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DYNAMIC ASPECTS OF PERCUSSION EQUIPMENTS

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ABSTRACT

The paper highlights some aspects of modelling the dynamic processes taking place in the percussion equipments, known as hydraulic hammers. Theoretical and experimental aspects of the behaviour of equipments on test stand are highlighted. Simple models approach for calculating the effect of such equipment for their sizing and diversification are made.

KEYWORDS*:* percution, algorithm, dynamics, model, experimental.

1. Introduction

Recent needs for breaking rocks in quarries, demolition of concrete structures, trough-cut of the bituminous, gravel or concrete roads, etc., have led to the development of technological equipments, known as pick hammers or hydraulic hammers.

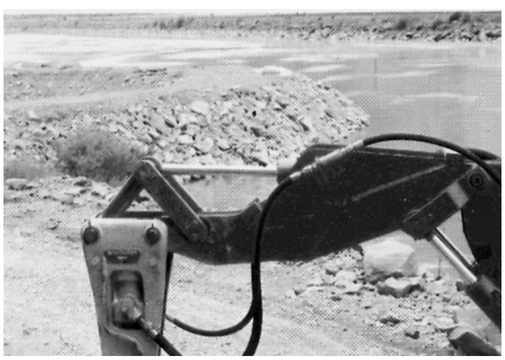


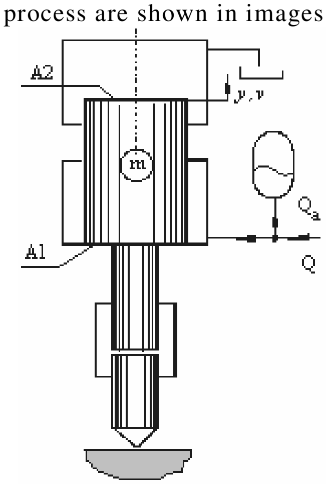
Fig.1. The use of percussion equipment

Such equipments are capable of generating high percussion energy of 400-10.000J, at frequencies of 200-1500 strikes / min.; the machines are designed for construction equipments as excavators, loaders, buldo-excavators, multifunctional equipments, etc. Fig.1. illustrates several examples of the use of such equipment.

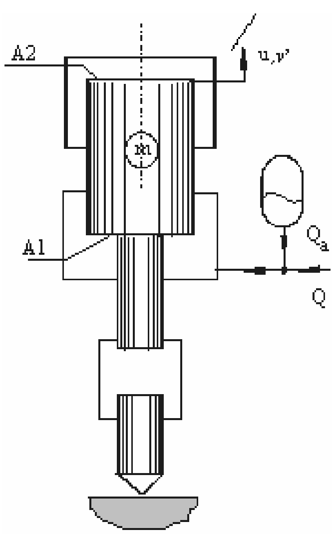
The dynamic process that takes place in the percussion equipments is characterized by the fact that the functional phases are governed by the positions of the lead distributor of the striker equipment and by the preset pressure level for the valve of the pressure level of the equipment [2], [3], [5]. This makes each stage to change the functional components that interact in the dynamic, changing areas, including the striker working areas, the pressure levels, the modes and levels of circulating flow the nature of the process inside the equipment, etc.

2. The process phases of the percussion equipment

The dynamic process of this equipment has the following structural phases, comprising: the lifting striker, the slow down striker and reaching the maximum stroke, the charging the hydraulic accumulator until reaching the maximum pressure adjusted to be obtained at the starting phase of descent, called post-filling, then drop striker, the percussion itself, after which the process starts up again. The description of the phases resulting from the dynamic process are shown in images in Fig.2.



a)



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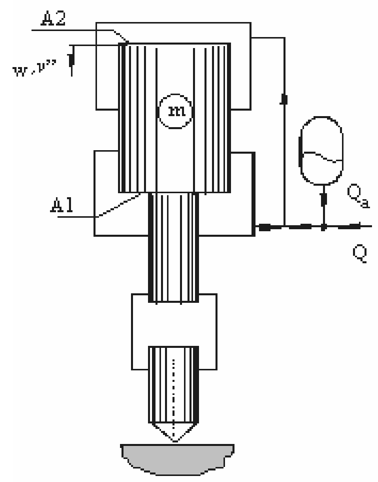

c)

Fig.2. Dynamic process phases

3. The mathematical modeling of equipment processes

3.1. Model foundation

The dynamic model of these equipments is described by the distribution of the hydraulic fluid between the chambers of the striker, the pump and the hydropneumatic accumulator, that means we have a flow equation and a motion equation of the equipment striker element. For each phase conditions are imposed for the initial and final parameters: the stroke of the striker, the striker speed, the position of the striker and the pressure from the system. The assumptions are that the model equations are: friction forces negligible compared to the forces of pressure, flow losses between the striker chambers negligible compared to the flow circulated between the control units, the tank pressure considered to be null, the loading and unloading process of the hydraulic accumulator considered adiabatic (t <1min) [1], the striker clashes with the tool and the working environment considered perfectly plastic. Speed of the striker after the striking the tool is null and always starts from the same position. The equations of the process are:

Striker lifting:

$$\begin{cases} Q = \dot{y}.A_1 - K_a.p^{-\frac{1+k}{k}}.\dot{p} \\ m.\ddot{y} = p.A_1 - mg \end{cases} \qquad (1)$$

the initial phases are: $t = 0;\ y(0)=0;$ $\dot{y}(0)=0;\ p(0)=p_o.$

the final phases are: t=t1; y(t1)=y1; p(t1)=p1.

The slow down striker and post-filling:

$$\begin{cases} Q = \dot{y}.A_1 - K_a.p^{-\frac{1+k}{k}}.\dot{p} \\ m.\ddot{u} = p.A_1 - mg - p \cdot A_2 \end{cases}; \qquad (2)$$

The initial phases are: t = 0; u(0)=0; $\dot{u}$(0)= $\dot{y}$(t1); p(0)=0.

The final phases are:

$t = t'_2 ; u(t'_2)=0; \ p(t'_2)=p_2<p_R;$

The post-filling hydraulic accumulator condition is:

$$t = t''_2 ; \ p(t''_2) = p_R ,$$

the total length of the process of the slow down striker and post-filling:

$$t_2 = t'_2 + t''_2 .$$

Lowering the striker and percussion:

$$\begin{cases} \dot{w}.A_2 = Q + \dot{w}.A_1 + K_a.p^{-\frac{1+k}{k}}.\dot{p} \\ m.\ddot{w} = p.(A_2 - A_1) + mg \end{cases} \qquad (3)$$

the initial phase:

t = 0; w(0) = 0; $\dot{w}(0)=0$; $p(0)=p'(0)=p_R$.

the final phase conditions: $w(t_3) = s$ (the striker stroke),

$$\dot{w}(t_3) = v_{percussion} .$$

3.2. Final ecuations of the dynamic model

From equations (1), (2) and (3) by processing the successive mathematical equations the followings dynamic model of the phases of the striker is derived:

the striker lifting:

$$\begin{cases} K_{11}.(K_{12} - v)\dot{v}^2 - K_{13}(K_{12} - v)\dot{v} - \\ -K_{14}.v + K_{15} - \ddot{v} = 0 \\ \frac{2}{p}.\dot{p} - K_{16}.p^3 - K_{17}.p^2 - \ddot{p} = 0 \end{cases} \qquad (4)$$

where the coefficients K_{1i} represent the structural system coefficients at the stage of the lifting striker and $v = \dot{y}$ represent the lifting speed.

Dependency coefficients of constructive and functional dimensions of the equipment are given by:

$$K_{11} = m / p_o V_o ;$$
$$K_{12} = Q / A_1 ;$$
$$K_{13} = 2mg / p_o V_o ;$$
$$K_{14} = mg^2 / p_o V_o ;$$
$$K_{15} = mg^2 Q / p_o V_o A_1$$

The striker flow and post filling comes as follows:

$$\begin{cases} K_{21}(Q - A_1.v')(K_{22}.\dot{v}' + K_{23}.u + K_{24})^2 - \\ -K_{25}.v' - \ddot{v}' = 0 \\ \frac{4}{p}\ddot{p} - (\frac{6}{p^2} + K_{26}p^2 + K_{27}).\dot{p} + \\ + K_{28}.p^2 - \dddot{p} = 0 \end{cases} \qquad (5)$$

where the coefficients K_2i represent the structural system coefficients of the braking phase striker and the hydraulic accumulator of the post-filling; v' - speed braking.

Dependency of the coefficients between constructive dimensions and functional dimensions of the equipment is given by:

$$K_{21} = A_1 / mp_o V_o ; \ K_{22} = m / A_1 ;$$
$$K_{23} = EA_2 / l.A_1 ; \ K_{24} = mg / A_1 ;$$
$$K_{25} = EA_2 / lm; \ \ K_{26} = A_1^2 / mp_o V_o ;$$
$$K_{27} = EA_2 / lm;$$
$$K_{28} = EA_2 Q / lmp_o V_o .$$

Lowering the striker and percussion as follows:

$$\begin{cases} K_{31}(\dot{v}'' - g)^2 (K_{32} - v'') - \ddot{v}'' = 0 \\ \frac{2}{p}\dot{p} - K_{33}p^3 - K_{34}p^2 - \ddot{p} = 0 \end{cases}; \qquad (6)$$

where the coefficients K_{3i}- represent the structural system coefficients at the phase of lowering the striker and percussion

$v'' = \dot{w}$ - the lowering speed.

Dependency coefficients, constructive and functional dimensions of the equipment is given by:

$$K_{31} = m / p_o V_o = K_{11} ;$$
$$K_{32} = Q / (A_2 - A_1);$$
$$K_{33} = (A_2 - A_1) / mp_o V_o ;$$

$$K_{34} = g(A_2 - A_1) / p_o V_o .$$

The dynamic model of the percussion equipment is given by the equations (4), (5) and (6), which are solved according to the initial and final conditions.

It is noted that the dynamic equations are nonlinear equations and solving the model is done by the numerical methods, which are linked together by the completion of the initialisation phase or question.

4. Proofs of the dynamic parameters change

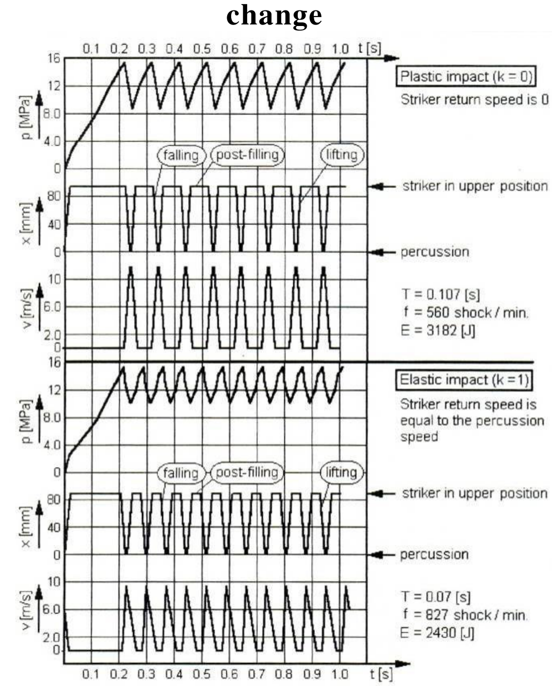

Fig.3.Diagram of experimental variation of dynamic parameters

Diagrams in Fig. 3 are obtained on a test-stand for an experimental percussion equipment [3], [5]. Diagrams are reproduced as diagrams recorded directly on a model which allowed the direct recording of the striker stroke, of the striker speed and the pressure of the hydraulic fluid, in a simulation of the percussion environment between plastic and perfectly elastic conditions. [9].

5. The results of numerical modeling

The result of modeling by numerical methods, the equations (4), (5) and (6), according to [8], on an existing experimental model [8], led to the image as shown in Fig.4.

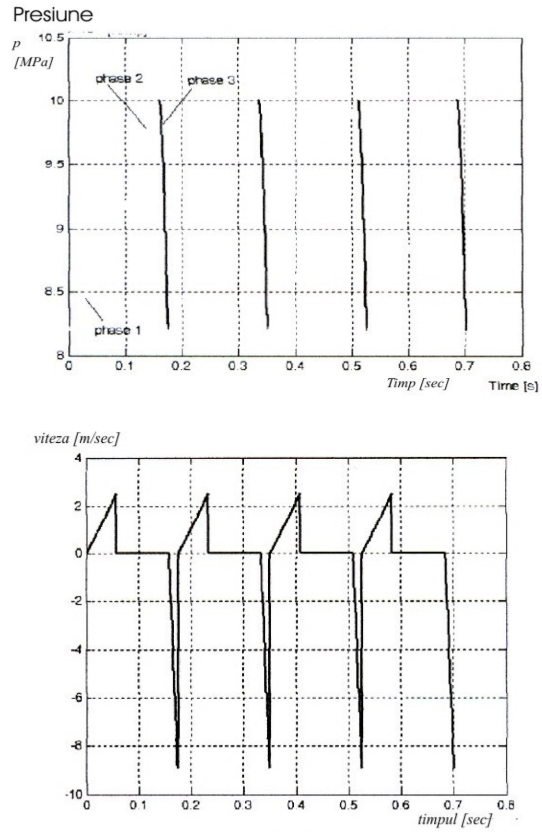

Fig.4. Percussion equipment parameters variation
a) strikers speed variation
b) system pressure variation

6. Conclusions

From issues presented in this paper result that these technological equipments are characterized through continous variation of dynamical parameters for each functional phases. The energy of the equipment inhere at each percussion through the kinetic energy devolved to the striker. This energy is transmitted to working body that is supported on the base material. This fact lead to conclusion that the entire dynamic process depends a lot on the striker - working body - material percussion nature.

The mathematical model is much simplified both through model terms neglecting, and through the suppression of striker - working body and striker - base material interactions. However it is a complex nonlinear model with very difficult operating mode. The experimental and theoretical data are very closed, from the qualitative viewpoint, while there are alluded on two different types of models in provided energy basically supposition, as follows: tested model with 2500 J and 600 ppm, and theoretical model with 1200 J and 350 ppm.

The diagrams for experimental tests suggest the way which the energetically parameters of percussion equipment are influenced by the working body percussion mode. This influence is shown by those the percussion mode imposes the initial conditions of the process at the beginning of striker lifting [6].

The paper bases the simplified onset of these equipments dynamics, which allows theirs designing and variance from dynamic evolution and performances points of view.

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