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A METHOD FOR DETERMINING THE PRESSURE LOSS COEFFICIENTS

Assoc.Prof.Dr. Eng. Niculai HAUK
Assoc.Prof.Dr. Eng. Cristian SIMIONESCU
"Dunarea de Jos" University of Galati
Dept. of Mechanics

ABSTRACT

For braking elements of mechanisms operated by hydraulic cylinders is used hydraulic resistance which controls the working fluid. Determination of these systems is difficult, especially in the design phase. This paper proposes a combined method for determining the functions describing the variation of pressure loss coefficients depending on the parameters of the proposed work.

KEYWORDS: hydraulic cylinders, mechanism, cushioning

1. INTRODUCTION

In many technical applications, hydraulic cylinders set in motion important masses. To reduce the effects of the end of the race impact of hydraulic cylinders is required to reduce the initial impact speed.

In the design phase of machines using these systems is started with a limited amount of information. The mathematical models that describe the functioning of machinery entering data about:

- The kinematics of equipment;
- Used hydraulic schemes.

Integration of differential equations describing the operation of the appliance while in design requires data on the characteristics of hydraulic system components.

In case of hydraulic cylinders provided with cushioning system at end of stroke, interested, among others, specific parameters of variable hydraulic resistance.

This paper proposes a way of determining these characteristics. The analysis started from previous experience [2]. Experimental results are used to certify the results obtained from numerical simulations with specialized programs.

2. Experimental results

Figure 1 shows the detail of the hydraulic cushioned impact at the end of stroke. Adjustable hydraulic resistance contains a cone partially obstructing the discharge of hydraulic oil. Hydraulic oil reaches the cone through a hole that runs from the passive chamber of the hydraulic cylinder. The hole and the hydraulic resistance with cone produces pressure dependent of hydraulic oil flow that passes.

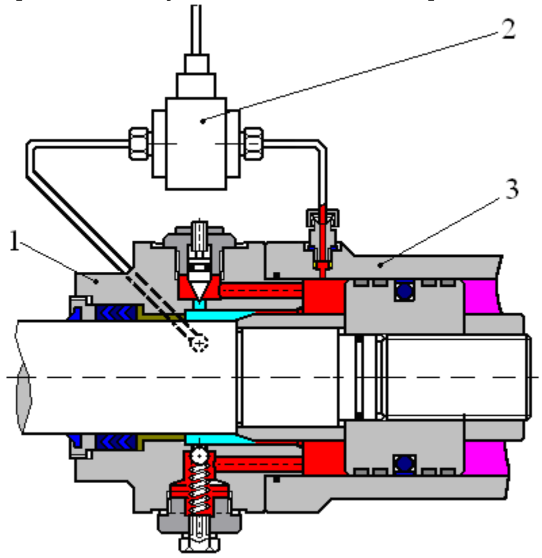

Fig.1 Detail of a hydraulic cylinder with maximum braking end of race: 1 - sealing and support system with hydraulic resistance included, 2 - differential pressure sensor, 3 - hydraulic cylinder body

The experimental study of the characteristics of these elements was performed using a technical trick. To work with known and stable flow was necessary for the piston cylinder to be fixed but allowing the passage of hydraulic oil. Also, should blocked the second escape route of hydraulic oil.

Figure 2 shows the whole scheme changed.

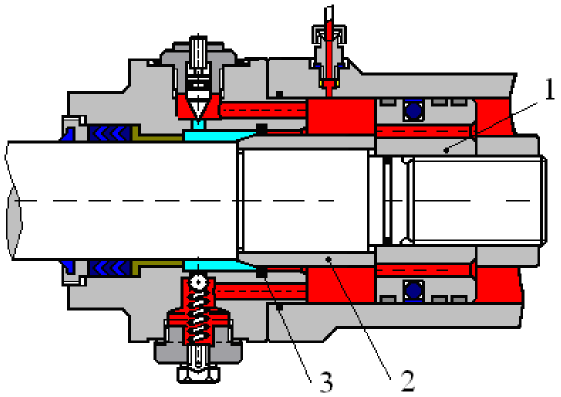

Fig. 2 piston assembly drilling-1, 2 bush, three additional sealing

Size and number of holes are so chosen that thei do not cause significant pressure drops.

Tests were performed on a specialized stand. Determinations were made for more apertures of hydraulic resistance at different flow rates. Were measured the $t^{o}C$ temperatures and the Δp pressure drops.

In tables 1 and 2 are presented results for the opening of hydraulic resistance of 1mm and 4mm

Table 1

Opening of real hydraulic resistance 1 mm

t	*°C*	41	41	42	42.5	43	43	44	44
Q	*l/min*	4.2	8.3	12.3	18.3	25	35	50	70
Δp	*MPa*	0.06	0.14	0.23	0.44	0.81	1.59	3.33	6.62

Table 2

Opening of real hydraulic resistance 4 mm

t	*°C*	35	36.5	37	37	46	46	46	46
Q	*l/min*	4.46	8.31	12.3	18.4	35.7	50.3	69	90.1
Δp	*MPa*	0.06	0.1	0.15	0.23	0.55	0.98	1.75	3.02

For the experiment, we used hydraulic oil whose viscosity is characterized by the values shown in Table 3.

Table 3

Temperature C^{o}	Viscosity $\upsilon\left[{}^{\circ}E\right]$	Viscosity υ $[m^2/s]$
30	7,3	55,5E-6
50	4,05	30E-6
70	2,8	19E-6

3. RESULTS OF THE VIRTUAL SIMULATION

Virtual experiments were performed on a hydraulic cylinder with amortization of movement at maximum stroke. The elements of geometry are similar to those of the cylinder used in the real experiment. The axonometric representation of the virtual cylinder is shown in Figure 3.

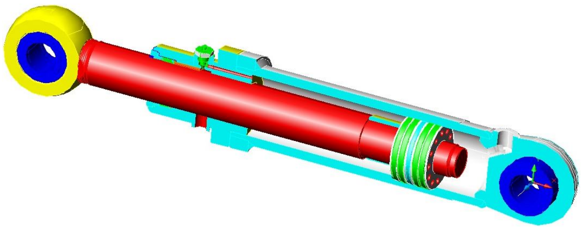

Fig. 3 . Hydraulic cylinder used in the virtual experiment

A detail of the variable hydraulic resistance area is shown in Figure 4.

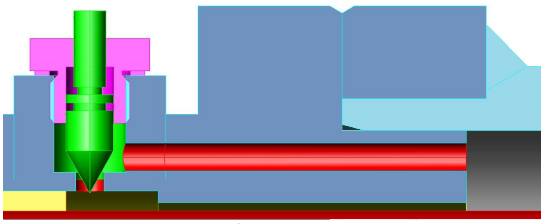

Fig. 4. Detail of the adjustable hydraulic resistance

Flow simulations of the entire virtual cylinder was observed that the pressure behind the piston drilling is relatively uniform. It differs slightly from the supply pressure in the cylinder. Therefore it is preferred to simplify the problem considering the special piston flow from behind. Based on this hypothesis, was built body of the liquid within the area considered. Axonometric representation is shown in Figure 5.

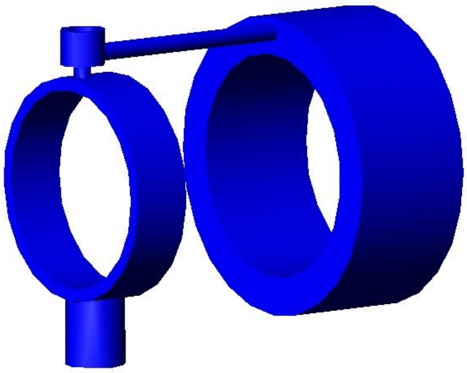

Fig. 5. Body fluid

There have been studied the effects of onehalf of body fluid because the flow is symmetrical. In Figure 6 is presented the finite element mesh. We worked with an average accuracy of calculation for different openings of adjustable hydraulic resistance and flow in Tables 1 and 2.

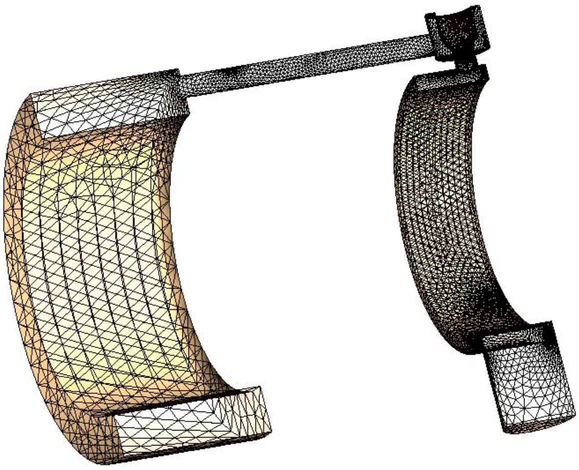

Fig. 6. Mesh body fluid

Graphic results of virtual simulation of flow are presented in Figures 7 (a and b).

In order to obtain point values of the parameters were considered the reference points plotted in Figure 8. Especially are interested in pressure difference between points 1 and 2.

Were compared the results from the virtual experiment to the real experiments done in terms of input parameters. The differences are due to the real cylinder geometry. It is affected by errors of execution and tears. They occur mainly in the surface area and in the active edges of hydraulic resistance.

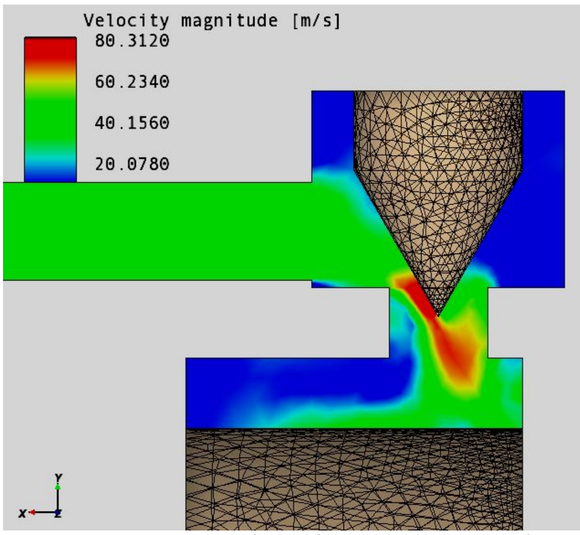

Fig. 7a. Detail of the flow in the area of hydraulic resistance.

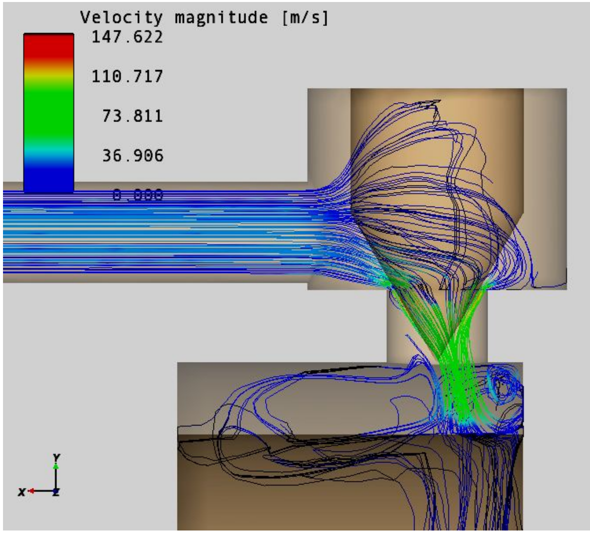

Fig. 7b Detail of the flow lines in the area hydraulic resistance.

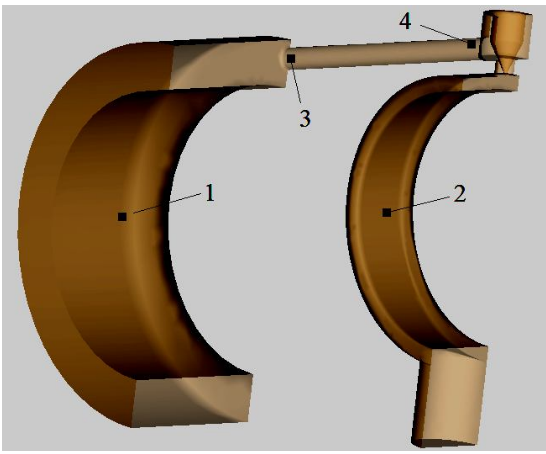

Fig.8. Points that were made reporting the parameters of interest

3. RESULTS AND CONCLUSIONS

Some of the results of virtual experiments are presented in Tables 3 and 4. Keeping the same temperature and flow rate variation it results that the pressure drop is between zones 1 and 2 (Figure 8).

Table 3

Open virtual hydraulic resistance 1 mm

t	*°C*	41	41	42	42.5	43	43	44	44
Q	*l/min*	4.2	8.3	12.3	18.3	25	35	50	70
Δp	*MPa*	0.04	0.14	0.3	0.65	1.2	2.3	4.6	9.1

Table 4

Open virtual hydraulic resistance 4 mm

t	*°C*	41	41	42	42.5	43	43	44	44
Q	*l/min*	4.2	8.3	12.3	18.3	25	35	50	70
Δp	*MPa*	0.01	0.05	0.09	0.2	0.65	1.4	2.3	3.86

Total fall of pressure may be considered as a sum of pressure drop of the hole and adjustable hydraulic resistance. Knowing the flow that passes through the hole and its geometry can be computed successively:

- flow rate:

$$V_{duz} = \frac{4Q}{\pi D_{duz}^2} \quad (1)$$

- Reynolds number:

$$Re_{duz} = \frac{V_{duz} \cdot D_{duz}}{\nu(t)} \quad (2)$$

- flow coefficient Cd_{duz}

$$C_{duz} = \begin{cases} \dfrac{1}{\left(1{,}5 + 13{,}74\sqrt{\dfrac{l_1}{d_1 \cdot R_e}}\right)^{0{,}5}} & for\ \dfrac{d_1 R}{l_1} \\ \dfrac{1}{\left(2{,}28 + 64 \cdot \dfrac{l_1}{d_1 \cdot R_e}\right)^{0{,}5}} & for\ \dfrac{d_1 R}{l_1} \end{cases} \quad (3)$$

- pressure drop on the hole:

$$\Delta p_{duz} = \frac{Q^2 \cdot \rho}{2Cd_{duz}^2 \cdot \left(\dfrac{\pi D_{duz}^2}{4}\right)^2} \quad (4)$$

- pressure drop on adjustable hydraulic resistance:

$$\Delta p_{dr} = \Delta p - \Delta p_{duz} \quad (5)$$

- $A_{(z)}$ flow area equivalent hydraulic diameter:

$$D_{hdr} = \frac{4A_{(z)}}{P_{(z)}} \quad (6)$$

Hydraulic wet area is

$$Ph_{(z)} = 2 \cdot \pi \cdot \left(2R - z \cdot tg\frac{\alpha_v}{2}\right) \quad (7)$$

Reynolds number is calculated by

$$Re_{dr} = \frac{V_{dr} \cdot D_{hdr}}{\nu(t)} \quad (8)$$

where the throttle flow coefficient:

$$Cd_{dr} = \frac{Q}{\dfrac{\pi D_{0dr}^2}{4}\sqrt{\dfrac{2}{\rho}\Delta p_{dr}}} \quad (9)$$

Based on data from real and virtual experiments were prepared tables 5 and 6.

Table 5. Real experiment

z_{dr}= 1 mm

Q	Δp_t	Δp_{dr}	Δp_{duz}	$\sqrt{Re_{dr}}$	$\sqrt{Re_{duz}}$	Cd_{dr}	Cd_{duz}	*t*
l/min	*MPa*	*MPa*	*MPa*					*°C*
4.2	0.06	0.05	0.01	44.2	17.9	0.16	0.46	41.0
8.3	0.14	0.12	0.02	62.2	25.2	0.22	0.54	41.0
12.3	0.23	0.19	0.03	76.9	31.1	0.26	0.57	42.0
18.3	0.44	0.36	0.07	94.6	38.3	0.28	0.60	42.5
25.0	0.81	0.67	0.13	111.	45.1	0.28	0.62	43.0
35.0	1.59	1.33	0.25	132.	53.4	0.28	0.64	43.0
50.0	3.33	2.85	0.47	160.	64.8	0.27	0.66	44.0
70.0	6.62	5.73	0.88	189.	76.7	0.27	0.67	44.0

Table 6. Virtual experiment

z_{dr}= 1 mm

Q	Δp_t	Δp_{dr}	Δp_{duz}	$\sqrt{Re_{dr}}$	$\sqrt{Re_{duz}}$	Cd_{dr}	Cd_{duz}	*t*
l/min	*MPa*	*MPa*	*MPa*					*°C*
4.2	0.04	0.03	0.01	44.3	17.9	0.21	0.46	41.0
8.3	0.14	0.12	0.02	66.2	25.2	0.22	0.54	41.0
12.3	0.30	0.26	0.04	76.9	31.1	0.22	0.57	42.0
18.3	0.65	0.57	0.08	94.6	38.3	0.22	0.60	42.5
25.0	1.20	1.06	0.14	111.	45.1	0.22	0.62	43.0
35.0	2.30	2.05	0.25	132.	53.4	0.23	0.65	43.0
50.0	4.60	4.12	0.48	160.	64.9	0.23	0.67	44.0
70.0	9.10	8.21	0.89	189.	76.8	0.23	0.68	44.0

As expected, in the virtual experiment, flow coefficients are smaller. This is due to sharp edges which do not appear on the real model.

Laws of variation of flow coefficients can be translated into a form convenient for numerical simulation programs used in the various equipments analyzed.

The proposed method eliminates the physical design phase experiment. This reduces design time and costs involved. The data obtained are consistent and closer to reality with increasing precision calculation.

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