTONOMOUS AUTOMATED ACCUMULATING COMPLEX FOR THE ROBOTIZED PUNCHING PROCESS

The accumulating complex was designed for automated loading with discoid billets of unified single-crank presses in robotized punching processes. Advanced variants of the task practical implementation by means of technical, diagram, design upgrading and processing equipment retooling are suggested. Raising the productivity and reliability of the facility, simplifying and cheapening its construction is based on the use and integral combination of possibilities provided by «active», «passive», information parameters influence on the formation and correction of operational production flows of its function supporting systems.

Keywords: special tooling, accumulating complex, billets loading, robotized punching processes, automation, innovations.

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АВТОНОМНИЙ АВТОМАТИЗОВАНИЙ НАКОПИЧУВАЛЬНИЙ КОМПЛЕКС ДЛЯ РОБОТИЗОВАНОГО ПРОЦЕСУ ШТАМПУВАННЯ

Створено накопичувальний комплекс для автоматизованого завантаження штучними дископодібними заготовками уніфікованих однокривошипних пресів у роботизованих процесах штампування. Запропоновано сучасні варіанти практичної реалізації поставленої задачі технічним, схемним та конструкторським модернізуванням і переоснащенням технологічного обладнання. Підвищення продуктивності й надійності роботи засобу, спрощення й здешевлення його побудови засновано на використанні та комплексному поєднанні можливостей впливу «активних», «пасивних», інформаційних параметрів на формування і корегування операційних виробничих потоків систем забезпечення його функціонування.

Ключові слова: спеціальне оснащення, накопичувальний комплекс, штучне завантаження заготовок, роботизовані процеси штампування, автоматизація, інновації.

Formulation of the problem. One of the important tasks in automating the production processes of punching is arrangement of automatic loading and billets orientation. It is particularly important through the lens of reducing the unattractive manual labor and increasing the efficiency of technological equipment.

Despite numerous research and engineering developments, this problem can not yet be considered completely solved for the class of small and medium-sized articles such as plates with implicitly expressed design features (orientation keys) and distinctive physical and mechanical properties (which are expressed, for example, in the process of metal billets transportation by sliding as a result of structuring and the residual magnetization of their surface layer, in the case of using billets from materials of reduced rigidity and strength, friability, etc.) because such kind of articles is impossible to apply traditional automation operations on loading and orientation of billets with mechanical entrapment. Their designing is a complicated research and technical problem, and the search for the latest solutions involves the use of knowledge, experience gained on the need for a comprehensive set of measures in the individual operations automation using industrial robots in various production fields:

- engineering improvement of universal technological equipment;
- upgrading the construction of the part (billet) itself, which should be suitable for the conditions of its manipulation with the possibility of entrapment, transfer and accurate positioning in the operating space;
 - changes in the technological process in order to adapt it to the technical capabilities of the existing industrial robot that is available or purchase this process for servicing;
- selection of the parts orientation devices (it should be noted that the choice of the parts orientation method and the choice of the bases for their entrapment during transportation are closely linked);
- selection of part magazine (billets) (the use of billets storage units reduces the time spent by personnel while robots work preparation, and allows to combine technological equipment of different efficiency into a single cycle);
- manufacture of new special or specialized equipment (design and manufacture of such additional equipment, as well as improvement of the technological equipment itself, normally require comparatively little time and can be performed by the own efforts of the manufacturer);
- special measures to provide safety (security);
- development of the layout scheme, planning mutual arrangement of the technological equipment, robots, operation panels, loading mechanisms, storage magazines, containers and vehicles in the exact compliance with the technological procedure of production operations performance and requirements to the accuracy of positioning;
- design and control over the processing sector operation algorithm (preceded by the development of technological processes and technological calculations (determining the processing mode and time, necessary and possible auxiliary and final time determination, the robot actuator operation best trajectories and velocities and cycles and cyclograms, determining the storage magazines capacity calculation).

Recent research analysis. The known similar solutions of such tasks are implemented in the modern equipment complexes for punching articles using the single-billet loading [1 – 14]. In the above works data are presented on their composition, structural architecture, operation, specifications and capabilities. Consideration of the existing developments features allows analyzing and characterizing them from the standpoint of analogues when selecting and comparing structural elements, the operation and configuration principle, interaction type; it gives them an assessment from a constructive, technological and economic point of view, unifying nodes and parts etc.

Such technological complexes are based on the use of magazine, stack and bunker types of accumulating (storage) devices [15, 16]. Analysis of their layout indicates the existence of several target nodes (tools) common to all of their three types: charge capacity, trapping device, accumulating device, cut-off devices, power supply, reset, activator of movement, manipulator of oriented billets supply to the punching zone, drives. The variety of designs is developed due to variations in the layout and ways of implementing these specified facilities. The simplest version of the technological complex is a unified press equipped with one of the supply or feeding types. Currently, slide gate devices, revolving or clamshell loaders, manipulators and industrial robots are generally used [see. 9 to 19].

Such developments are cinematically complicated, characterized by a large number of friction pairs and considerable dissipation of energy, they have limited lifetime and require preliminary preparatory and routine operations, require high precision of their components manufacturing and their adjustment using specialized processing equipment. In a number of cases, they are complicated, expensive in cost, provide for the maintenance by trained personnel. But their disadvantage is that they can not be universal due to the existence of manufactured objects wide variety and complexity; the broad spectrum of functional tasks to be solved, principles and methods of their realization; the use of materials that do not completely satisfy the whole set of technical and technological requirements, their compatibility and other factors.

Identification of previously unsettled parts of the general problem. High return of the equipment included into the flexible production systems requires, as a rule, its equipping with automated billets (parts) warehouse, as well as the tools and special equipment necessary for the uninterrupted operation of the studied manufacture types.

Development of production systems in order to improve the operation reliability and timely provision of all elements within the technological process includes the use of perfect upgraded systems to ensure their functioning. At the same time, experience shows that the increase in the level of automation is achieved by a significant complication of structures and technological equipment systems, and, consequently, increase in their cost. Therefore, the required level of automation must be economically justified.

Expansion of the robotic system spheres of application, emergence of compact and simultaneously powerful performing facilities, development of technical automation means, elemental base, circuitry and control systems enable the use of a higher level design, introduction of new technical solutions, approaches and principles of operation when creating adapted special technical equipment for the preparatory stages of particular industrial production processes, where the use of traditional means is inappropriate or does not permit to technically solve the problem as a whole. Such problems are solved by introducing constructive technical changes in the transport routes, orientation, sorting, billets discharge, performing nodes, entrapment devices, equipping the latter with auxiliary external information sensors that respond to the presence of the manipulation object, its shape, size, weight, surface condition, clamping force, sliding, positioning etc.

Statement of assignment and methods of its solving. The purpose of this processing tool is development of multi-product loading and accumulating automated complex for single-piece disc-shaped billets feeding that functions interactively in flexible manufacturing robotic connection with the universal single-crank presses and combines the possibility of coupling with the available processing equipment of the present-day machine builder, with minimal modifications of the existing auxiliary equipment, by the authors' own efforts, in compliance with emerging innovation trends.

Study results and their discussion. The paper suggests consideration of technical implementation options for autonomous accumulating complex, designed to serve single-crank presses of single-action, open, with a normal force of 250 kN, in compliance with the

existing standard GOST 9408-89, and provides obtaining pressed articles (perforated parts from the disk-shaped billets) by means of loading billets in bulk into the storage hopper, their further orientation, sorting, single-piece feeding, synchronous with the press's operation feeding to the punching press, punching (hole perforation) and stipping articles off from the punching press. Performance of the operations given sequence and the nodes coordinated operation is provided by the electronic control unit.

The presented development in general represents the totality of functionally connected facilities and devices constructively united on the general sequential logic principle of operation, and includes the loading bunker device (storage-hopper), sloping storage magazine of billets, standard one-crank press, special structure punch, device feeding billets to the punch: pneumatic manipulator KMO.63 C 4212, device for removing products from the punch, device for controlling the technological complex.

Technical data and specifications of the development:

Number of billets loaded simultaneously into an empty bunker, pcs.	600
Loading lot weight, kg	24
Diameter of billets, mm	60
Thickness of billets, mm	1,5
Operating modes:	a) «manual»; b) «automatic»: – «single», – «cyclic»
Average productivity of the complex in the automatic mode at full loading of the bunker with billets, punched articles per minute (pcs. / min)	40
Mean duration of one cycle, sec.	6
Capacity of the slip storage magazine, pcs.	8
Positioning accuracy, mm	$\pm 0,2$
Rotation angle of the feeding device rod, degrees	45 - 240
Supply voltage, V	220 / (-24)
Air pressure in the performing mechanisms' line, MPa (kgf / cm ²)	0.45 (4.5)
Billet loading bowl dimensions, mm:	
diameter	450
height	150

The components interaction of the developed complexes and their work by operations are described below and, for clarity, explained by the scheme of the bunker-loading vibration device (Fig. 1) and by the block diagram of the technological complex control device (Fig. 2).

Disks-billets, of the given diameter and the fixed thickness, are loaded «in bulk» into the bunker-loading device (Figure 1). By means of electromagnets (4) the bunker is brought into oscillatory motion. The bowl (1) of the vibro-bunker with the screw-shaped transport track is installed on the inclined elastic-spring supports (6). Due to such mounting, vertical and horizontally tangential perturbation components are transmitted to the billets. Under their influence, orientation (the billet lies flat), stratification and circular movement of the billets are performed. The profile of the accumulator's bottom (2) has a small slope from the center of the bowl to the walls and ensures the billets displacement during their movement to the periphery of the bunker and on their way to the transport track. The billets are aligned one by one and move along the spiral of the tray.

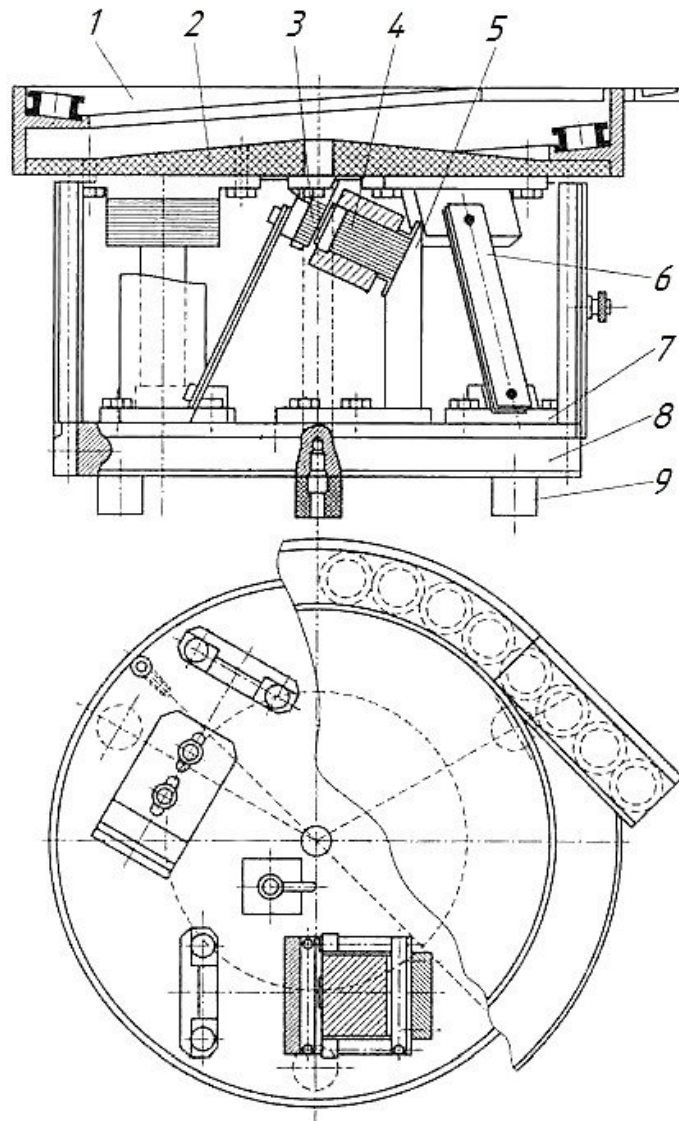


Figure 1 – Diagram of the bunker loading vibration unit:

- 1 – bowl for loading billets; 2 – textolite conical bottom;
- 3 – anchor; 4 – electromagnetic vibrator; 5 – vibrator mount column;
- 6 – suspension (elastic spring support) mounting the storage bunker bowl;
- 7 – bracket; 8 – foundation; 9 – shock absorber rubber

To eliminate the overlapping movement of the billets, sorting them from deformed disks and those with large burrs along their pathway, an «active» cramping-proof slot is made. It is formed by the rubberized ejector shaft, the axis of which is located downstream at a small angle (approximately 30°) to the tangent of the transport track reference circle. The height of this slot is regulated and set about 1,5 of the billet thickness. The ejector shaft drive rotates at high speed, entraps the topping billet and ejects it through the inner side wall of the tray into the storage bowl. The billet repeats the pathway covered. The rotation frequency of the ejector motor shaft has two discrete values and is set from the control panel.

The billets output from the vibro-bunker tool of the storage device is of a probabilistic, random nature. To ensure the coordinated operation of the storage device and the press, the complex is equipped with an intermediate inclined storage magazine.

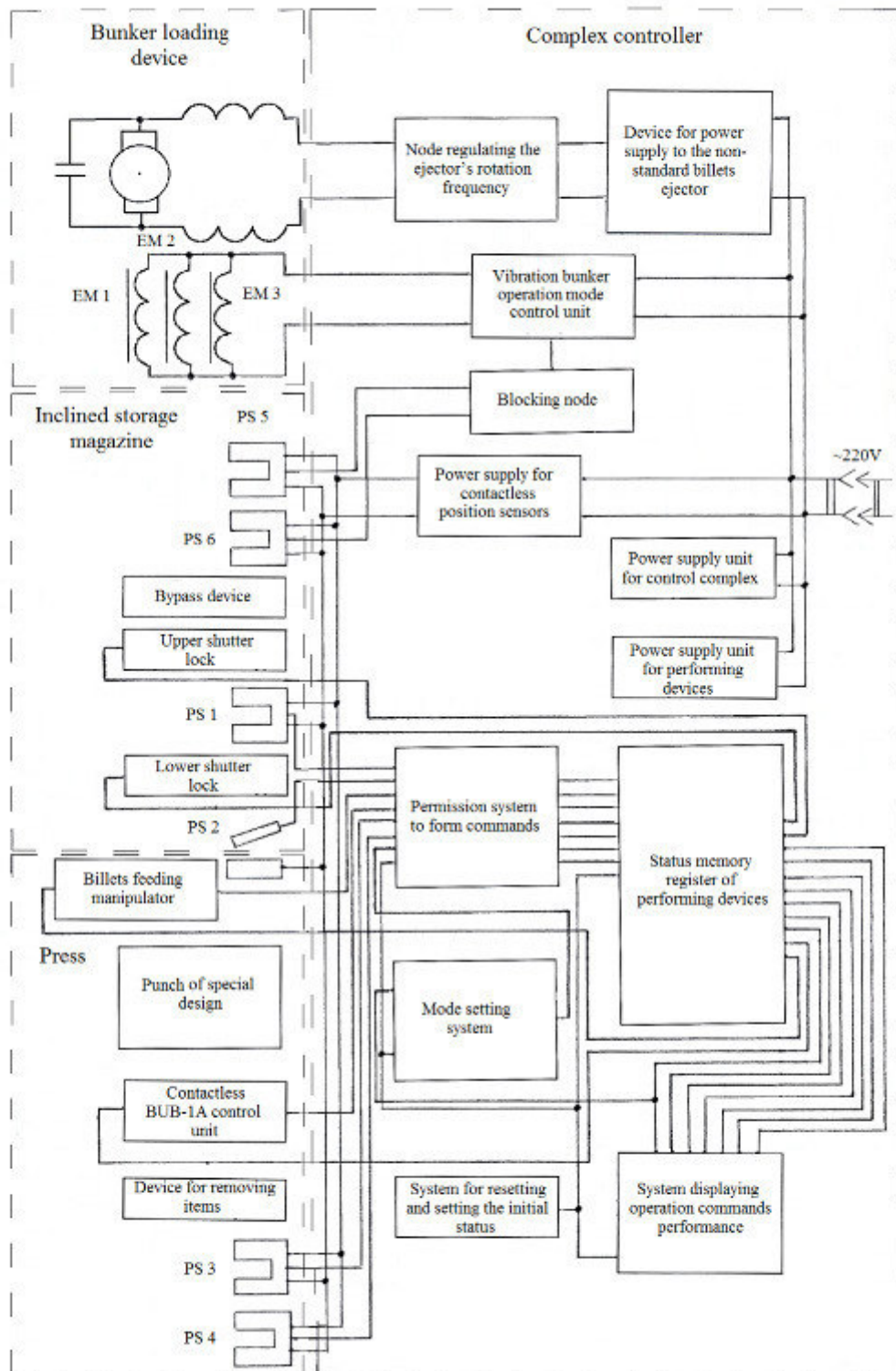


Figure 2 – Block diagram of the device for controlling the robotic processing punching complex

In the initial state (Figure 2), the lower electromagnetic shutter of the bypass device, the «feeder» of the inclined storage magazine, is closed, and the upper one is open. Billets follow one by one from the vibro-bunker device and, under the influence of the component gravity, fill the storage magazine. When forming a stack of 8 billets, using the contactless position sensors PS 5, PS 6 and the logical locking device, the drive of the vibro-bunker device is disconnected, feed of the billets stops and overflow of the inclined storage magazine tray is eliminated. When feeding the billet into the press punch and reducing the stack, the logical device switches on electromagnets of the vibro-bunker and carries out the additional filling of the magazine. The process is repeated. The filling of the inclined storage magazine does not depend on other proceeding operations, it is performed simultaneously with the press operation. The best accumulation mode is selected by the optimal conditions for vibrotransporting of billets into the vibro-bunker by choosing the vibration amplitude, by adjusting the voltage supplying electromagnets EM 1 – EM 3 (with the constant previously selected stiffness of the inclined elastic columns (6) and width of the gap: anchor (3) – electromagnet magnetic conductor (4) of the drive), visual control of which is performed by means of the voltmeter built-in on the control panel.

In the «operation» mode, if there is a billet in the initial position in the storage tray of magazine (sensor PS 1 between the electromagnetic shutters of the bypass device is set in the logical «one» position) and there are no interlock signals, the control device switches on the bypass device (the lower electromagnetic shutters' stops are lowered, those of the upper ones are raised), and the billet slides from the storage magazine tray onto the surface of the matrix and moves slowly along it. At the time of slipping, the PS 2 sensor is activated, which trigs the single-shot pulses shaper with the constant duration sufficient to switch on the device of feeding a billet into the punch. According to the circuit design, the bypass device is in the «on» position from the moment the «start» command given up to the moment when the position sensor PS 2 is activated. All this time the upper electromagnetic shutter stops of the bypass device are in the raised position, keeping the next-to-the-last and the above disposed billets from slipping and falling into the punch.

The ramming device, designed on the basis of the unified pneumatic manipulator KM0.63 C 4212, through the V-shaped entry by means of the rod, sends the billet until bumping into the opening of the matrix node and ensures the alignment of the billet geometric center with the vertical mandrel of the punch. The ramming device drive is actuated by the electro-pneumatic valve by the command of the PS 2 position sensor.

Moving the rod of the ramming device is regulated by the location of the stops, which the angle of the air engine shaft rotation is varied with. Speed of the drive shaft's rotation in the forward and reverse direction is changed by means of the pneumodrossels Dr 1, Dr 2. Constructively, the device has a track microswitch, triggered from the camshaft mechanism at the end of the drive shaft backward stroke and signalling that the operation of the billet ramming to the punch is completed. After this command, the press start circuit generates a single pulse and actuates the press by the electronic control unit BUB – 1A. The article punching (perforation) is being performed.

BUB – 1A has a perfect control system and only performs the operation if all the functional units, press systems are properly operating, there is no interlocking signal and the energy carriers' parameters are within the normal limits. Therefore, due to the presence of the press drive actuation pulse, we confirm the fact of the punching operation performing. This principle is the basis of the processing operation completion control and it allows to avoid installing additional position sensors. The punching completion control circuit is connected in parallel to the electropneumatic valve of the press drive and generates the command signal for the subsequent ejection operation on the trailing edge of the press start pulse, i.e., after the punching completion (holes perforation). Wherein, according to functional features of the press, this signal ends when the press rod rises to the upper position.

To be safe, the electropneumatic valve of the device for stripping the article off the punch is opened with a short delay. The pneumatic cylinder is activated. Its shaft pushes a punched (perforated) disk from the punching unit and sends some progressive pulse to it. The disc falls into the inclined chute and under the action of the component gravity slides into the receiving bunker of the finished parts.

In the process of ejection, the «flag» rigidly connected to the shaft in the extreme right position of the ejector enters the gap of the PS 3 generator sensor magnetic conductor, at the signal of which the direction of air supply to the cylinder changes. The shaft returns to its initial position. It is identified by the signal of the logical «one» from the position sensor of the PS 4 ejector initial state. This signal is simultaneous with the signal for the processing system cycle operation completion.

From the control panel, actuation of the system operation is envisaged in the «manual» and «automatic» modes.

In the «manual» mode, there is a possibility of individual units' sequential actuation: the bypass device, the ramming device, the press, the ejector, as well as one complete cycle of the system operation in the «single-piece feeding» mode when the «Start» button is pressed.

In the «automatic» mode, the signal from the PS 4 sensor at the end of the cycle is the command for performing the subsequent cycle by the system. Thus, its operation cycle-after-cycle is repeated according to the algorithm described above.

The electronic control device of the complex has a number of interlocks, ensuring its reliable operation.

Each subsequent operation can be performed only after the completion of the previous one. For this purpose, in the control device there is a register of memory cells to store information about the condition of the respective unit, which are set into the initial «zero» position before the beginning of each operation cycle. Information on the operations progress for visual inspection is output to the control panel via a display system. It is visual and necessary both in the setup mode and in the operating mode.

The start-up of the complex can only be performed when the ejector's shaft is in the extreme left position, derived from the matrix, and in the presence of the billet in the initial position in the inclined storage magazine.

The press can only be started when the ejector shaft is withdrawn in both «automatic» and «manual» modes.

In the «manual» mode, if two or more buttons are pressed simultaneously, the control command will not follow. Control can only be carried out by a single performing device.

At any time, at any stage of operation, it is possible to stop the complex operating by pressing the «Stop» button.

With the help of this development, high-performance, reliable, inexpensive, flexible, technology-based punching systems with piece loading of billets can be designed and equipped with auxiliaries, which are fundamentally different from the industrial and prior-art analogues. Such technological means can be easily implemented and operated both independently and within the functional lines. It is possible to modify the developed version depending on the functional tasks to be solved and the parts manufactured type changes, under the operations previous algorithm, by introducing structural changes in the vibration transport tracks, orientation nodes, storage magazine or by their replacement.

In order to improve the performance and reliability of the developed tool, special equipment and electronic position sensors, contactless control circuits for actuators and mechanisms are constructed; operating, diagnostics, control, and locking systems are designed.

Conclusions. The accumulation complex was designed for automated loading of discoid workpieces (billets) into the unified single-crank presses in the robotized punching processes. The present-day variants of the task practical solving by means of engineering,

circuit and design modernization and retooling of the processing equipment are suggested. Improving the productivity and reliability of the device operation, simplifying and cheapening its construction is based on the use and integrated combination of the «active», «passive», information parameter possibilities influencing the formation and correction of operational production flows in systems ensuring the device functioning.

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