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ON THE INFLUENCE OF TEMPERATURE ON THE CUSHIONING ABILITY OF THE HYDRAULIC CYLINDERS

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ABSTRACT

This paper presents some aspects related to the way the cushioning capacity of hydraulic cylinder is affected by the temperature variations of the hydraulic fluid. We have analysed the case of the hydraulic cylinders with cushioning systems, which act translational moving objects. The modification of the systems behavior is due to the significant variation of the hydraulic resistance with the viscosity of fluid. This leads to the modification of the hydraulic resistance of the cushioning system, responsible for braking the moving parts.

KEYWORDS: hydraulic cylinders, cushioning, hydraulic fluid viscosity

1. INTRODUCTION

The hydraulic oils, used to activate the mechanical systems, can reach different temperatures depending on:

-the ambient temperature where the machine is located;

-the cooling / heating ability of the hydraulic system;

-the sizes of hydraulic resistances as sources of heating by viscous friction;

-the speed of the hydraulic fluid circulation;

-the exposure to sunlight;

-the exposure to atmospheric air circulation which produces the exchange of heat by convection.

For a significant increase of the productivity has become necessary a increase of working speed. This requirement leads to an increase of the mechanical inertia and hence an increased risk of major mechanical shocks when the mechanical system reaches the end of the race.

If the machines are equipped with hydraulic cylinders is applied the cushioning at end of the race. This produced a significant increase in braking efficiency. The process has the disadvantage of affect of the size of the hydraulic cylinders. Also, the price increase significantly.

Unfortunately braking effectiveness depends on the temperature of the hydraulic fluid used. At startup, when the hydraulic fluid temperature is equal with the environment temperature, it is possible get an effective cushioning and, after a time, due to the warming of the hydraulic fluid, the cushioning effect may become insignificant.

2.THE HYDRO-MECHANICAL MODEL AND THE WORK HYPOTHESES

In order to highlight influence of temperature on the hydraulic braking capacity at the end of stroke of the hydraulic cylinders, fitted with cushioning system, a virtual experiment was conceived. In Figure 1 there is a schematic diagram of the system. Cinematic and hydraulics elements are included in the scheme.

The hydraulic cylinder, fitted with impact cushioning at both ends, act on a technological element found in linear movement.

Technological and friction forces acts on components of the mobile assembly.

Active forces are generated by the pressure difference between the faces of the hydraulic piston.

The pressure losses occurring outside the hydraulic cylinder are neglected.

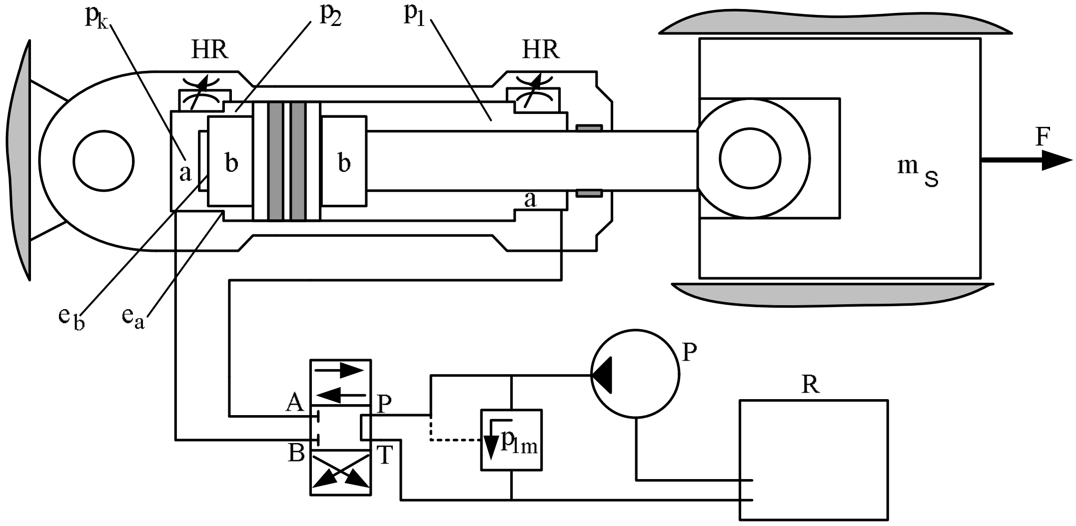

Fig. 1 The work scheme of a hydraulic cylinder fitted with impact cushioning at both ends

Braking at the end stroke is achieved by increasing the hydraulics resistance of the circuit for hydraulic fluid disposal. The hydraulic fluid is eliminated from the hydraulic cylinder on two paths. In Figure 2 the fluid body is shown.

The fluid leaves the variable volume "A" and reaches the reservoir "B" by the paths "1" and "2". The geometry of circuit "2" does not depend on the piston position, as it happens on the circuit "1".

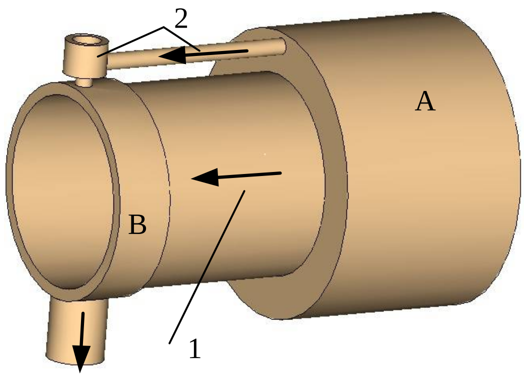

Fig. 2 Fluid body

In Figure 3, the effects of the adjustable hydraulic resistance on the flow are schown. Figure 4 shows the fluid flow lines through the two paths.

Assessment of the flow characteristics is achieved through numerical simulation. It was established relationship between the flow coefficients "Cd" and "$\sqrt{R_e}$" with

$$C_d = \begin{cases} K_d \cdot \sqrt{R_e} & \text{for} \quad R_e < R_{ecr} \\ C_{max} & \text{for} \quad R_e > R_{ecr} \end{cases} \qquad (1)$$

were

$$R_e = \frac{v \cdot d}{\upsilon} \qquad (2)$$

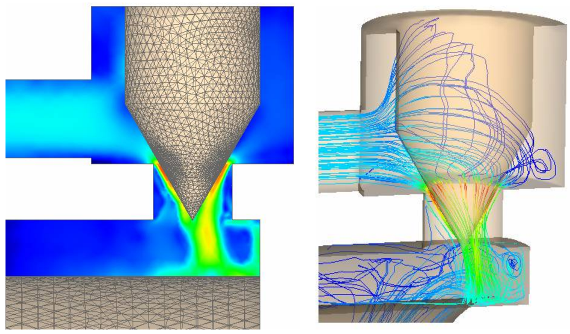

Fig. 3 Adjustable hydraulic resistance

Parameter υ is the kinematic viscosity and its value depends on the temperature of the hydraulic fluid.

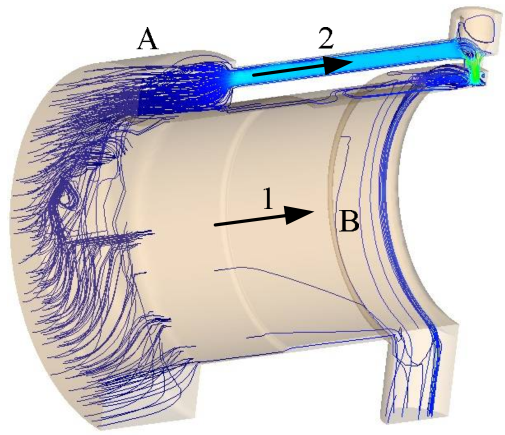

Fig. 4 Flow lines on the two routes

For the calculation of the viscosity at a certain temperature the following approximate relationship was used

$$\upsilon_t = \upsilon_{t=50^O C} \cdot \left(\frac{50}{t}\right)^{2.1567} . \quad (3)$$

The variation of viscosity with temperature changes the hydraulic resistance. The expression of the flow discharged from the hydraulic cylinder depends of the relative position between the edges "e_a" and "e_b":

-phase " I ", before the edge "e_b" enters the volume "a"

$$Q_e = Q_2 + Q_1 = \sqrt{\frac{2 \cdot \Delta p_{2k}}{\rho\left(\frac{1}{Cd_{dz}^2 A_{dz}^2} + \frac{1}{Cd_{dr}^2 A(z)^2}\right)}} \quad (4)$$

$$+C_{dS} A_{CS} \sqrt{\frac{2 \cdot \Delta p_{2k}}{\rho}} =$$

- phase " II ", the edge "e_b" is inside the volume "a"

$$Q_e = Q_2 + Q_1 = \sqrt{\frac{2 \cdot \Delta p_{2k}}{\rho\left(\frac{1}{Cd_{dz}^2 A_{dz}^2} + \frac{1}{Cd_{dr}^2 A(z)^2}\right)}} \quad (5)$$

$$+\frac{\pi \cdot D_m \cdot \delta^3 \cdot \Delta p_{2k}}{96\eta \cdot l_S}$$

Based on the mathematical expressions of the pressure and of forces balance, a differential equation of motion is obtained:

$$f = \begin{cases} f_I\left(x, \dot{x}, \ddot{x}, p_1\right) = 0 \;\; for \; 0 \le x \le x_0 \\ f_{II}\left(x, \dot{x}, \ddot{x}, p_1\right) = 0 \;\; for \; x_0 < x < x_0 + l_b \end{cases} \quad (6)$$

The solution of this differential equation is performed numerically.

2. NUMERICAL APPLICATION

To illustrate how the change of temperature affects the braking capacity (at end of stroke) a numerical simulation on an modified computer program was made.

The simulation are made at two usual temperatures of the hydraulic fluid (20 ° C and 80 ° C).

The remaining parameters are not changed. Data from the numerical simulations are presented in tabular (1 and 2) and graphical form - Figure 5.

The H46 hydraulic oil was considered as hydraulic fluid.

The used geometric and functional parameters correspond to a normal hydro-mechanical system. Only those results which are relevant for the analysis were retained.

Table 1

t ms	x m	v m/s	a m/s^2	P_2 MPa	Q2 l/s	Q1 l/s	P1 MPa
0	0	0.00	1.66	0.15	0	0	18.00
20	0.33	33.29	1.66	0.15	0	0.21	18.00
40	1.33	66.48	1.66	0.15	0	0.42	18.00
60	2.99	99.67	1.66	0.15	0	0.63	18.00
80	5.32	132.8	1.66	0.15	0	0.84	18.00
100	8.20	147.3	0	0.15	0	0.93	14.48
120	11.15	147.3	0	0.15	0	0.93	14.48
140	14.10	147.3	0	0.15	0	0.93	14.48
160	17.04	147.3	0	0.15	0	0.93	14.48
180	19.99	147.3	0	0.15	0	0.93	14.48
200	22.94	147.3	0	0.15	0	0.93	14.48
220	25.89	147.3	0	0.15	0	0.93	14.48
240	28.83	147.3	0	0.15	0	0.93	14.48
260	31.77	142.5	-1.15	10.8	0.63	0.27	18.00
280	34.36	116.6	-1.14	10.8	0.63	0.11	18.00
300	36.50	99.05	-0.62	8.86	0.57	0.06	18.00
320	38.38	89.81	-0.32	7.71	0.53	0.04	18.00
340	40.21	85.02	-0.17	7.13	0.51	0.03	18.00
360	41.79	82.47	-0.09	6.84	0.50	0.03	18.00
380	43.43	81.03	-0.05	6.69	0.49	0.02	18.00
400	45.04	80.17	-0.03	6.62	0.49	0.02	18.00
420	46.63	79.61	-0.02	6.58	0.49	0.02	18.00
440	48.22	79.22	-0.02	6.55	0.48	0.02	18.00
460	49.8	78.92	-0.01	6.54	0.48	0.01	18.00

Table 2

t ms	x m	v m/s	a m/s^2	P_2 MPa	Q2 l/s	Q1 l/s	P1 MPa
0	0	0.00	1.66	0.15	0	0	18.00
20	0.33	33.29	1.66	0.15	0	0.21	18.00
40	1.33	66.48	1.66	0.15	0	0.42	18.00
60	2.99	99.67	1.66	0.15	0	0.63	18.00
80	5.32	132.8	1.66	0.15	0	0.84	18.00
100	8.20	147.3	0	0.15	0	0.93	14.48
120	11.15	147.3	0	0.15	0	0.93	14.48
140	14.10	147.3	0	0.15	0	0.93	14.48
160	17.04	147.3	0	0.15	0	0.93	14.48
180	19.99	147.3	0	0.15	0	0.93	14.48
200	22.94	147.3	0	0.15	0	0.93	14.48
220	25.89	147.3	0	0.15	0	0.93	14.48
240	28.83	147.3	0	0.15	0	0.93	14.48
260	31.78	147.3	0	1.55	0.23	0.70	18.00
280	34.73	147.3	0	3.28	0.34	0.59	18.00
300	37.68	147.3	0	4.65	0.41	0.52	18.00
320	38.38	147.3	0	5.80	0.46	0.48	18.00
340	43.57	147.3	-0.07	6.77	0.49	0.44	18.00
360	44.49	143.9	-0.24	7.40	0.52	0.39	18.00
380	49.31	138.3	-0.31	7.67	0.53	0.35	18.00

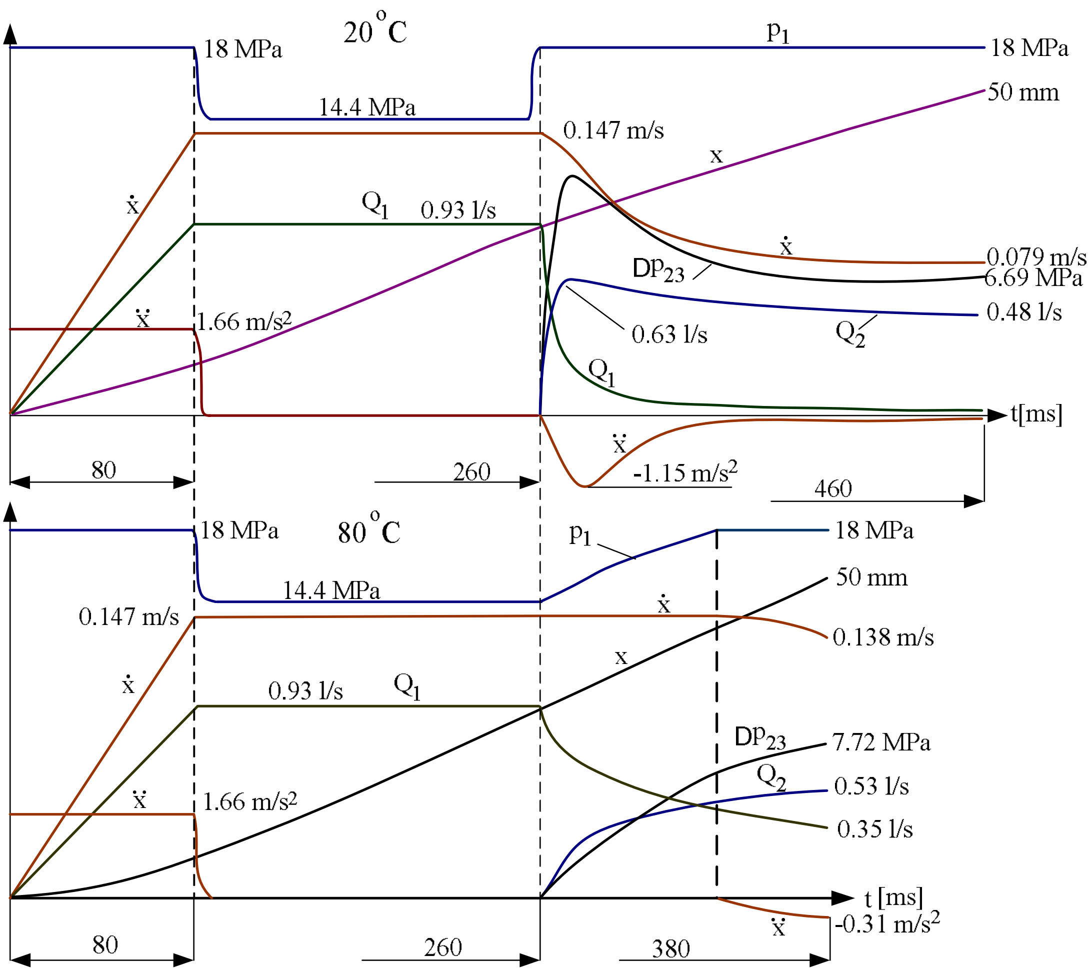

Fig.5 Graphic representation of the functional parameters

3. CONCLUSIONS

The tabular and graphical results indicate a significant impact of temperature variation on cushioning parameters.

The two numerical simulations indicate identical behavior on phase "I" (up to 260 ms).

In phase "II", there are notable differences:

- braking time increases and the speed lowers significant if the hydraulic fluid is cold;

- decrease of speed is reduced if the oil is hot.

The negative effect of the impact at the end of the race increases with the temperature of the hydraulic fluid.

Above a certain temperature, the reduction of the speed of the mobile system disappears completely. It results that the adjustment of the hydraulic resistance must be made on special stands. Also, the maximum temperature of the hydraulic fluid must limited.

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