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LIFT OF HYDRAULIC POWERED MATERIALS AND DRIVEN BY A PROGRAMMABLE AUTOMATIC

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Abstract: *The paper presents the stages of designing a lift for materials, hydraulically driven by a programmable automatic. The introduction presents the history of the lift, the advantages and disadvantages of the hydraulic lift compared to the mechanical lift with drums, rollers and cables.*

Keywords*: Lift, hydraulic, regime dynamic, automatic programmer.*

In 1867 Leon Edoux presents at the Universal Exhibition in Paris "the first safe direct action hydraulic lifts". The four cast iron guide columns of the elevator were also containers for four counterweights, fastened by chains that rolled down over the rollers, ensuring passenger safety. In 1868 Waygood manufactured the first hydraulic lift.

Operating principle: The operating principle of a hydraulic lift is incredibly simple, it's just a cab attached to a lift system.

Of course, modern passenger and freight elevators are much more elaborate. They need advanced mechanical and electronic systems to manage the substantial weight of the lift cab and its cargo. In addition, they have there is a need for safety and control mechanisms so that everything works smoothly when passengers use them.

The most commonly used models of elevators are hydraulic lifts with direct drive and hydraulic lifts with an indirect drive.

Hydraulic lifts use a hydraulic cylinder operated from the inside by a fluid. You can see this in the sketch below.

2. The operating principle

The cylinder is connected to a hydraulic source (usually hydraulic systems use high-pressure resistant oil). The hydraulic system has the following components:
- a tank (fluid reservoir);
- hydraulic pump, powered by an electric motor;
- safety valve;
- hydraulic track regulator;
- a solenoid valve between the cylinder and the tank;
- reinforcements and pipes.

The hydraulic pump generates sub pressure fluid which through the valves and pipes act the cylinder vertically. When the valve opens the fluid will return to the tank (control unit) and the elevator will descend. When the valve is closed, the liquid under pressure has nowhere to go except in the cylinder. Thus, the fluid collected in the cylinder pushes the piston upward by lifting the elevator cab. To lower the lift, the control system sends a signal to the valve. When the electrical system opens the valve, the fluid that is collected in the cylinder can flow into the liquid reservoir. The weight of the machine and load pushes down the piston that drives the fluid into the tank. The car slowly descends. To stop the cabin on a lower floor, the control system closes the valve again.

2.1 Advantages and disadvantages of the hydraulic lift

- This system is simple and extremely efficient but has some disadvantages.
- In most cases, hydraulic lifts are used where no speed greater than 1 m / s is required.
- There is no limit to high weight. For hydraulic lifts, the normal run goes up to 25 m, and with some special constructions, it can go up to 35 m.
- Maintenance cost - in general, less maintenance work is required on hydraulic lifts, because the pump-engine system works in the oil and has a longer life (lower usage, high reliability).

- To the hydraulic lifts, the engine is running only on the way up, that is, it works half the time compared with the engine at the electric lifts.

- The machine room - the well - to the hydraulic lifts the static and dynamic loads press on the foundation of the building, which by its construction is very resistant. At the electric lifts, the respective loads are taken from the roof of the building that must be specially strengthened.
- Emergency - at hydraulic lifts, the evacuation (at power failure) is very simple, the cab descends to the station below without the need for engine (control unit) operation.

3. The mathematical model of a hydraulic lift equipped with the valve

3.1. Analysis and simulation of the hydraulic system

We will analyze the numerical simulation using the Mathcad environment. Dynamic simulation has two objectives: one is to investigate the dynamic characteristics of the system when climbing and to analyze the existing problems, as well as to adjust the system parameters. A second objective is to compare the dynamic characteristics of the solenoid valve and the downstream hydraulic regulator.

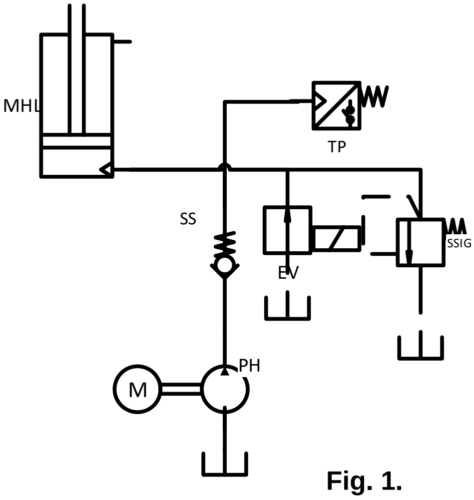


Fig. 1.

3.2 The mathematical model

An elevator is a machine used to lift goods vertically to one or more floors

The lifting mechanism of a lift (figure 1) consists of the metal frame on which a platform slides through which the load is lifted. The load is driven by an MHL hydraulic cylinder. For high productivity, it is necessary to optimize the lifting or lowering of the lifting mechanism. The acceleration (deceleration) process must be evaluated as a whole (hydraulic pump - solenoid valve). In figure 1 the hydraulic circuit is classic: the MHL hydraulic cylinder is fed by the PH pump through the sense valve.

For lifting shall be connected the electric motor E. For lowering is actuated the solenoid valve EV. The braking is provided by the hydraulic resistance of the pipes. The descent is made under the weight of the platform and the load.
- mechanical system analysis.

when lifting $F=2*F_f$ (1)

when descent $F=2*S$ (2)

The mechanical parameters of the hydraulic cylinder (space, speed, acceleration) change according to the physical process [2]. They may exceed the limit values of:
- maximum pressure of the hydraulic source
- full speed

$$v_{max} = \frac{Q_a}{A_a} = \frac{Q_p}{A_a} \tag{3}$$

- maximum acceleration

$$a_{max} = \frac{p_0 \cdot A_a - F_{max}}{m} \tag{4}$$

but the pump continues to introduce liquid into the space between the pump and the cylinder leading to increased acceleration. (F=ct)

$$\frac{\partial q}{\partial t} = ke\frac{\partial p}{\partial t} \tag{5}$$

or can be expressed through the relationships:

$$a = \frac{pA_a - F}{m} \tag{6}$$

provided that p satisfies:

$$p = \frac{E\Delta V}{V} = \frac{EQ_d \cdot t}{V_a + V_S} = \frac{MQ_d}{V_a + A_a \cdot S} \cdot t \tag{7}$$

and result :

$$a = \frac{A_a}{m} \cdot \frac{EQ_d}{V_a + A_a \cdot S(t)} \cdot t - \frac{F}{m} \tag{8}$$

where: S - lift load; Ff - the frictional forces of the sled and the pulley;

- the coefficient of friction; s, a, v - the space, speed and acceleration of the stem; t - time; Aa - the area of the cylinder; E - the modulus of elasticity; V - total volume of fluid; - volume of liquid due to compression; Qd, Qp-flow through the respective pump distributor.
From the expression (8) the acceleration increases linearly with time until either the maximum pressure or the maximum speed (3) is reached.
The process equations are:
where: S - lift load; Ff - the frictional forces of the sled and the pulley;
μ - the coefficient of friction; s, a, v - the space, speed and acceleration of the stem; t - time; Aa - the area of the cylinder; E - the modulus of elasticity; V - total volume of fluid; ΔV - volume of liquid due to compression; Qd, Qp- flow rate through the distributor respectively of the pump
From the expression (8) the acceleration increases linearly with time, until either the maximum pressure or the maximum speed (3)
The process equations are:

$$p_0 = \frac{F}{A_a} \tag{9}$$

it is the moment of beginning the displacement at which the acceleration is zero:

$$t_0 = \frac{V_a \cdot p_0}{E \cdot Q_d} = \frac{V_a \cdot F}{A_a \cdot E \cdot Q_d} \tag{10}$$

if :

$$k_1 = \frac{A_a \cdot E \cdot Q_d}{m \cdot V_a} \quad \text{and} \quad k_2 = \frac{F}{m} \tag{11}$$

then :

$$a = k_1 \cdot t - k_2 \tag{12}$$

again

$$v = \int a(t)dt = \frac{k_1}{2} \cdot t^2 - k_2 \cdot t \tag{13}$$

$$s = \int v(t)dt = \frac{k_1}{6} t^3 - \frac{k_2}{2} t^2 \tag{14}$$

and pressure

$$p = \frac{ma + F}{A_a} = \frac{m(k_1 t - k_2) + F}{A_a} \tag{15}$$

In conclusion, the speed becomes constant (no increases) when it is reached $Q_{max}=Q_p$ or $p_{max}=p_s$.

1) Evolution of the parameters of the system where it is reached $Q_{max}=Q_p$

$$p_{01} = F / A_a \tag{16}$$

$$t_{01} = \frac{V_a}{E \cdot Q_p} \cdot \frac{F}{A_a} \tag{17}$$

if $v_{max} = Q_d / A_a$ results from the equation (13)

$$\frac{k_1}{2} t_{a1} - k_2 t_{a1} = Q_1 / A_a \tag{18}$$

where it can express itself

$$t_{a1} = \frac{k_2 + \sqrt{k_2^2 - 2k_1 Q_p / A_a}}{k_1} \tag{19}$$

$$a_{a1} = k_1 \cdot t_{a1} - k_2 \tag{20}$$

and after the time $t_{01} + t_{a1}$ acceleration $Qa = 0$

$$v_{a1} = v_{\max} = Q_p / A_a \tag{21}$$

$$s_{a1} = \frac{k_1}{} t_a{}^3 - \frac{k_2}{2} t_a{}^2 \tag{22}$$

$$p_{a1} = \frac{m \cdot a_{a1} - F}{A_a} = \frac{m\left(k_1 \cdot t_{a1} - k_2\right) + F}{A_a} \tag{23}$$

Finally, they can be written $s(t), v(t), a(t), p(t), Q(t)$ dpending on time:

$$t = 0,001 \ldots t_{01} + t_{a1} + 0,1 \quad [s] \tag{24}$$

$$(t)=\frac{t_{01}{}^{2}}{3}\left(\frac{t_{a1}}{2}-k_2\right) \tag{25}$$

$$v_1(t)=\begin{cases}\frac{k_1}{2}t^2-k_2\cdot t & daca\ t\le t_{01}+t_{a1}\\ v_{a1} & daca\ t>t_{a1}+t_{01}\end{cases} \tag{26}$$

$$a_1(t)=\begin{cases}\frac{k_1}{2}-k_2 & daca\ t\le\left(t_{01}+t_{a1}\right)\\ 0 & daca\ t>\left(t_{a1}+t_{01}\right)\end{cases} \tag{27}$$

$$p_1(t)=\begin{cases}\frac{p_{a1}}{t_{01}+t_{a1}} & daca\ t\le t_{a1}+t_{01}\\ p_s & daca\ t>t_{a1}+t_{01}\end{cases} \tag{28}$$

$$Q_1(t)=\begin{cases}0 & daca\ t\le\frac{\Delta V}{Q_{\max}}\\ Q_p & daca\ t>\frac{\Delta V}{Q_{\max}}\end{cases} \tag{29}$$

Lift – Hydraulic circuit

Initial dates :

$s=700\,daN$ $D=5cm$ $1daN=10N$ $1bar=10^5Pa$

$a=15\,deg$ $d=3{,}6cm$ $V_a=5000cm^3$

$Q_p=4000\frac{cm^3}{s}$ $h=70cm$ $V_b=3000cm^3$

$\Delta p=10bar$ $E=1{,}5\cdot10^4bar$

$m=\frac{S}{g}$ $m=713{,}801kg$ $G=S\cdot\sin\alpha$ $G=1{,}812\cdot10^3N$

$A_a=\frac{\pi D^2}{4}$ $A_b=\frac{\pi\left(D^2-d^2\right)}{4}$ $A_a=19{,}635cm^2$ $A_b=9{,}456cm^2$

$p_s=3\cdot\left(\frac{G}{A_a}+\Delta p\right)$ $p_s=57{,}681bar$ or : $p_s=100bar$

1.The acceleration phase of the mechanism assuming that $p_a<p_s$ $F=0\,N$

$p_{01}=\frac{G+F}{A_a}$ $p_{01}=9{,}227bar$ $t_{01}=\frac{V_a}{E\cdot Q_p}\cdot\frac{G+F}{A_a}$ $t_{01}=7{,}689\cdot10^{-4}s$

$k_1=\frac{A_a\cdot E\cdot Q_p}{m\cdot V_a}$ $k_1=3{,}301\cdot10^5\,cm/s^3$ $k_2=\frac{G+F}{m}$ $k_2=253{,}815\,cm/s^2$

$t_{a1}=\frac{k_2+\sqrt{k_2^2\frac{2k_1\cdot Q_p}{A_a}}}{k_1}$ $t_{a1}=0{,}036\,s$

$a_{a1}=k_1\cdot t_{a1}-k_2$ $a_{a1}=115{,}998\,m/s^2$ $very\ high\ volume$!!!

$\Delta V=1\cdot10^2\cdot cm^3$

$v_{a1} = \frac{Q_p}{A_a}$ $\qquad v_{a1} = 2.307\, m/s$ $\qquad q_1 = \frac{\Delta V}{Q_p}$

$s_{a1} = \frac{k_1}{6} \cdot t_{a1}^3 - \frac{k_2}{6} \cdot t_{a1}^2$ $\qquad s_{a1} = 2{,}384 cm$ $\qquad q_1 = 0{,}025 s$

$p_{a1} = \frac{m \cdot a_{a1} - (G+F)}{A_a}$ $\qquad p_{a1} = 412{,}468\ bar$ $\qquad$ *very high volume* !!!

$t = 0 \cdot s, 0{,}001 \cdot s \ldots t_{01} + t_{a1} + 0{,}1 \cdot s$ $\qquad s(t) = \cdots \frac{t^2}{3} \cdot \left(\frac{k_1}{2} \cdot t - k_2\right)$

$$p_1(t) = \left| \begin{array}{lll} \frac{p_{a1}}{t_{01}+t_{a1}} \cdot t & if & t \le t_{a1} + t_{01} \\ p_{01} & if & t > t_{a1} + t_{01} \end{array} \right. \qquad v_1(t) = \left| \begin{array}{lll} \frac{k_1}{2} \cdot t^2 - k_2 \cdot t & if & t \le t_{a1} + t_{01} \\ v_{01} & if & t > t_{a1} + t_{01} \end{array} \right.$$

$$v_1(t) = \left| \begin{array}{lll} \frac{k_1}{2} \cdot t^2 - k_2 \cdot t & if & t \le t_{a1} + t_{01} \\ 0 & if & t > t_{a1} + t_{01} \end{array} \right. \qquad Q_1(t) = \left| \begin{array}{lll} 0 & if & t < q_1 \\ Q_p & if & t > q_1 \end{array} \right. \qquad \begin{array}{r} Q_p = 4 \cdot 10^{-3}\, m/s \\ q_1 = 0{,}025\ s \end{array}$$

2. The acceleration phase of the mechanism in the event that $p_a > p_s$

$p_{02} = p_{01}$ $\qquad t_{02} = t_{01}$

$a_{a2} = \frac{p_s \cdot A_a - (G+F)}{m}$ $\qquad a_{a2} = 24{,}969\, m/s^2$ $\qquad t_p = \frac{a_{a2} + k_2}{k_1}$ $\qquad t_p = 8{,}333 \cdot 10^3\ s$

$v_p = \frac{k_1}{2} \cdot t_p^2 - k_2 \cdot t_p$ $\qquad v_p = 0{,}093\, m/s$ $\qquad s_p = \frac{k_1}{6} \cdot t_p^3 - \frac{k_2}{2} \cdot t_p^2$ $\qquad s_p = 0{,}023\ cm$

$t_s = \frac{v_{a1} - v_p}{a_{a2}}$ $\qquad t_s = 0{,}078\ s$ $\qquad t_{a2} = t_p + t_s$ $\qquad t_{a2}$ =0,086 s

$s_s = \frac{a_{a2} \cdot t_s^2}{2}$ $\qquad s_s = 0{,}076\ m$

$s_{a2} = s_p + s_s$ $\qquad s_{a2} = 0{,}076\ m$

$p_{a2} = \frac{m \cdot a_{a2} - (G+F)}{A_a}$ $\qquad p_{a2} = 81{,}546\ bar$ $\qquad$ *and is* $< p_{a1}$

3. Calculation of working parameters in the acceleration period of the mechanism

$$h_k = \frac{\frac{A_b \cdot h}{10 \cdot \sqrt{A_b^3}} + \frac{V_a}{\sqrt{A_b^3}} - \frac{V_b}{\sqrt{A_a^3}}}{10 \cdot \frac{1}{\sqrt{A_a}} + \frac{1}{\sqrt{A_b}}} \qquad h_k = 25{,}368\ cm$$

$C_1 = \frac{A_a^2 \cdot E}{A_a \cdot h_k + V_a}$ $\qquad C_2 = \frac{A_b^2 \cdot E}{A_b \cdot (h - h_k) + V_a}$ $\qquad C_1 = 1{,}052 \cdot 10^3\ daN/cm$ $\qquad C_2 = 247{,}378\, daN/cm$

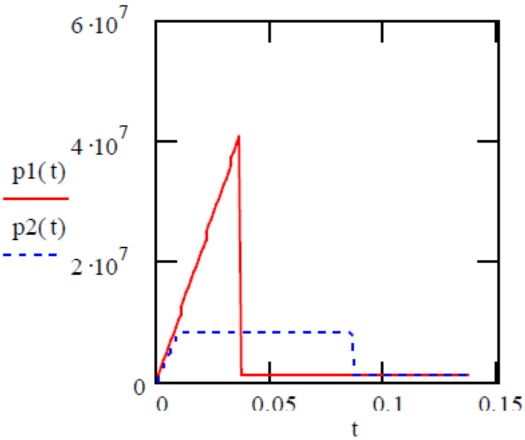
$f_{0_{min}} = \frac{1}{2\pi} \cdot \sqrt{\frac{C_1 + C_2}{m}}$ $\qquad f_{0_{min}} = 6{,}79\ Hz$

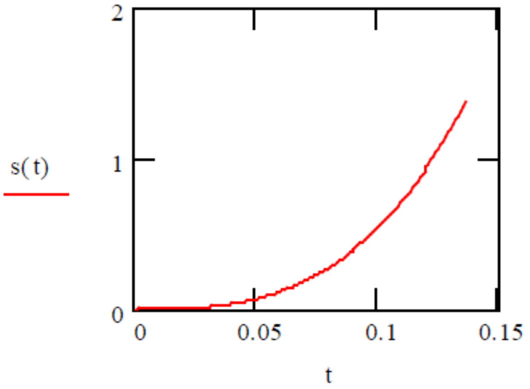
$a_{a_{dm}} = \frac{2\pi \cdot f_{0_{min}} \cdot v_{a1}}{18}$ $\qquad a_{a_{dm}} = 4{,}828\, m/s^2$ $\qquad t_{a_{dm}} = \frac{18}{2\pi \cdot f_{0_{min}}}$ $\qquad t_{a_{dm}} = 0{,}422\ s$

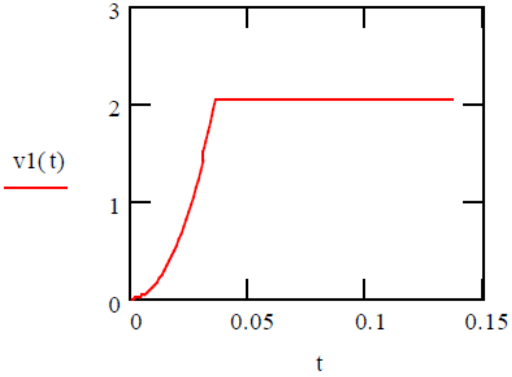
$\Delta V_3 = \frac{p_s \cdot V_a}{E}$ $\qquad \Delta V_3 = 3{,}333 \cdot 10^{-5}\ \ m^3$

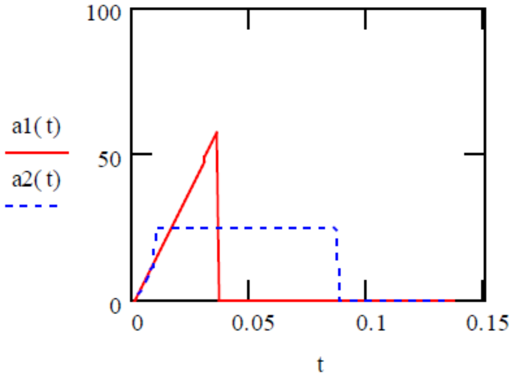
$$p_2(t) = \left| \begin{array}{l} \frac{p_{a2}}{t_{01}+t_p} \cdot t \quad if \quad t \le t_p + t_{01} \\ p_{a2} \ \ if \ \ \left(t_{01} + t_p\right) < t \le (t_{01} + t_{a2}) \\ p_{01} \quad if \quad t > (t_{01} + t_{a2}) \end{array} \right. \qquad v_1(t) = \left| \begin{array}{lll} \frac{k_1}{2} \cdot t_2 - k_2 \cdot t & if & t \le t_{a1} + t_{01} \\ v_{a1} & if & t > t_{a1} + t_{01} \end{array} \right.$$

$$a_2(t) = \left| \begin{array}{l} \frac{k_1}{2} \cdot t - k_2 \quad if \quad t \leq \quad if \quad t + t_{01} \\ a_{a2} \quad if \quad t_{01} + t_p < t \leq t_{01} + t_p + t_s \\ o \quad if \quad t > t_{a2} + t_{01} \end{array} \right. \qquad Q_1(t) = \left| \begin{array}{lll} 0 & if & t \leq q_1 \\ Q_p & if & t > q_1 \end{array} \right.$$









4. Conclusions

The evolution of the process is influenced by three factors: the time, space and frequency of the lifting mechanism:

a) Time t_a must be chosen from 0.1 ... 0.5 (s) because its decrease does not lead to a significant increase in acceleration, and its increase leads to a decrease in productivity.

b) Space must be chosen in the range 1.7 ... 10 cm which correlates with the acceleration through the formula: $s_a = v^2 / 2a$. A smaller space requires an acceleration over 10m/s^2 and the larger space is inadmissible for the mechanism.

c) c) The influence of its own frequency can be presented as follows: a low value of its own frequency leads to intermittent operation. Companies specialized in hydraulic systems recommend that their own frequency should not be less than 3 Hz. In order to increase its frequency, the surface of the hydraulic cylinder must be increased and the oil volume must be as small as possible. The numerical simulation study was performed for a load totaling 700 kg. We observe that in the case of lifting the lift to the maximum load the maximum extreme point of pressure is realized around 4.9 Mpa in a time of t = 0.35s, while in the case of the minimum load the maximum extreme point is obtained at half the value for the maximum load in - a long time t = 0.39s. In the case of lowering the hydraulic lift with the maximum load the maximum pressure reached is 3.8 Mpa in a time of 0.31s, and in the case of the minimum load, it is 3.80 Mpa reached in a time of 0.32s. The study may be extended to other masses, but the essential characteristics have been highlighted in the ranks above.

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