Proceedings of the 15th International Conference on Manufacturing Systems – ICMaS
Published by Editura Academiei Române, ISSN 1842-3183

"Politehnica" University of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania, 26–27 October, 2006

THEORETICAL RESEARCH REGARDING THE DYNAMIC BEHAVIOR OF THE HYDRAULIC PRESSES WITH POWER COMPENSATOR IN THE APPROACH PHASE

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Abstract: *The paper presents a theoretical research over the dynamic behavior of the hydraulic presses driven by pumps with power compensator, in the approaching phase. There are presented the physical and systemic models and, also, the graphical results for the evolution of the main dynamic parameters with respect to time, which were obtained due to a computer assisted simulation program.*

Key words: *presses, dynamic behavior, mathematical modeling, simulation, pressing systems.*

1. INTRODUCTION

The dynamic behavior analysis of the hydraulic presses driven by pumps with power compensator is a very important research direction, because there are very complex systems and are frequently used for cold and hot pressing. The modern tendencies are the continuous increase of the number of the working cycles on minute [1], due to the request of high production of the plastic deformation parts. This has determined the need to know all about the hydraulic pressing systems dynamic behavior, in all phases of the pressing cycle: approaching phase, pressing phase and return phase. The approach phase is the first period of the pressing cycle. This is the phase when the moving crosshead of the pumps hydraulic presses, under the action of the gravity G of the mobile mass M is approaching at high speed to press the material which is subjected to plastic deformation. The high speed is obtained due to the liquid aspirated by cylinder piston through the filling vessel RU and, sometimes, supplemented with the liquid flow from the pump. This is the subject of this paper.

The better knowledge of the dynamic behavior on each working phase (approach, pressing and return) it is necessarily in order to design a high performance hydraulic press. The dynamic behavior research is done both on the theoretical and experimental ways [2]. This are the first researches about the dynamic behavior of the hydraulic presses equipped by pumps with the power compensator, realized in our country by authors.

This article presents only the theoretical research over the dynamic behavior of the 0,4 MN hydraulic press, with power compensator, in the approach phase. This press can be see in the Plastic Deformation Laboratory from University POLITEHNICA Bucharest.

2. THE HYDRAULIC PRESSES MODELING

The authors developed a theoretical research over the dynamic behavior of the 0.4 MN hydraulic press, with power compensator, for all phases of the pressing cycle, but in this paper are presents only the results for the *approach phase* of the working cycle. In this phase, the moving crosshead of the hydraulic presses is approaching at high speed to press the material. This approaching process was analyzed by the mathematical modeling and computer simulation. What is specifically for this driving system with the power compensator, consists in the fact that the pumps have a variable flow, respect to pressure, due this power compensator.

2.1. The physical model

In order to study the dynamic behavior we consider a physical model, like in Fig. 1, which consists in a linear hydraulic actuator MHLP (the main pressing hydraulic cylinder) and the attached hydraulic circuit, including the piece which to be presed SD.

The head is moving under the action of the gravity *G* of the mobile mass *M* and the pump flow around the active area A_1 of the piston. It is descending with velocity *v*, acceleration a on the approaching stroke *x*, versus the dry and wet friction forces F_{fg} and, also, the inertia of the system.(mobile masse *M* with the weght *G*).

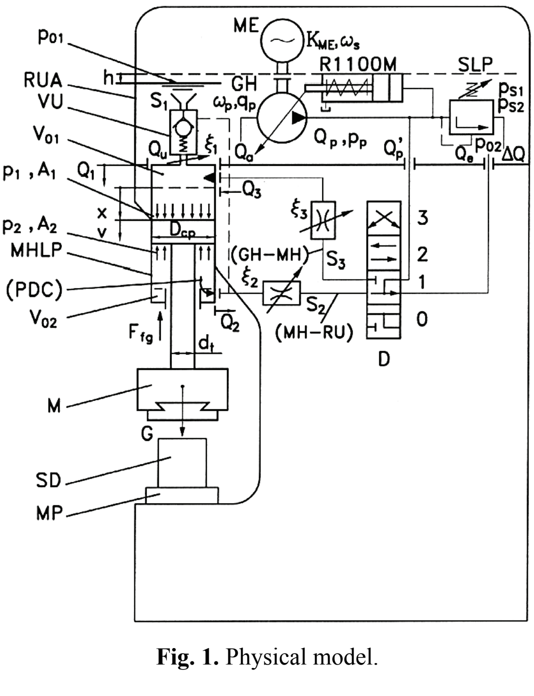

Fig. 1. Physical model.

The variable capacity q_p of the pump GH depends of the p_p pressure in the system and is established by the power compensator R1100M. The pump suction flow is Q_a and the instant flow generated by pump is Q_p to the instant angle speed ω_p. The pump is acting by a electro-motor ME, with synchronize angle speed ω_s and KME electric characteristic of the motor.

The maximal pressure in the pressing circuit is controlled by the pressure valve SLP, which may the flow ΔQ passes through the valve. The valve characteristic have two specifically pressure points: p_{s1} and p_{s2}. Also, in the Fig. 1 it can se the S2 and S3 the section pipe evacuation and the approaching/pressing circuits.. The approaching/pressing flow is Q_3 and the evacuation flow is Q_2 from MHLP and Q_e to the RUA oil tank. The equivalent coefficient of the pressure losses are ξ_2 for the evacuation circuit and ξ_3 for approaching /pressing circuit. The distribution system D have 4 working position which can control the movement of the pressing head, the approach position is the 1 position.

2.2. The global systemic model of the approach phase

The global systemic model for the approach phase is presented in the Fig. 2.

As the physical model shows the system is made from 9 interconnected systemic elements [2]. This is the base of the global systemic model elaboration (Fig. 2), which consists in the following systemic elements: the electrical action motor ME, as a quadripolar element, with U and I electric parameters, and ω_p and M_p mechanic parameters; the hydraulic generator GH, as a hexapolar element, with ω_p and p_p input values and Q_p and M_p output values; the power compensator R1100M, as a bipolar element, with pressure pump p_p the input values and variable capacity of the pump q_p like the output values; the filing valve VU, as a quadripolar element, with Q_{u0} and p_u input values and Q_u and p_{01} output values; the pressure limitation valve SLP, as a bipolar element, with p_{11} maximal pressure as input value and ΔQ valve flow as output value, which reduces the pressure to p_{12}; the circuit COND GH-MH, as a quadripolar element, with Q_p and p_3 input values and Q_3 and p_p output values; the hydraulic linear pressing actuator MHLP, as a hexapolar and multivariable element, with p_2, Q_1, and (G-Ffg) input values and Q_2, x, p_1 output values; the

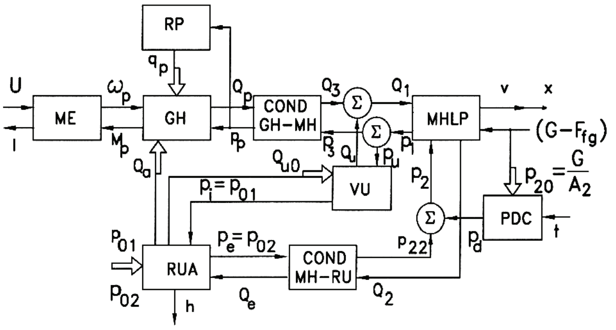

Fig. 2. Systemic model.

decompressing process PDC, as a bipolar element, with the pressure p_{20} as a impute value and the presing force p_d as output value; the evacuation circuit COND MH-RU, as a quadripolar element with Q_2 and p_{02} input values and Q_e and p_{22} output values; p_{02} – the filling suction vessel RUA, as a bipolar element with $(Q_e - Q_a)$ input value, and h output value, which represents the liquid level variation from RUA, knowing the area A_{RUA} and working at a atmospheric pressure p_{01}.

The global systemic model not contain the pressure limitation valve SLP, as a systemic element, because in this phase, this element have not a real participation.

2.3. The mathematical model of the approach phase

The mathematical model, based on the physical model, Fig. 1, and the systemic model, Fig. 2, describes the dynamic behavior of the hydraulic pressing systems, driven by pumps with power compensator, for the approach phase, but is not presented in this paper because is not enough space for this.

3. MODELING AND COMPUTER AIDED SIMULATION PRINCIPLES

The research has been developed using the modern method of analysis and synthesis of the system components, based on the modeling and computer aided simulation of the dynamic behavior [2, 4–6].

The elements and systems modeling were achieved during several stages: physical modeling, systemic modeling, mathematical modeling and IT modeling.

The analysis and synthesis assumes the description of the Electro-hydro-mechanic elements dynamic behavior using mathematical modeling based on several algebraic and differential equation systems, as the most accurate representation of the characteristics of the physical model depicted in the Fig. 1. Based on this mathematical formalization and the existing dependencies, it can synthesize them like in [6–9].

One very interesting phenomenon which has a great influence over the dynamic behavior of the hydraulic presses is the decompressing process (PDC). This process take place under the cylinder piston and consist in the a détente of the liquid which is under the hydrostatic pressure generated by the weight G of the crosshead with mass M over the minimum surface of the piston A_2. The variation of this hydrostatic pressure p_d, respect to time can see in the next Fig. 3.

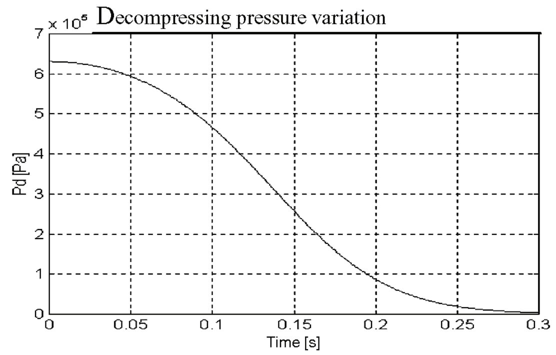

Fig. 3. The decompressing pressure variation.

Due to the dynamic phenomenon, that occurs in the working cycle of the hydro-mechanic actions, is a result of the interaction between the hydro-mechanic subsystem and the working process itself, the systems theory [8, 9] was employed as the bases for the development of the theoretical research. From the systemic perspective, the hydro-mechanic action systems consist from 2-poles, 4-poles and 6-poles elements, characterized by specific input and output entities which are linked and interact one with another [2, 6–8].

The systemic model, depicted in Fig. 2, developed starting from the physical model, was the bases of the mathematical model which enabled us to establish a simulation model (IT modeling), using a very modern software. In order to solve this mathematical model, we have used a dynamic systems simulation program using numerical methods. Using MATLAB and the special package SIMULINK, we have obtained the simulation model which, also, is not presented here.

This simulation model has permitted to determine the graphical variation of important parameters like stroke, velocity, acceleration, pressure, pump flow etc.

4. DYNAMIC BEHAVIOR STUDIES

In order to solve the mentioned mathematical model, using MATLAB and SIMULINK, we have used the test data generated by the constructive and functional parameters of the 0.4 MN hydraulic press.

The computer aided simulation has enabled is to obtain the variation graphs of the following entities: approach stroke *x*, velocity *v*, acceleration *a*, filing pressure p_u, pump flow Q_p , pump pressure p_p , the filing flow Q_u. and the MHLP exit pressure p_2,. In the Fig. 4 it has presented the variation of the approach stroke *x,* of the press crosshead which can be maximum 0.100 m, in 0.3 s, before beginning of the deformation process.

The approach velocity is depicted in the Fig. 5. The maximal value about 0.700 m/s is the same with the one provided in the technical design data.

The acceleration *a*, depicted in Fig. 6, presents stronger oscillations at the beginning, but after a short increasing, it stabilizes to null value, like the crosshead velocity *v*. The maximum value is about 4 m/s^2.

The Fig. 7 presents the evolution of the filing pressure. It is very interested to remark a very shortly decreasing of the pressure under the atmospheric value, created due suction flow developed by cylinder piston.

In the Fig. 8, it has represented the pump pressure variation during the approach process. The final value of the pressure, $p = 2.5\times10^5$ Pa = 2.5 bar, belongs to the normal pressure values for the approach process.

Fig. 9 are presenting the variation of the filing flow, which has an allure like the velocity diagram (2). The maximum value of the filing flow is about 3.5×10^{-3} m^3/s, which corresponds with the calculated value.

In the Fig. 10 is presented the variation of the MHLP exit pressure p_2, the low value being to 5×10^5 Pa. The diagram form is in correspondence with acceleration variation, but in a veritable mirror of that.

This very original variation is generated by the decompressing phenomena which has place under the cylinder piston.

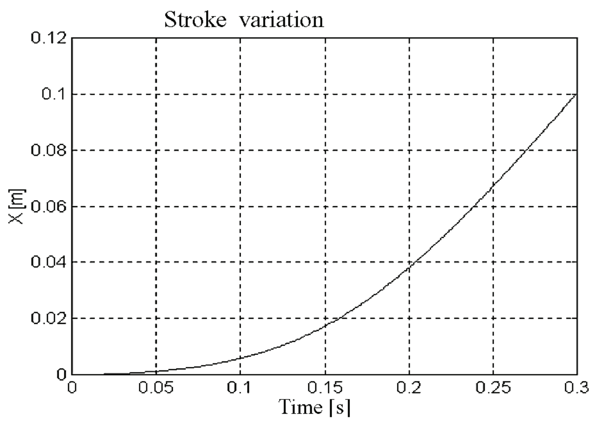

Fig. 4. Stroke variation.

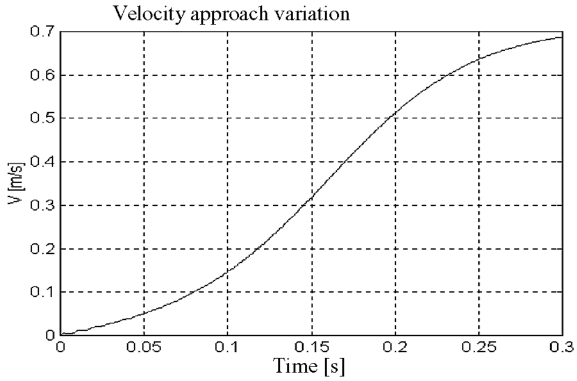

Fig. 5. Velocity variation.

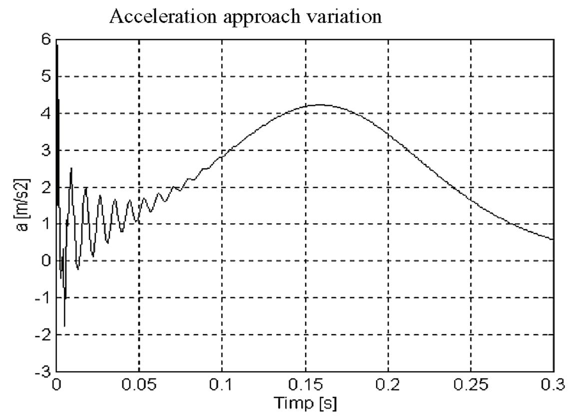

Fig. 6. Acceleration variation.

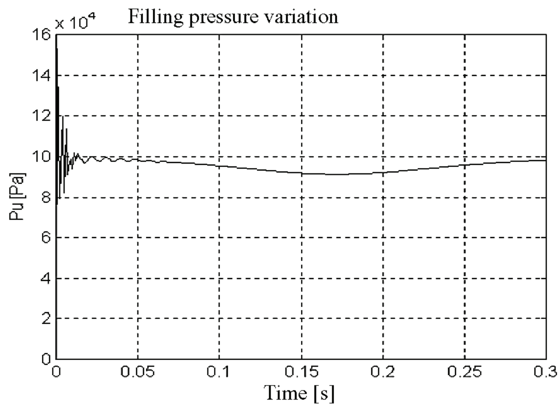

Fig. 7. Filing pressure variation.

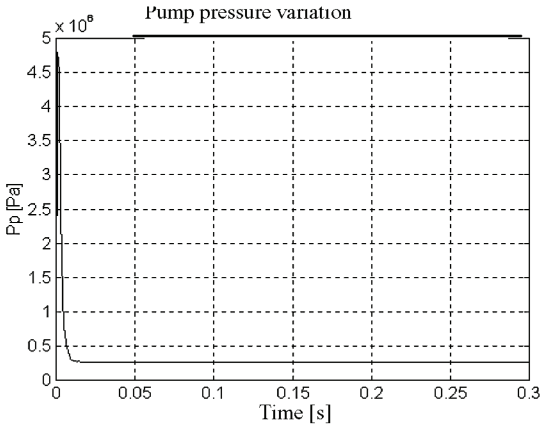

Fig. 8. Pump pressure variation.

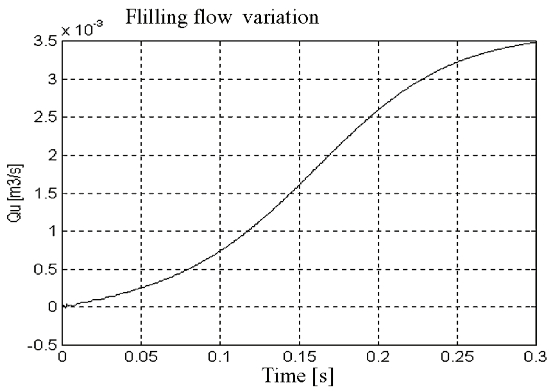

Fig. 9. Filling flow variation.

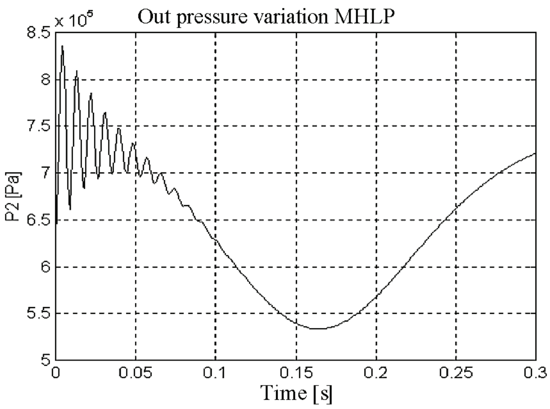

Fig. 10. MHLP exit pressure variation.

The Fig. 11 presents the pump flow variation during the approach process, when the pump flow remain constantly, at the maximum value, while the pump pressure is very low, like in the Fig. 8.

In approach phase the effect of the power compensator is not very important, because the working pressures are very small, and the flow is maximally.

This is the specifically dynamic behavior, in the approach phase, of this presses family.

These are the first results of the theoretical research over the hydraulic presses with power compensator, which will be continued with an experimental research.

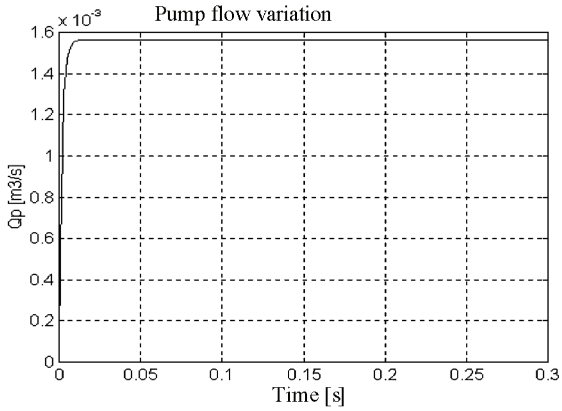

Fig. 11. Pump flow variation.

5. CONCLUSIONS

The analysis of the 0.4 MN press dynamic behavior, in the approach phase, was done using the mathematical modeling and the computer aided simulation. The results, which were obtained, emphasize the variation of several parameters as it is computed using the classical equations, thus validating the mathematical models, which were developed. The research must be continued further by the experimental research in order to validate this theoretical model.

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