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Automatizing the Auxiliary Operations of a Superfinishing Machine

Part II. Development of structural compilation variants

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Abstract: *The paper investigates and determinates the rate of "automation-friendliness" of pistons, accomplished according to the methodology of department "Automation of discreet production". The object is analyzed, also the technological process, operational transport, the location of machines and devices in the workshop. Different variants of construction are investigated. The variants are analyzed.*

Keywords: *Automatic lines, technology, superfinishing, hydraulics, pumps, automation, industrial robots.*

1. Introduction

The subject of this paper is a continuation of Part I Analysis of the Technological Process and Performance of Superfinishing treatment of Pistons for Axial Piston Pumps and Motors. After analyzing the technological process for the superfinish treatment of pistons for gamma axial piston pumps and motors, the necessary theoretical and actual basic operation times and total off-cycle losses were determined, defining the respective one-hour, eight-hour and yearly productions satisfying the possibilities of automating semi- automatic superfinishing machine.

The aim of the present work is to develop and analyze structural compilation of innovative variants with the installation of automatic modules for automating the auxiliary feeding/unloading operations of the semi-automatic superfinishing machine (SAMS) of the pistons and the selection of the most suitable innovative variant that satisfies specific the working conditions [1].

2. Determining the "automation-friendliness" of the pistons

Research and determination of the "automation-friendliness" of the pistons is carried out according to the methodology of the Department of Automation of Discreet Production [2]. It is a complex indicator that analyses the design and technology from the point of view of: preparation for automatic production, development and assembling of units, maintenance and repair of the pistons. Technology and fitability requirements are particularly important for large-scale, mass or over-mass production [2, 3, 4, 5, 6, 7].

The shape and dimensions of the piston Bt.17 [01.A] is shown in fig. 1 in the text of Part I. The element analysis is done by a differential scheme to evaluate the parameters, arranged in seven steps whose numerical code markings for each rate take into account the complexity of the automation to perform the operations [2, 6, 7, 8, 9, 10, 11, 12,].

The total mark of the pistons is $B\Sigma = 1 + 0 + 0 + 2 + 1 + 4 + 5 = 13$ [2]. From the "characteristic for the complexity categories of automation" $K_{av} = 2$ [2], i.e. the automation is of medium complexity. It is necessary to be developed a system for orientation and feed of the parts/preforms. It is advisable to carry out an experimental check.

3. Analysis of the object

Considering the developed common technological process, between the operational transport, the location of the machines and the devices in the workshop is analyzed the technological process of the basic and auxiliary operations for superfinishing of the pistons of the existing SASM.

The automated feeding supply to SASM is built on a systematic approach, consistent with several steps using appropriate modular elements, produced by high reliability and performance companies such as Bosch Group-Rexroth, SORMEL, Valley Automation Ltd, Acco Industries Inc-non-Mar, Feeder System, SMC, FESTO, Simens [5, 8, 9, 10].

4. Development of Structural Component Variants

In Fig. 1 and Fig. 2 are shown modules and elements involved in the innovative structural components of SASM [2, 5, 6, 7, 9, 10, 11, 12]

4.1. Variant 1. The structural component consists of: Vibratory Bunker Feeding Device (VBFD) with a cylindrical cup 1.1 or with a conical cup 1.2. LVBFD 1.3 is used to maintain a constant level of pistons in VBFD cups. Its base is inclined by $\theta = 3^o \div 5^o$ with the help of a pneumatic cylinder 1.4, a lift of Linear Vibratory Bunker Feeding Device (LVBFD) is provided up to $\alpha = 25^o \div 30^o$. Pistons must be (correctly oriented) with the head in the SASM work area. If they are moved with the holes forward, they are oriented by a hook 2.1. It enters to the piston hole, starts to rise upward under the action of the next transported pistons, and reorients to 180º, reversed with the head forward. There are also two options for orientation with a guiding device 2.2 rotatable at 90º or an orientation device 2.3 rotating 180º.

The pistons thus oriented are moved to the SASM: on a sloped channel-chute 4.1 under their own weight, or by a two-shaft roller conveyor system 4.2 with angled displacement of the axle line of the rollers or by using a LVBFD. All three types of transport systems also appear as piston collectors. With the installation of sensors on the transport systems, a piston stock is always maintained, and the VBFD can operate for a certain period of time.

4.2. Variant 2. With this option, transportation and guidance are simultaneously carried out by a bunker feeder with hooks. The pistons are pour in the VBFD's housing. After turning the hooks 3.1 they are penetrated into the pushed pistons in the casing 3.2. At this point, the pistons are shaken by the movement of the hooks that enter the holes of the pistons. Thus, the forward-facing ones are transported in the hole-chule 3.3 of the VBFD housing and are fed into the transport system 4.1, 4.2 or 4.3.

4.3. Variant 3. It is performed by an elevator 5, the pistons are placed in a chaotic state in a bunker 5.2. Hence, they are taken by the moving conveyor belt 5.1 by fitting its angled slopes. Pistons through the elevator are fed to hook 5.3. If the plunger is oriented with the forward head, it passes directly into the transport system 4.1, 4.2 or 4.3. If the piston is oriented with the hole forward is hinged with the hook 5.3, it is oriented and re-entering to the transport system 4.1, 4.2 or 4.3.

The orientation can be accomplished by a square tube 5.4 in which with angled strips mounted, to ensure the pistons move by their own weight entering 4.1, 4.2 or 4.3.

4.4. Variant 4. For this option, a feeder system is used. This is achieved by 2 oppositely moving conveyor belts 6.3 and 6.4. The pistons are placed in a chaotic state on a conveyor belt 6.3 from an opening 6.5. When they are conveyed simultaneously, the pistons strike in bulkheads and through an opening 6.6 where they receive first guidance. They then pass through an aperture 6.6 in the oppositely moving belt 6.4 with respect to strip 6.3. Both conveyors moves at different speeds. The dropped pistons in stripe 6.4 move to the partitions 6.7 where they receive their final orientation and fall into a teflon plate conveyor 6.1 which feeds them into the SASM working area.

The transportation can also be carried out with LVBFD 6.2. In both versions, sensors are placed and they provides continuous feeding to SASM.

4.5. Variant 5. The company has developed means of transport (a cart carrying base cassettes) for inter-operational transport.

The pistons in the base cartridges 7.12 thus arranged are very convenient to be used by the industrial robot-portico 7. The base cassette 7.12 is placed on the pallet station 7.2. By stepper conveyor 7.3 is imported into the positioning table 7.4. Using a slot 7.1 mounted on two linear modules 7.7 and 7.8, a plane movement along the X and Y axes covering the base cassette 7.12 is provided. A vertical module 7.5 is also installed on the carriage, providing Z-axis movement. A lowering end of the module has a gripper 7.9, capable of 360º rotation around its own axis, with mounted soft jaws. The pistons are oriented in the base cassette 7.12 with the plunger head up. A program is implemented that the portable robot sequentially crawls all the cells of the base cartridge 7.12 by manipulating the pistons on a teflon plate Conveyor 7.6 automatic feed of the SASM.

This component can be used at the SASM output, by appropriate control, to split the pistons into groups over 0.001 μm to ensure the installation of the hydraulic pumps.

4.6. Variant 6. This option is compiled by Robot Hexapod 8. It is even faster. The following modulus are used: pallet station 7.2, stepper drive 7.3 for inserting the base cartridge into positioning table 7.4. The robot hexapod 8 is equipped with a gripper 8.1 rotating 360° about its vertical axis with the possibility of another movement and placing the plunger on the plate conveyor 7.16.

4.7. Variant 7. On fig. 2 is shown a designed structure 9 with modular elements of the company "Rexroth". For the three sizes are developed modules 9.1; 9.2 and 9.3. They are replaceable and are mounted in technological sockets of a linear module 9.4. At the maximum, the module contains a frame of aluminium profiles with integrated gearwheel with belt driven by a digital AC servo drive.

Through a vertical module 9.5 comprised of circular linear bearings on which a plate with built-in transition from twin screw pair is mounted, powered by a digital AC servo drive. A gripper is attached to the plate, which raises the pistons one step upwards. After a signal received by a sensor, a separator driven by a pneumatic cylinder 9.6 is triggered, the semi-finished piston enters to a transport system 9.7 and after that to the SASM.

Linear module 9.4 moves one step for each outlet. The other outlets 9.2 and 9.3 are comprised of module 9.5.

4.8. Variant 8. The last proposed structural component 10, shown in fig. 2 also consists of three size outlets 10.1; 10.2 and 10.3 for the currently viewed pistons Bt 14.2; Bt 17 and Bt 21. After a superfinishing of the piston heads, which has a working time $t_w = 60$ s, they are arranged by an outlet-oriented operator in a lying position.

The operator manipulates the outlets at a certain height before the SASM. On table. 1 is shown the parameters of the piston types, their number and weight, and the shops at the two selected heights.

After filling in the outlets with the specified number of pistons, they are locked and can be placed in the technological bed 9.7. All three outlets can be mounted on a 10.6 carriage, which can be moved both by hand and with a 9.4 linear module.

The pistons are fed to the conveyor system 9.5 by means of a separator driven by a pneumatic cylinder 10.4 by a given signal and falling into a chute 10.5 to the SASM. Pistons in outlets go down under their own weight. Outlets can be equipped with pins, cams or drums, if necessary.

Table 1. Number of pistons in outlet

No	Piston type	Variant	Parameters							
			d	l	h	$G_б$	η	ΣG_h	$G_м$	$\Sigma G_{hм}$
			mm	mm	mm	kg	pcs.	kg	kg	kg
1	2	3	4	5	6	7	8	9	10	11
1	Bt 14.2	I	14.2	55	1000	0.030	70.42	2.114	-	-
2	Bt 17		17	73.2	1000	0.080	58.82	4.71	-	-
3	Bt 21		21	93.8	1000	0.140	47.62	6.67	-	-
4	Bt 14.2	II	14.2	55	600	0.030	42.25	1.268	1.35	5.2
5	Bt 17		17	73.2	600	0.080	35.29	2.823	2.96	6.8
6	Bt 21		21	93.8	600	0.140	28.57	3.999	4.2	8.5

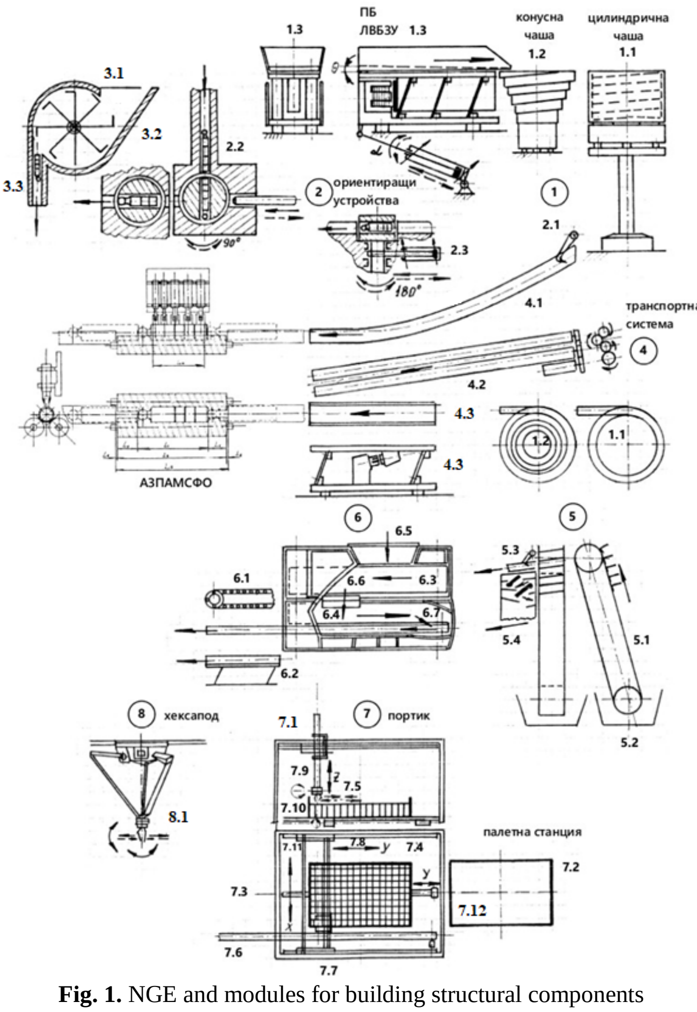

Fig. 1. NGE and modules for building structural components

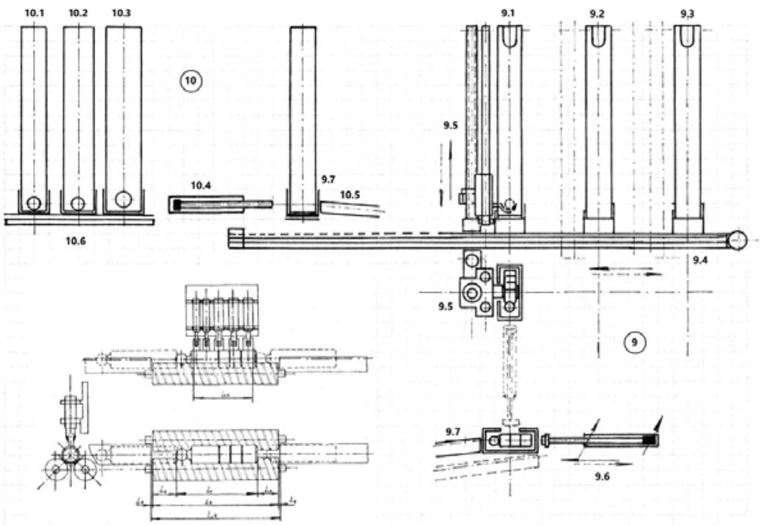

Fig. 2. NGE and modules for building structural components

5. Variant choice

At this time, it is very difficult to determine the factors that will influence to the choice of option when compiling the proposed structural components. Moreover, globalization has a significant impact on the prices of the purchasing elements and how the development effectiveness is determined. The same applies to both the wages of operators and the energy used [2, 4, 8, 11].

Efficiency as a global issue has long been a fundamental principle in shaping the philosophy of each firm and its operational strategy. It is a set of factors that combine all the costs of a producer [5, 6, 8, 9, 10, 13, 14]. The company must divide its performance policy into three areas:

1. *Energy savings*. Since automation is driven by different drives, they use different types of energy (pneumatic, hydraulic, electrical, etc.).
2. *Saving of production.* Improve the efficiency as a whole.
3. *Preservation of time.* Increase efficiency by optimizing working time.

The variety of the elementary base, modules, automation, etc. that can be used in the construction of reliable automatic machines and lines is very wide.

6. Analysis of the proposed variants

The choice of variant is based on the most important criteria, factors and parameters: productivity, cost, quality of produced products, competitiveness, markets, flexibility, adjustments, etc.

The main requirement in choosing a variant is that the pistons must not hit each other after polishing and superfinishing the spherical surface of the pistons. In the proposed variants 1, 2, 3, 4 and 5, the feeding, the transport and the orientation are accompanied by strikes between the surfaces of the pistons. The smoothness of the surfaces, which in superfine processing cannot be erased.

Options 6 and 7 are superb, but there is no area in the workshop. The superfinishing time of the spherical surface of the pistons is in the order of $t_w = 60$ s. This time is almost twice as great as a super finish operation on the cylindrical part.

After analyzing the proposed options and considerations, an automated feed supply to the SASM of option 8 was developed.

7. Composition of AFSASM

The composition of AFSASM (automated feeding semi-automatic superfine machine) is shown on fig. 3, which is adjustable for the piston: Bt. 14.2, Bt.17 and Bt.21. It is built by SASM-1; feed chute - 2; frame - 3; outlet (storing oriented pistons) - 4, carrier holder - 5, linear module - 6; Separator - 7; drive group - 8; inductive sensor - 9; optical sensors 10 (presence of pistons in store 4) and 11 (presence of pistons in chute) [2, 5, 6, 7, 8, 10, 12, 13, 14].

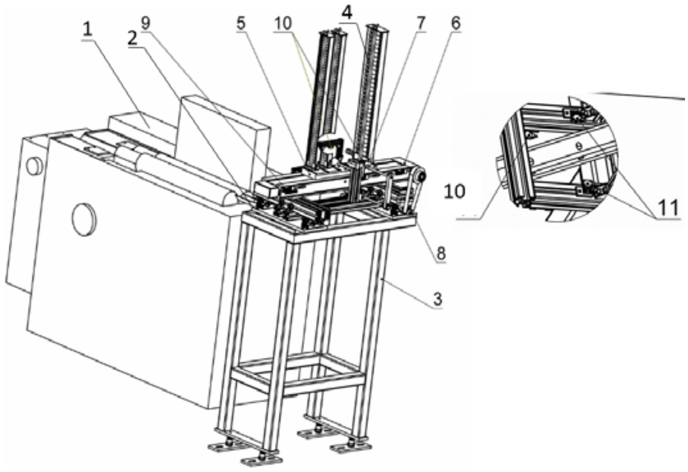

Fig. 3. Overview of AFSASM

Operating principle. Depending on the set program for a certain size-type piston, five stores 4 are loaded. On the carrier 5 are fixed two diagonally spaced spring retainers. Initially, the chute 2 is loaded manually with the corresponding plunger type to the level of the top mounted optical sensor 10. The stroke of the separator 7 is set, separating one piston from the store 4 into the chute 2.

After emptying the first outlet, the carrier 5 moves in one step to load the next second store 4. During this time the empty outlet 4 is removed from the carrier 5 and manually loaded with new pistons and then returned to the output position on the carrier fixture 5. The optical sensors 10, 11 reports the presence of the pistons in the outlets 4. The inductive sensor measures the position of the carrier device 5. The adjustment for the next type of piston is followed.

8. Conclusion

From the performance, reliability and service analysis provided by the proposed innovative competitive structural components, the following can be drawn:

1. The category of pistons complexity with $B_{\Sigma}=13$, is investigated and analyzed, and it corresponds to a category of complexity $K_{avg}=2$, showing that the automation of the pistons is of moderate complexity. Variants need to be developed. Choice of technical and economic option is made.
2. The existing: a common technological process; between operational transport; the location of the machinery and devices in the final processing plant; the technological process of the basic and auxiliary operations for the superfinishing of the pistons of the existing SASM are analyzed, according to the calculated speeds, minute, hourly and yearly outputs of each type-dimensional market for axial-piston pumps and motors.
3. Eight innovative competitive structurally compliant variants are investigated, built on a modular principle for the auxiliary operations.
4. Efficiency has been investigated in terms of: energy saving; saving space; improving efficiency; price; storing time; which items will be purchased; which are the most reliable and most advantageous prices.
5. The proposed innovative competitive structural-compartmental variants, developed on a modular basis, in line with the proposed considerations, are analyzed. An eighth option has been selected, for which the relevant design documentation has been developed.

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Автоматизация вспомогательных операций суперфиниширующей машины

Часть II. Разработка вариантов структурной компиляции

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Резюме: В статье исследуется и определяется скорость “удобства автоматизации” поршней, выполненная в соответствии с методологией отдела “Автоматизация сдержанного производства”. Объект анализируется, а также технологический процесс, оперативный транспорт, расположение машин и устройств в мастерской. Исследованы различные варианты конструкции. Анализируются варианты.

Ключевые слова: Автоматические линии, технологии, суперфиниширование, гидравлика, насосы, автоматизация, промышленные роботы.