БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **70**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **70**

София • 2018 • Sofia

Automatizing the Auxiliary Operations of a Superfinishing Machine

Part I. Analysis of the Technological Process and Performance of Superfinishing treatment of Pistons for Axial Piston Pumps and Motors

Lubomir Dimitrov, Luben Klochkov*, Nikolay Stoimenov***

** Technical University - Sofia, 1000 Sofia, Bulgaria.*
*** Institute of Information and Communication Technologies – BAS, Sofia, Bulgaria.*
Emails: lubomir_dimitrov@tu-sofia.bg, lklochkov@tu-sofia.bg, nikolay@iinf.bas.bg

Abstract: *The paper presents requirements for axial piston pumps and motors. The technological process is analyzed. The transport between the different operations is examined. Also the productivity of superfinishing machine is investigated and determinated. The theoretical tact is calculated on basis of 250 000 details/year with 8 hours work shift. To determine the actual tact, a number of experimental laboratory tests have been carried out in differently selected operating modes.*

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

1. Introduction

The increasing interest in the use of hydraulic drives as a specific form of power transmission is widely used in the various branches of industry in the automation of continuous and discrete processes and operations in transport, machine building, chemistry, metallurgy, construction, etc. A special place in hydraulic drives is the axial piston pumps (axial piston engines) built into hydraulic machines and systems. They are in the basis of drive components of hydraulic systems and possibility for automatic regulation and control [1, 2, 3, 4, 5, 6].

The aim of the present work is to analyze the technological process and the productivity of the superfinishing of the pistons embedded in axial-piston pumps and motors.

2. Functional Purpose and Requirements

The pistons are designed for use in axial piston hydraulic pumps and motors. From a functional point of view, the pistons slides into the cylinder block and forms a "rotor group". It is the main working organ of this type of hydraulic products, converting hydraulic power into mechanical - hydraulic motors, or mechanical energy in hydraulic - hydro pumps [1, 7].

On Fig. 1 is shown the structural drawing of the piston type: Bt. 17 [01.A] (Bt 14.2 [01.A] and Bt 21 [01.A]). In the constructive drawing are presented the extremely high requirements such as: very small deviations of form and high class of roughness of working surfaces, narrow tolerances of fields of functional dimensions; the presence of a very hard and wear-resistant layer on the work surfaces, etc.

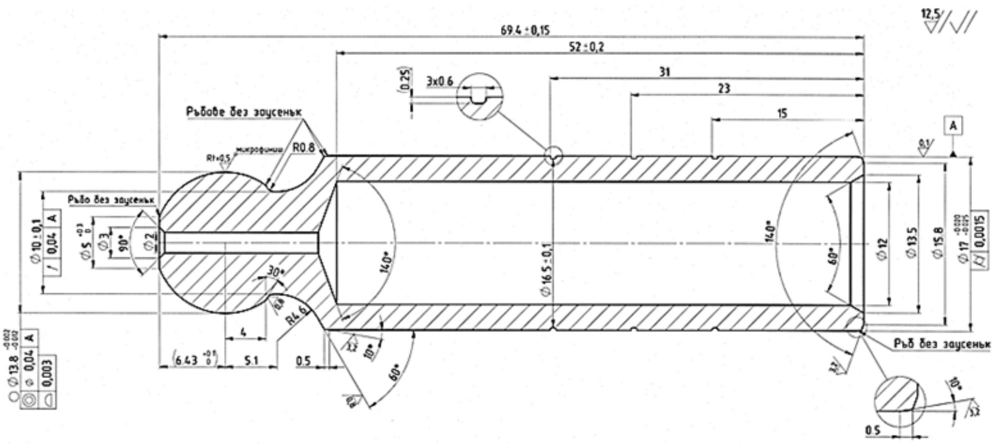

Fig. 1. Drawing of type size Bt.17 [01.A]

3. Analysis of the Technological Process

The sequence of the existing developed technological process is consistent with the very varied 13 basic operations performed on different automatic machines, semi-automatic machines and other non-automated equipment, implemented by operators. In this connection, these discrete operations, basic and auxiliary with a substantial difference in times, make it difficult to automate the whole process. Even more of the machines makes and other details in three-shift work regime [2, 3, 4, 8, 9, 10,].

The developed inter-operative transport is implemented with carts, fitted with three-dimensional "drawers" mounted on telescopic strips. This allows the installation of three types of base cartridges allowing them to be used in all operating states of the treated pistons/parts. The size of the base cartridges is consistent with the basket size of semi-automatic machines.

The tenth superfinishing operation of the piston's outer cylindrical surface is carried out on a non-centrifugal semi-automatic superfine machine (SASM), model 5M-45r, Supfina, Germany. (Figure 2). It is compiled of a chute 1 that pulls out the processed pistons; ironing head 2 for superfinish; chute 3 loaded with pistons for treatment and a set of rollers 4 providing the linear axial feed of the pistons. The process represents smoothing by means of oscillating abrasive stones (fastened to the smoothing head) whereby unevenness with a height of 1 ÷ 1,5 μm is removed from the treated surface without altering the geometry.

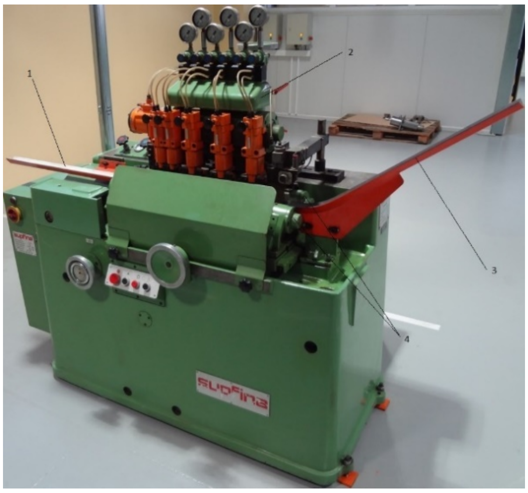

Fig. 2. Semi-automatic SM57-452 superfinishing machine

4. Determining the productivity of SASM

From marketing researches made on the international markets a desired productivity of Q = 250,000 pcs/year is formed from the proposed three sizes of pistons. It is assumed that in that quantity the remaining existing axial-piston pumps and motors will also be included [2, 9, 10, 11, 12].

Theoretical tact

It is preferable to use the calculation of the theoretical performance with a coefficient of utilization $\eta_{util} = 0{,}7$ of SASM in the lower operating range in order to have the opportunity if needed to be increased the productivity for the pistons, respectively axial-piston pumps and motors.

Calculations for the theoretical and actual tact of the average piston - Bt17 type.

The calculations are based on the set productivity Q_{yp} = 250 000pcs/year and intended Q_{yi} = 275002,5 pcs/year. productivity; at 250 and 260 working days per year with one shift of 8 hours and one-hour working regime, indicated in Table 1. It is evident that in the calculations made, the time difference is minimal and falls within the permissible limits and as a result, are used for comparisons the highest tact τ^T = 25.45s/pc. [2, 8, 10, 11, 12, 13].

Table 1. Calculation of the theoretical tact

No	Theoretical tact $\tau^T = \frac{\Phi}{Q_{yp}}$			Φ – year fund work time $\Phi_{yfwt} = Wd.c_{sh}.\eta_{util}.8.3600$							Qy – year productivity $Q_{yp} = Q_{yd} + Q_{rrи} + Q_{eрт}Q_{r.бр.}$				
								time			Climed	Yearly desired			
	indication	indication	Time	Φyfwt	Work days per year	Coefficient shift	Coefficient of utilisation	Work shift	1 work hour	In seconds	$Q_{yc.}$	Q_{yd}	$Q_{r.r.и.}$	$Q_{r.p.ч.}$	$Q_{r.бр.}$
			s	Σ, s	Wd/pcs	C_{sh}	η_{util}	h	h	s	pcs/y / pcs/h	pcs/y / pcs/h	pcs/y / pcs/h	pcs/y /pcs /h	pcs /y /pcs /h
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	τ_1^T	τ_{11}^T	24.48	6120000	250	1	0.85	8	-	3600	250000	-	-	-	-
			22.25								-	275002.5	250000	25000	2.5
		τ_{12}^T	24.48	6120000	1	1	0.85	-	1	3600	125	-	-	-	-
			23.12								-	132.31	120.19	12	0.12
2	τ_2^T	τ_{21}^T	25.46	6364800	260	1	0.85	8	-	3600	250000	-	-	-	-
			23.14								-	275002.5	250000	25000	2.5
		τ_{22}^T	25.45	6364800	1	1	0.85	-	1	3600	120.19	-	-	-	-
			23.13								-	132.31	120.19	12	0.12

Actual tact

To determine the technological limitation working hours – t_{wl}. in superfinishing of the cylindrical part of the piston, a number of experimental laboratory tests have to be made in differently selected operating modes [2, 5, 6, 11, 14, 15].

On figure 3 is shown s a schematic diagram of the superfinishing of the piston (1). By the chute (5), the piston (1) enters the working area (L_1) of the SASM.

It is typical in the superfinishing processes the choice of double acting oscillating fluctuations of the abrasive stones (4) fixed to the smoothing head (3) by pneumatic cylinders (7). In the case of reciprocating movements, a new trajectory of the grains of the abrasive stone (4) is provided at each revolution of the piston, eliminating consecutively the existing roughness without creating new traces. After removing the roughness between the abrasive stones and the treated cylindrical surface, a "solid" oil film is formed which acts against the further release of metal from the piston. The technological process is carried out with very little pressure on the abrasive stones on the cylindrical surface of the piston and a minimum, low cutting temperature. The removal of the micronutrients is of the order of 1-2 μm without alteration of the piston's macrogeometry.

The linear velocity of the piston is determined by the axial displacement of the rollers (2) arranged at a certain angle, polished in a hyperbolic shape, providing after adjustment of the upper line of the cylindrical part of the piston to lie exactly on one straight. Spiral grooves are provided along the length of the rollers, ensuring the rapid leakage of the contaminated, specially honing oil, also providing the role of cooling liquid.

To ensure the desired prescribed narrow field tolerances and the high class of precision and smoothness of the working surfaces of the three types of pistons in superfine treatment (Table 2) and to meet the requirements of the BDS and the international DIN, ISO and EN standards in Table 3, summed intervals of: the peripheral piston speeds; linear piston feed rate; the oscillating velocity of the stones located on the ironing head; the direct pressure of each abrasive stone on the surface of the piston, and what the removed addition to be. After experimenting, the actual experimental speeds are also described.

In addition to the tolerances in Table 2, the dimensions of: the length of the rollers - L_3; the distances of penetration and removal of the pistons from the rollers - L_2; the distance between the rollers and the chute - L_4; the total distance between the two chutes - L_5 and the total working length for the superfinishing treatment performed by five abrasive stones in an non-central arrangement.

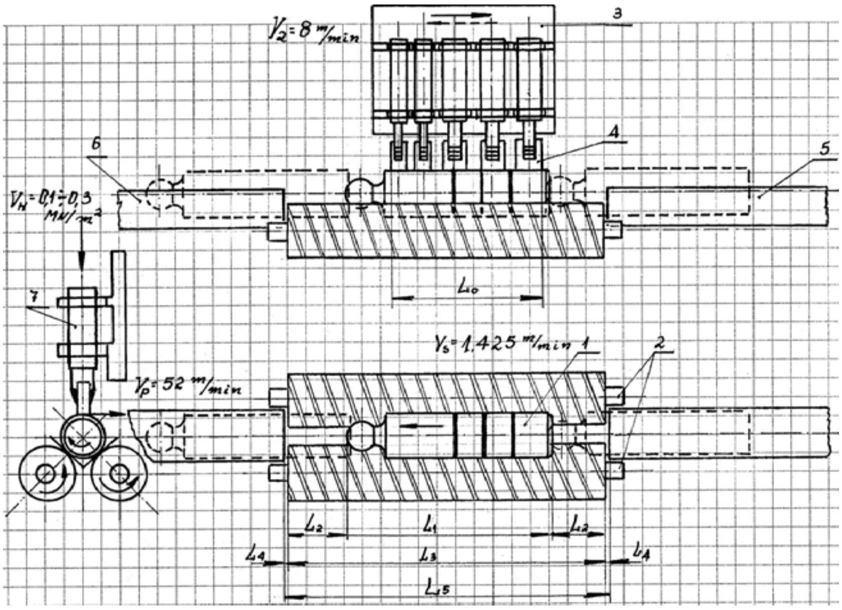

Fig. 3. Principal scheme of superfinishing treatment

To determine the optimal modes of operation in a non-central superfinishing process, ensuring that the prescribed narrow tolerance fields, high accuracy and smoothness classes, cylindrical deflection, etc. are achieved. For the three types of pistons, a number of experimental tests have been made.

After capturing, processing and analysis of the results for the technological working time limit were obtained for Bt 14.1, t_{wl}^{1}=23.47 s; Bt 17, t_{wl}^{2}=23.97 s, and Bt 21, t_{wl}^{3}=25.00 s, and for the empty strokes - supply and outlet Bt 14.2, t_{es}^{1}=2.32 s; Bt 17, $t_{es.}^{2}$=2.92 s, and Bt 21, t_{es}^{3}=3.95 s.

The obtained data is presented in Table 4. Also, the total own losses, the accumulated losses from repair activities as well as the total over-cyclical losses were also applied. The cyclic times, the time losses caused by tools, equipment, organizational and technical reasons, adjustments and adjustments, ongoing repairs and planned repairs are reported [2, 3, 8, 9, 11, 12, 13].

The actual obtained values are necessary in developing the structural component options for the implementation of the feeder operations of SASM. If these values are assumed to be theoretically true, calculations of the adjustable semiautomatic machine of declared and desirable performance can be made for a one-year period shown in Table 5. The calculations made are for the three types of pistons. Of the total declared annual productivity of 250,000 pcs/year it is accepted that the three sizes are equal. The performance is calculated for each type of seconds, minutes, hours, and work shifts. Calculated and productivity at declared Q_y = 250,000 pcs/year and desired with added 10% as spare parts and for a waste of the order of 0.001%, which is Q_{yd} = 275,005 pcs/year. Calculations are made at 8h workday, double-shift and quarter-shift work. Calculated with the yearly desired productivity for 260 working days and one-shift work Q_y = 275,756 pcs/year.

5. Constructive reliability

When designing a new AT, constructors always take into account its predictable reliability. But recently, people talks about the predicted structural reliability of the manufactured AT, for how long it will work. In other words, the manufacturers of articles and automation equipment, even with the conclusion of the contract for development, production and implementation, take into account the envisaged structural reliability. On this basis they set the warranty period in which they will work. The colossal development of new materials, new technologies, a new element base, etc., lead to sensitive changes in the new modules and NGEs. Therefore, the device itself very quickly undergoes a change during its development [2, 8, 9, 6, 11, 12, 13].

6. Conclusions

The following conclusions can be drawn from the calculations for the performance and reliability of the technological process undergoing superfinishing:

1. Extremely high requirements and working regimes for superfinishing the cylindrical part of the pistons (Table 2 and 3) are analyzed.
2. Examined and analyzed is the existing technological process of the basic superfinishing and auxiliary - feeding / unloading operations of the semi-automatic machine for superfinishing of cylindrical part of piston model "SM57-452"
3. Laboratory tests have been carried out in different modes of operation ensuring the desired technological limitation time t_{wl} = 25,45s/pcs. based on the theoretical (Table 1) and actual (Table 4) tact, used to calculate the productivity for monthly and yearly time periods (Table 5).
4. By means of automation of auxiliary feeding/unloading operations, an increase in the productivity and quality of a semi-automatic superfinishing machine for non-adjustable and adjustable hydraulic axial piston pumps and motors is achieved.

Table 2. Piston tolerances

No	Piston indication	Piston diameter	Piston total length	Working length for superfinish	Piston entry / removal distance	Length of working rollers	Distance between the rollers and the chutes	Distance between the two chutes	Allowable difference in d of individual pistons	Class of smoothness	Deviation from cylindricality
		d [mm]	L_1 [mm]	L [mm]	L_2 [mm]	L_3 [mm]	L_4 [mm]	L_5 [mm]	[μm]	R_a [μm]	[μm]
1	2	3	4	5	6	7	8	9	10	11	12
1	Bt 14.2 [01.A]	14.2 -0.020 -0.025 ⌭ 0.0015	55±0.15	41.33	50/20	530	1	540	to 5	0.1	to 1.5
2	Bt 17 [01.A]	17 -0.020 -0.025 ⌭ 0.002	69.19±0.15	52.91	50/20	530	1	540	to 5	0.1	to 1.5
3	Bt 21 [01.A]	21 -0.020 -0.025 ⌭ 0.0015	93.8±0.15	73.86	50/20	530	1	540	to 5	0.1	to 1.5

Table 3. Cutting speeds

No	Name	Indications	Dimensions	Recommended speed intervals	Experimental received velocities
1	2	3	4	5	6
1	Peripheral speed of the piston	V_P	m/min	30÷120	52
2	Linear speed feed rate of the piston	V_S	m/min	0.5÷3	1.425
3	Oscillation velocity of the stones located on the ironing head	V_A	m/min	6÷12	8
4	Direct pressure on each of the stones located on the ironing head on the piston	V_H	MN/m^2	0.1÷0.3	0.1÷0.3
5	Removed addition	δ	μm	2	1÷1.5

Table 4. Actual tact

No	Piston sizes	$\tau_i^a = T_c + \Sigma t_{ou.c.w}$ $\tau_i^a = T_c + t_{emp.mx} + t_{ou.c.w}$ Actual tact of SASM	$T_c = t_{wl} + t_{emp.m}$			$\Sigma t_{ou.c.w} = \Sigma C_U + t_{equ.} + t_{org.t} + t_{adj.} + t_{pcs.} + t_{ong.r.} + t_{pwr.}$										
						$\Sigma t_{own.w} = \Sigma C_U + t_{equ.}$			$\Sigma t_{add.} = t_{org.t} + t_{adj.} + t_{pcs.}$				$\Sigma t_{rep} = t_{ong.r.} + t_{pwr.}$			
			Limiting working time	Time for empty moves	Working Cycle Time	Time lost due to tools	Time lost due to equipment	Total own time losses	Losses of time caused by organizational and technical reasons	Loss of time caused by settings and adjustments	Loss of time caused by waste	Total additional time losses	Loss of time caused by ongoing repairs	Losses of time caused by planned-warning repairs	Total time losses caused by repairs	Total over cycle losses on time
	pcs.	τ_i^a [s]	T_{wl}	$T_{emp.mx}$	T_c [s]	ΣC_U	$t_{equ.}$	$\Sigma t_{own.w}$	$T_{org.t}$	$T_{adj.}$	$T_{pcs.}$	$\Sigma t_{add.}$	$T_{ong.r.}$	$T_{pwr.}$	Σt_{rep}	$\Sigma t_{ou.c.}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Bt 14.2	τ_1^a=25.75	23.37	2.32	25.69	0.02	0.01	0.03	0.01	0.001	0.001	0.012	0.01	0.008	0.018	0.06
2	Bt 17	τ_2^a=26.95	23.97	2.92	26.89	0.02	0.01	0.03	0.01	0.001	0.001	0.012	0.01	0.008	0.018	0.06
3	Bt 21	τ_3^a=29.01	25.00	3.95	28.95	0.02	0.01	0.03	0.01	0.001	0.001	0.012	0.01	0.008	0.018	0.06

Table 5. Productivity for yearly period

No	Type sizes			Calculated actual tact			Working shifts		
	Indications	pcs./year	Yearly working days	$\tau^a_{i\,s}$	$\tau^a_{i\,min}$	$\tau^a_{i\,h}$	8	16	24
				S/pcs.	min/pcs.	h/pcs.	h/pcs.	h/pcs.	h/pcs.
1	2	3	4	5	6	7	8	9	10
1	Bt 14.2	83 334	-	25.75	2.33	139.80	1118.4	2236.8	3355.20
2	Bt 17	83 333	-	26.95	2.23	133.80	1070.4	2140.8	3211.20
3	Bt 21	83 333	-	29.01	2.07	124.10	992.8	1985.6	2978.40
4	average	-	-	27.24	2.51	132.57	1060.53	2121.06	3181.53
5	claimed	250 000	-	-	-	-	265133.32	-	-
6	desired	275 005	-	-	-	-	275737.80	-	-

R e f e r e n c e s

1. Lazarov S. and Ilcho Angelov "Theory and Practice of Hydro Drives", NIS-TU, Sofia, 2010
2. Ganovski Vl., Boyadzhiev Il., Klochkov L., Automatic lines, Printing Center "TU-Sofia", S. 1989
3. Boyadzhiev Il, L. Klockkov, B. Monev "Manual for Laboratory Exercises and Course Design on Automatic Lines", Printing Center, TU-Sofia, 1989
4. Neshkov T., M. Milushev, A. Bachvarov "Introduction to Mechatronics", TU, Sofia., 2009
5. Neshkov T. "Taxonomy in Mechatronics", HERON PRESS, Sofia. 2014
6. Innovation, European, National and Regional Policies, Applied Research and Communications Foundation ARC FUND, ISBN 978-954-9456-12-7
7. Dimitrov L. "PRINCIPLES OF MECHANICAL ENGINEERING, DESIGN, DESIGN OF MECHANICAL COMPONENTS", HERON PRESS, Sofia, 2009
8. Automation of discreet production, under the editing of Prof. Vl. Ganovski, Monograph, Mechanical Engineering, M., 1987, "Techniques", 1990
9. Volkevich L.I. "Automatization of production processes", M., Mechanical engineering, 2005
10. Neshkov T., "Flexible Automation of Installation (Mechatronic Approach)", Monograph, Technical University, Sofia, Department of ADP, Sofia, 2007
11. Groover, M.P., Automation, Production Systems, and Computer-Intergrated Manufacturing: International Version, 3/E, ISBN -13: 978-0132393218, 2007
12. Lotter B., Manufacturing Assembly Handbook, Butterworths, ISBN: 0-408-0356-7, 1986
13. Boothroyd, G. (2005). Assembly Automation and Product Design. 2nd Edition, Boca Raton: CRC Press.

Автоматизация вспомогательных операций супер финишной машины

Часть I. Анализ технологического процесса и выполнение супер финиширования поршней для осевых поршневых насосов и двигателей

Л. Димитров, Л. Клочков, Н. Стоименов

Резюме: *В докладе представлены требования к осевым поршневым насосам и двигателям. Проанализирован технологический процесс. Рассматривается транспорт между различными операциями. Исследуется и определяется также производительность супер финишной машины. Теоретический такт рассчитывается на основе 250 000 деталей в год с 8-часовой рабочей сменой. Для определения фактического такта был проведен ряд экспериментальных лабораторных испытаний в разных режимах работы.*

Ключевые слова: *Автоматические линии, технологии, супер финиширование, гидравлика, насосы, автоматизация, промышленные роботы.*