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PARTICULARITIES IN DETERMINING THE FUNCTIONAL PARAMETERS OF A HYDROSTATIC SYSTEM

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ABSTRACT

Adopting an optimal constructive variant for a hydrostatic installation starts from the calculus of functional and dimensional parameters of composing elements. A right choice has to regard the dependencies between the characteristic values for hydraulic elements. In this paper, a reduced power installation is presented. The installation has classical equipment for distribution, adjustment and control in order to action two hydraulic cylinders. One of these has movement in vertical plane, with variable load. The other assures a horizontal movement of a trolley assembly. Also, are defined specific equations which allow determining a dynamic behaviour of equipment, calculating hydrostatic parameters essentials for installation functioning: working fluid pressures and flows, transferred hydraulic forces and powers etc.

KEYWORDS: hydraulic system, hydraulic cylinders, working parameters, working load

1. INTRODUCTION

The fluid drive represents the drive which provides a double energy conversion, transforming mechanical energy in hydraulic energy and then, back in mechanical energy. The parameters of the two types of mechanical energy, entry and exit, may be different in terms of kinematics and dynamics, this being the purpose of the drive [1], [2]. Therefore, the hydraulic drive system is defined as a set of constructive elements which perform the energy transformation and transfer from a force element, *EF* (operator) to a final execution element, *EE* (operated), with the help of a hydraulic environment. Schematically, a hydraulic drive is presented in figure 1 [3].

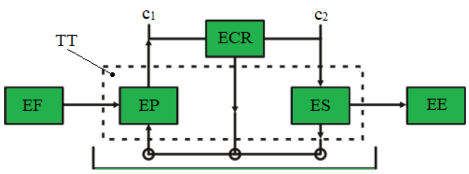

Fig. 1: The structure of a hydraulic drive: c1-mechanical-hydraulic conversion; c2-hydro-mechanical conversion; EP-primary element; ES-secondary element; ECR-control and adjustment elements; EE-execution element; TT-energy transformer-transmitter [3]

The elements which transfer, transform and take over the energy form together an energy transforming and transmitting block, *TT*, also known as converter. Because the hydrostatic drives provide many advantages to industrial activities, such as high reliability, the possibility to perform centralized service, doubled by the easy and precise command, providing a force element and a constant moment, regardless of the speed changes, the control capacity and the performance adjustment etc. [4-6], the structural elaboration of an installation and the calculation of the numerical values of functional and dimensional parameters for component elements must be made thoroughly. The paper suggests a calculation method for the parameters of certain main components, pumps and hydro-engines, for a hydrostatic installation, laboratory stand, in order to provide the auxiliary operations necessary for assembling the caskets of the rolls on the axle shafts [7].

2. STAND FOR ADJUSTING THE HYDROSTATIC PARAMETERS

The base of designing a hydrostatic system has two essential options: the adopted constructive solution and the calculation of the numerical values of functional and dimensional parameters for components. These values define the level of the work pressure and the transferred power.

The mechanical power transferred to the execution element, serviced by the hydraulic system is brought through the hydraulic power. Therefore, the flow value sets the size of all the system elements (nominal openings, capacity, load, weight etc.) The components of the adjustment system of the hydraulic parameters are presented in figure 2.

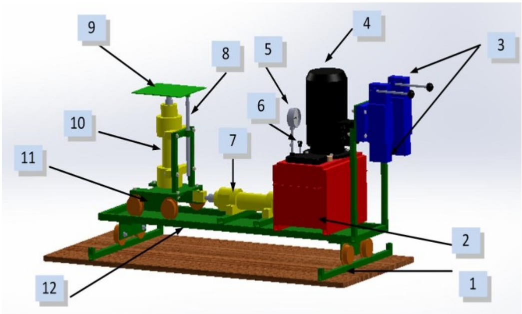

Fig. 2: System for adjusting the hydraulic parameters-components: 1-rolling track; 2-tank; 3-manual distributors; 4-electric engine and pump; 5-manometer; 6-regulator; 7-hydraulic cylinder with horizontal movement; 8-guide; 9-workbench; 10-hydraulic cylinder with vertical movement; 11-small metallic frame; 12-large metallic frame.

The pumps are selected from the catalogues and leaflets of the manufacturing trading companies based on the value of the maximum power necessary during the technical work cycle of the system. A pump capable of providing pressure from the system is selected and a value for the speed drive is adopted, analyzing if the selected volume unit performs the necessary maximum flow. The selection of the hydraulic cylinders is made according to the technological work cycle required by design and the option of hydraulic cylinder with double action and unilateral rod is selected. The hydraulic cylinders have as active element one or more pistons which move inside the work cylinders, being used to provide unidirectional force through a unidirectional track.

Therefore, two hydraulic cylinders were selected, one which performs a horizontal movement and the other for vertical movement, see figure 2.

3. CALCULATION OF WORK PARAMETERS

Because the hydraulic drives have a significant importance in this field, the practical examples require a technical calculation of these systems based on the fundamental relations which regard the calculation of mechanical and hydraulic parameters which occur in the operation of hydraulic systems, as well as the calculation for the fluid flows in terms of these systems. In terms of hydraulic cylinders, the work parameters considered are the power pressure and the administered flow.

3.1. Hydraulic cylinder with vertical movement

The list of the hydrostatic parameters which occur in the calculation of the adjustment installation includes:

- p [bar] – work pressure;
- L [mm] – length of rod track;
- g [kg] – load capacity;
- S_a [mm^2] – surface of active track;
- S_p [mm^2] – surface of passive track;
- D [mm] – interior diameter of case;
- d [mm] – rod diameter;
- i_{at} [s] – idle active time;
- i_{pt} [s] – idle passive time;
- l_{at} [s] – load active time;
- l_{pt} [s] – load passive time;
- i_{as} [m/s] – idle active speed;
- i_{ps} [m/s] – idle passive speed;
- l_{as} [m/s] – load active speed;
- l_{ps} [m/s] – load passive speed;
- Q_{ag} [l/s] – idle active flow;
- Q_{pg} [l/s] – idle passive flow;
- Q_{as} [l/s] – load active flow;
- Q_{ps} [l/s] – load passive flow;
- I_{af} [daN] – idle active force;
- I_{pf} [daN] – idle passive force;
- L_{af} [daN] – load active force;
- L_{pf} [daN] – load passive force.

The following numerical values are considered for the calculation of the hydraulic cylinder with vertical movement:

- $L = 70$ [mm];
- $p = 10 \div 100$ [bar];
- $D = 40$ [mm];
- $d = 32$ [mm].

Calculation of track surfaces

$$S_a = \frac{\pi \cdot D^2}{4} = 1256\ mm^2; \quad (1)$$

$$S_p = \frac{\pi \cdot \left(D^2 - d^2\right)}{4} = 452.16 \approx 452\ mm^2. \quad (2)$$

Calculation of forces

$$p = \frac{F}{S}[bar]; \quad (3)$$

$$F = p \cdot S \Rightarrow \begin{cases} F_a = p \cdot S_a \cdot 10^{-2}\,[daN]; \\ F_p = p \cdot S_p \cdot 10^{2}\,[daN]. \end{cases} \quad (4)$$

Calculation of movement speeds

$$v = \frac{L}{t} \cdot 10^{-3} \left[\frac{\text{m}}{\text{s}}\right]. \quad (5)$$

Table 1 presents the response time *[s]*, necessary for the calculation of the movement speeds *[m/s]*.

Table 1. Response time [s]

p [bar]	t_{ag} [s]	t_{pg} [s]	t_{as} [s]	t_{ps} [s]
10	2,27	2	2,81	2,44
20	2,25	1,18	2,78	2,05
30	2,23	1,14	2,10	1,17
40	2,21	1,11	2,06	1,06
50	2,11	1,02	2	1,04
60	1,90	1	1,85	1,01
70	1,77	0,98	1,78	1
80	1,74	0,94	1,74	0,86
90	1,71	0,87	1,70	0,79
100	1,68	0,74	1,69	0,71

Calculation of the flow on the crossing section

$$Q = v \cdot S \cdot 10^{-3} \, [\text{l/min}]. \quad (6)$$

Table 2 presents the values of the parameters for a hydraulic cylinder with vertical movement.

Table 2. Calculation of hydraulic parameters

Crt. no.	p [bar]	L [mm]	g [kg]	D [mm]	d [mm]
1	10	70	10	40	32
2	20	70	20	40	32
3	30	70	30	40	32
4	40	70	40	40	32
5	50	70	50	40	32
6	60	70	60	40	32
7	70	70	70	40	32
8	80	70	80	40	32
9	90	70	90	40	32
10	100	70	100	40	32

Crt. no.	s_a [mm^2]	s_p [mm^2]	F_{ag} [daN]	F_{pg} [daN]	F_{as} [daN]
1	1256	452	125,6	45,2	126,6
2	1256	452	251,2	90,4	253,2
3	1256	452	376,8	135,6	379,8
4	1256	452	502,4	180,8	506,4
5	1256	452	628	226	633
6	1256	452	753,6	271,2	759,6
7	1256	452	879,2	316,4	886,2
8	1256	452	1004,8	361,6	1012,8
9	1256	452	1130,4	406,8	1139,4
10	1256	452	1256	452	1266

Crt. no.	F_{ps} [daN]	t_{ag} [s]	t_{pg} [s]	t_{as} [s]	t_{ps} [s]
1	46,2	2,27	2	2,81	2,44
2	92,4	2,25	1,18	2,78	2,05
3	138,6	2,23	1,14	2,1	1,17
4	184,8	2,21	1,11	2,06	1,06
5	231	2,11	1,02	2	1,04
6	277,2	1,9	1	1,85	1,01
7	323,4	1,77	0,98	1,78	1
8	369,6	1,74	0,94	1,74	0,86
9	415,8	1,71	0,87	1,7	0,79
10	462	1,68	0,74	1,69	0,71

Crt. no.	v_{ag} [m/s]	v_{pg} [m/s]	v_{as} [m/s]	v_{ps} [m/s]
1	0,0308	0,0350	0,0249	0,0287
2	0,0311	0,0593	0,0252	0,0341
3	0,0314	0,0614	0,0333	0,0598
4	0,0317	0,0631	0,0340	0,0660
5	0,0332	0,0686	0,0350	0,0673
6	0,0368	0,0700	0,0378	0,0693
7	0,0395	0,0714	0,0393	0,0700
8	0,0402	0,0745	0,0402	0,0814
9	0,0409	0,0805	0,0412	0,0886
10	0,0417	0,0946	0,0414	0,0986

Crt. no.	Q_{ag} [l/s]	Q_{pg} [l/s]	Q_{as} [l/s]	Q_{ps} [l/s]
1	0,0387	0,0158	0,0313	0,0130
2	0,0391	0,0268	0,0316	0,0154
3	0,0394	0,0278	0,0419	0,0270
4	0,0398	0,0285	0,0427	0,0298
5	0,0417	0,0310	0,0440	0,0304
6	0,0463	0,0316	0,0475	0,0313
7	0,0497	0,0323	0,0494	0,0316
8	0,0505	0,0337	0,0505	0,0368
9	0,0514	0,0364	0,0517	0,0401
10	0,0523	0,0428	0,0520	0,0446

The influence of the workbench plate load is analyzed with different weights (g=10÷100 kg), progressively, to variations of the work pressure (p=10÷100 bar), by measuring the performance time of the hydraulic cylinder tracks. Figures 3 ÷ 10 present the pressure variations with the force, time, speed and work flow for the idle track and for the load track.

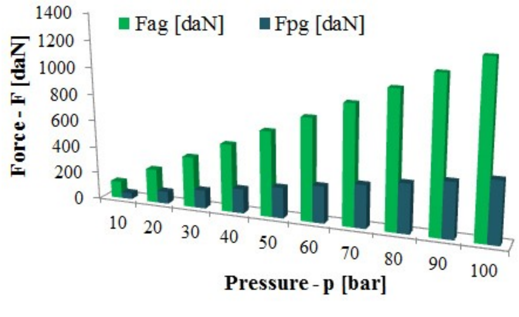

Fig. 3: Force-pressure variation for idle track

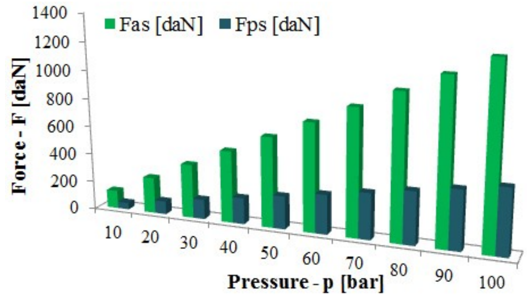

Fig. 4: Force-pressure variation for load track

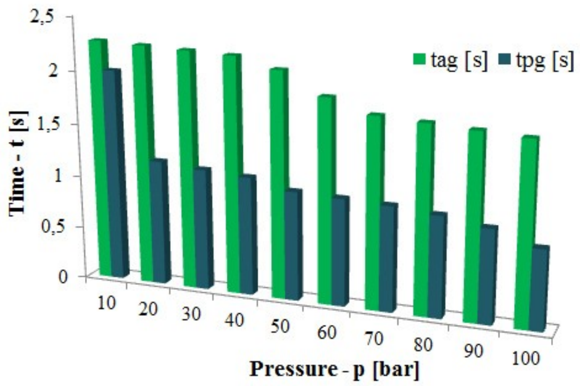

Fig. 5: Time-pressure variation for idle track

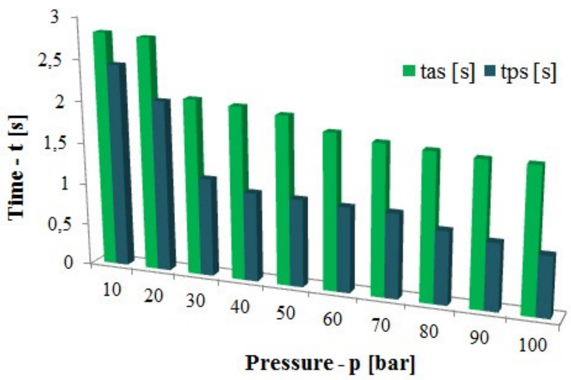

Fig. 6: Time-pressure variation for load track

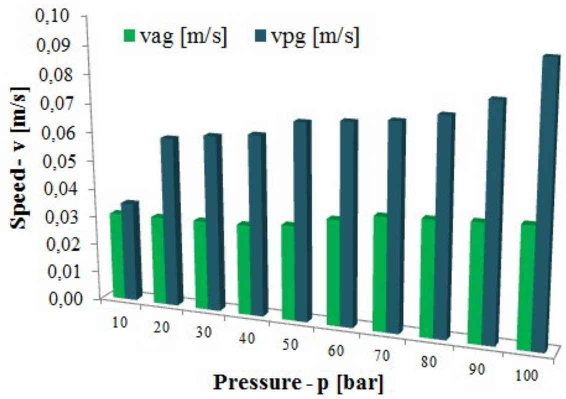

Fig. 7: Speed-pressure variation for idle track

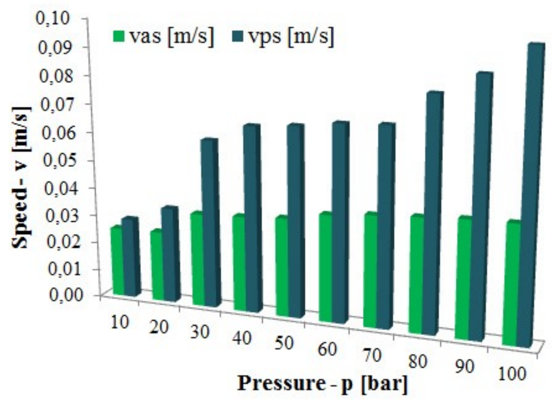

Fig. 8: Speed-pressure variation for load track

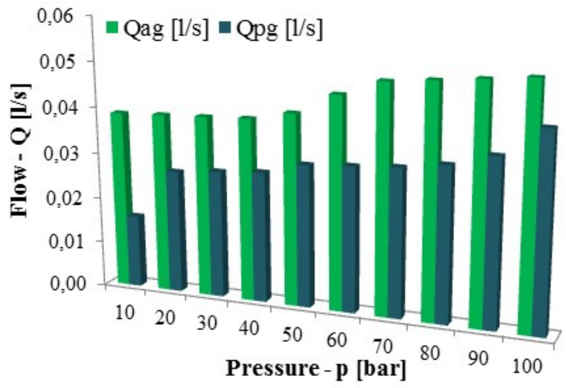

Fig. 9: Flow-pressure variation for idle track

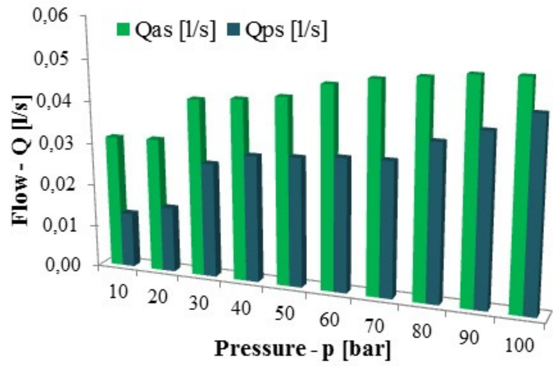

Fig. 10: Flow-pressure variation for load track

3.2. Hydraulic cylinder with horizontal movement

The list of the hydrostatic parameters which occur in the calculation of the installation includes:

- F_a [daN] – force for active track;
- F_p [daN] – force for passive track.

The following numerical values are considered for the calculation of the hydraulic cylinder with horizontal movement:

- $L = 125$ [mm];
- $p = 10 \div 100$ [bar];
- $D = 40$ [mm];
- $d = 28$ [mm].

Calculation of track surfaces

$$S_a = \frac{\pi \cdot D^2}{4} = 1256 \text{ mm}^2; \tag{7}$$

$$S_p = \frac{\pi \cdot (D^2 - d^2)}{4} = 640,56 \cong 641 \text{ mm}^2. \tag{8}$$

Calculation of forces

$$p = \frac{F}{S}[\text{bar}]; \tag{9}$$

$$F = p \cdot S \Rightarrow \begin{cases} F_a = p \cdot S_a \cdot 10^{-2}\,[\text{daN}]; \\ F_p = p \cdot S_p \cdot 10^{-2}\,[\text{daN}]. \end{cases} \tag{10}$$

Calculation of movement speeds

$$v = L/t \cdot 10^{-3}\ [\text{m/s}]. \quad (11)$$

Table 3 presents the response time *[s]*, necessary for the calculation of the movement speeds *[m/s]*.

Table 3. Response time [s]

p [bar]	t_{ag} [s]	t_{pg} [s]	t_{as} [s]	t_{ps} [s]
10	2,28	1,57	2,80	1,98
20	2,08	1,42	2,67	1,90
30	1,93	1,27	2,55	1,86
40	1,87	1,24	2,40	1,70
50	1,84	1,21	2,21	1,63
60	1,81	1,18	2,15	1,58
70	1,77	1,16	2	1,47
80	1,63	1,10	1,89	1,39
90	1,58	1,07	1,70	1,36
100	1,50	1,02	1,64	1,33

Calculation of the flow on the crossing section

$$Q = v \cdot S \cdot 10^{-3}\,[\text{l/min}]. \quad (12)$$

Table 4 presents the table systematization of the hydraulic parameters for a hydraulic cylinder with horizontal movement which occur in the calculation of the adjustment installation.

Table 4. Calculation of hydraulic parameters

Crt. no.	p [bar]	L [mm]	D [mm]	d [mm]	s_a [mm^2]
1	10	125	40	28	1256
2	20	125	40	28	1256
3	30	125	40	28	1256
4	40	125	40	28	1256
5	50	125	40	28	1256
6	60	125	40	28	1256
7	70	125	40	28	1256
8	80	125	40	28	1256
9	90	125	40	28	1256
10	100	125	40	28	1256

Crt. no.	s_p [mm^2]	F_a [daN]	F_p [daN]	t_{ag} [s]	t_{pg} [s]
1	641	125,6	64,1	2,28	1,57
2	641	251,2	128,2	2,08	1,42
3	641	376,8	192,3	1,93	1,27
4	641	502,4	256,4	1,87	1,24
5	641	628	320,5	1,84	1,21
6	641	753,6	384,6	1,81	1,18
7	641	879,2	448,7	1,77	1,16
8	641	1004,8	512,8	1,63	1,1
9	641	1130,4	576,9	1,58	1,07
10	641	1256	641	1,5	1,02

Crt. no.	t_{as} [s]	t_{ps} [s]	v_{ag} [m/s]	v_{ps} [m/s]	v_{as} [m/s]
1	2,8	1,98	0,0548	0,0796	0,0446
2	2,67	1,9	0,0601	0,0880	0,0468
3	2,55	1,86	0,0648	0,0984	0,0490
4	2,4	1,7	0,0668	0,1008	0,0521
5	2,21	1,63	0,0679	0,1033	0,0566
6	2,15	1,58	0,0691	0,1059	0,0581
7	2	1,47	0,0706	0,1078	0,0625
8	1,89	1,39	0,0767	0,1136	0,0661
9	1,7	1,36	0,0791	0,1168	0,0735
10	1,64	1,33	0,0833	0,1225	0,0762

Crt. no.	v_{ps} [m/s]	Q_{ag} [l/s]	Q_{pg} [l/s]	Q_{as} [l/s]	Q_{ps} [l/s]
1	0,0631	0,0689	0,0510	0,0561	0,0405
2	0,0658	0,0755	0,0564	0,0588	0,0422
3	0,0672	0,0813	0,0631	0,0616	0,0431
4	0,0735	0,0840	0,0646	0,0654	0,0471
5	0,0767	0,0853	0,0662	0,0710	0,0492
6	0,0791	0,0867	0,0679	0,0730	0,0507
7	0,0850	0,0887	0,0691	0,0785	0,0545
8	0,0899	0,0963	0,0728	0,0831	0,0576
9	0,0919	0,0994	0,0749	0,0924	0,0589
10	0,0940	0,1047	0,0786	0,0957	0,0602

Figures 11 ÷ 17 present the pressure variations with the force, time, speed and work flow for the idle track and for the load track and with the force for the active and passive track.

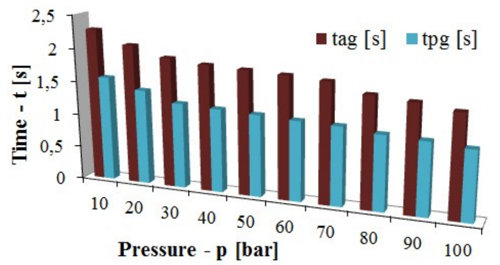

Fig. 11: Time-pressure variation for idle track

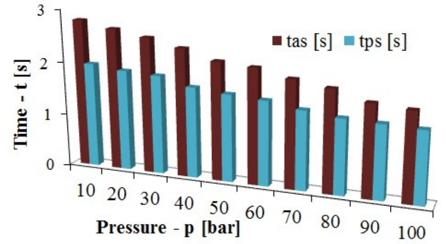

Fig. 12: Time-pressure variation for load track

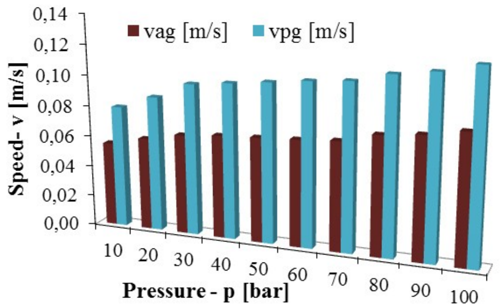

Fig. 13: Speed-pressure variation for idle track

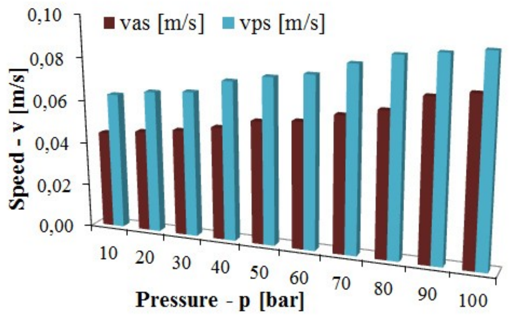

Fig. 14: Speed-pressure variation for load track

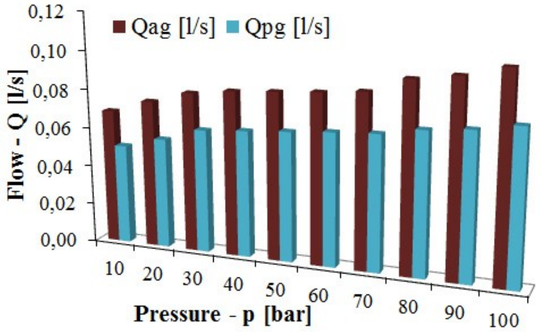

Fig. 15: Flow-pressure variation for idle track

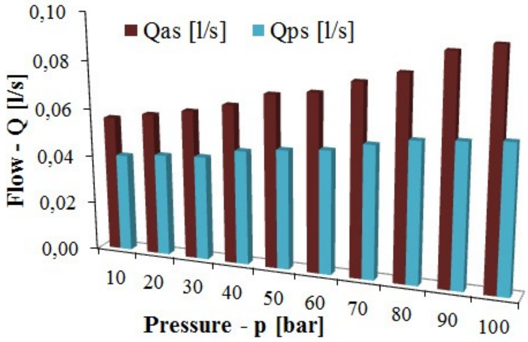

Fig. 16: Flow-pressure variation for load track

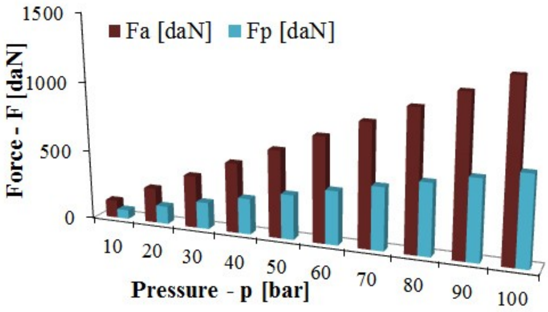

Fig. 17: Force-pressure variation for active and passive track

4. CONCLUSIONS

Following the analysis of the loading of the workbench with different weights, at different pressure variations, the hydraulic cylinder with vertical movement presents an increasing variation in the active forces in terms of the passive ones, relatively close in terms of value for the idle and load tracks.

The time-pressure analysis presents an increase in the run time of the track in the load, correlated with speed decrease for the passive tracks and for the active tracks.

The association flow-pressure indicates higher values for the active track in comparison to the passive track, in idle and in load.

When driving the hydraulic cylinder with horizontal movement, the correlation of time-pressure variation is made in terms of speed-pressure variation, logically observing the increases of the run time of the cylinder track in active tracks, doubled by decreases of the movement speed. At the same time, the study of the flow-pressure variation highlights higher values in terms of the flow for the load track.

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