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SELF OSCILLATORY HIGH PRESSURE (70 MPA) MULTIPLIERS, WITH LOGIC HYDRAULIC ELEMENTS, FOR HYDRO-FORMATION LIQUIDS. SIMULATION OF DYNAMIC OPERATION.

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Abstract: *This paper presents a dynamic simulation and operation of a series of self oscillatory high pressure (70 mpa) multipliers, with logic hydraulic elements, for hydro-formation liquids, as part of a national research contract, which is relating to a flexible modular system for plastic deformations true hydro formations with high hydraulic pressure, with a high level of technology for producing complex parts for auto vehicle construction technology, aeronautics or top industrial fields. The theoretical research field of the work will elaborate a mathematical dynamical simulating model for the high pressure multiplying phenomena using specialized software. The confirmation of these models will be checked throw comparison with experimental results through data acquisition from the real models.*

Key words: *Hydro-formation, dynamic, high-pressure, simulation, multiplier.*

1. INTRODUCTION

This paper presents a dynamic simulation and operation of a self oscillatory high pressure (70 MPa) multipliers, with logic hydraulic elements, for hydro-formation liquids, as part of a national research contract, which is relating to a flexible modular system for plastic deformations true hydro-formations with high hydraulic pressure, with a high level of technology for producing complex parts for auto vehicle construction technology, aeronautics or top industrial fields.

The theoretical research field of the work will elaborate a mathematical dynamical simulating model for the high pressure multiplying phenomena using specialized software.

The confirmation of these models will be checked throw comparison with experimental results through data acquisition from the real models.

This phase of the project realized a methodology development, requirements and formulates ways of meeting a maximal capacity of plastic deformation by hydro-formations and on this basis will develop an innovative system for flexible modular hydro-formations with high pressure technologies as performance benchmarks for processing complex moulds.

It produces an analysis of constructive solutions of the functional equipment available now in use, developed a database that allows highlighting strengths and weaknesses and demarches to the best way to success.

Are identified the optimization processes criteria and the possibilities of hydro-formations equipment.

To a correct forecast of the operation of equipment and a favourable assessment of the performances were traced achievements and success theoretical models simulation of the phenomena occurring in the process, the geometries adopted for the processing system, use specialized software.

In the conception of the flexible multifunctional equipment will take into account the possibility of mechanization of technological operations that require large strengths, high degree of mobility, low weight, the handling and easy adjustment with total controlled of the forces developed.

For CAD parametric design of deformation of the mould subassemblies, but also for the unity of strength and accessories was made an extensive bibliographic study and documentary research, regarding the system capacity development in various technological applications, mathematical modelling and numerical simulation in order to increase performance and highlighting some optimized solutions

2. PROBLEM DESCRIPTION

This project is proposing to develop a modular and flexible system for plastic deformations with high pressure like a very performant technology for aviation, automotive industry or other hygh technology industrial areas.

The novelty of the solutions is focused on generating and control of high pressure (70-280 MPa) with hydraulic auto-oscillating multipliers and uses it in innovative construction of the system. It is developing a new conception - stand for testing the hydro-formation technology by plastic deformation and modular equipment capable of satisfying a range of forms resulting from the semi-type plates and tubes.

The hydro-formations covers the field of plastic deformation defined as deep hydrostatic cupping as well as parts of deformation freely volume inside the tube type. As a result, the hydro-formation process can print semi-type plate's complex forms that cannot be achieved, in general, by mechanical cupping or if that is possible, the costs are unusually high.

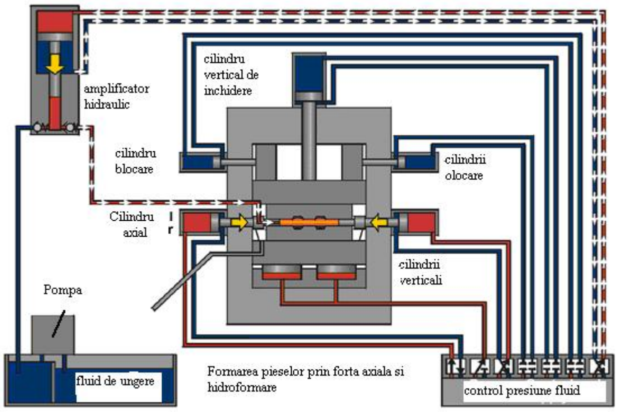

Fig. 1. Hydrostatic stand scheme for Hydro-formation.

Generally in the construction of the Hydro-formation equipment is used hydrostatic installations command drive based as shown in Fig. 1.

Multiplier used in the installation of hydro-formations is built to operate in automatic auto-oscillating regime, depending on the pressure of the hydro-formations fluid so the power consumed by the hydraulic power plant to remain relatively constant. The operation is automatically change to overcome the pressure of 1 MPa, provided by the hydro-formations pump fluid the 20 MPa on the first stage on the multiplier and 45 MPa for the last stage on the multiplier as in the diagram in Fig. 7.

Operation of the hydro-formation equipment started with the introducing of the form in the mold. One hydraulic cylinder secures the mold and other two controls the friction force between the two shells of the mold.

There also are used two additional cylinders for blocking the mold in the close position. If the procedure involved the hydro-formations of a tube, another two additional cylinders are used to apply the sealing system at the end of the tube.

All the pressures in the system are strictly controlled. The installation uses two types of fluids: hydraulic fluid used for powering the system and hydro-formation fluid used for the technological process. These two fluids are physically separated but they are functionally used together in the pressure multiplier.

The multiplier has the functional role to generate high pressure in the mold through hydro-formation fluid using the energy of the hydraulic oil from the powering system.

A normal rate of pressure amplifying is 1 to 4 so with a pressure of 32 MPa in the powering system we can obtain 128 MPa in the hydro-formation liquid.

3. APLICATION FIELD

The project is a partnership in a consortium which brings together a research institute in technical creativity, a technical university with a department specializing in hydraulic force equipment and expertise of specialists, a joint stock companies in the field of deformation manufacturing, capable by his capacity and technical assistance involvement in the execution of this high-level equipment.

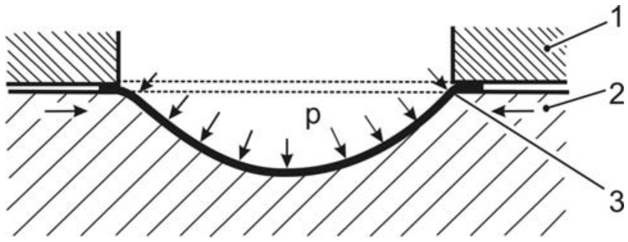

Fig. 2. Example hydrostatic cupping with the modifying flange position: 1. Restraint Flange, 2. Mold, 3. Semi-sheet.

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Hydrostatic cupping process represents a modern cold plastic deformation of plates and tubes.

This technology is known since the years '60, the difficulties of producing high pressure at very high fluid flow made the process to be applied only to firms with a high technological potential.

Hydro-formation is an unconventional method to obtain some cupping parts through direct or indirect action (through a membrane) of a fluid on the semi-sheet or pipe.

4. RESEARCH STAGES

This project is proposing to develop a modular and flexible auto-oscillating hydraulic multiplyer for plastic deformations with high pressure like a very performant technology.

The novelty of the solutions is focused on generating and control of high pressure (700-2800 bar) with hydraulic auto-oscillating multipliers and uses it in innovative construction of the system. It is developing a new conception - stand for testing the hydro-formation technology by plastic deformation and modular equipment capable of satisfying a range of forms resulting from the semi-type plates and tubes. This technology generates pulses of pressure in the system at every functional cycle. This pulses at a very known and controlled frequency induced in the metal sheet a less stress force that provide a perfect match to the desired form shell.

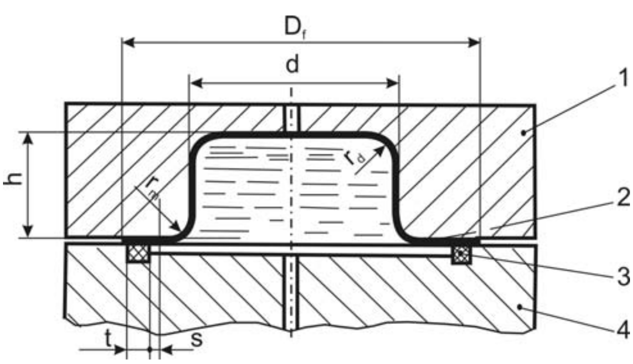

Fig. 3. Dimensional features from hydrostatic cupping
1. Mould; 2. Cupping part; 3. Gasket sealing; 4. Plate.

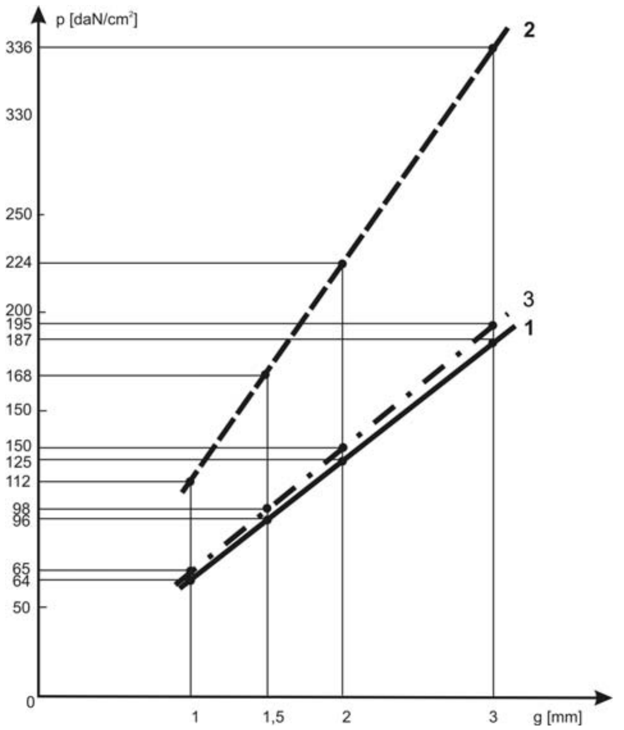

Fig. 4. Variation of cupping pressure depending on the thickness of semi-sheet: 1. Values obtained experimental; 2., 3. Values obtained about the theoretical relation.

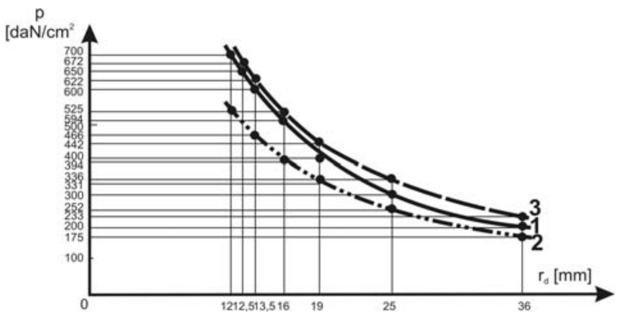

Fig. 5. Variation of cupping pressure according to fund a range of play.

1. Experimental curve (Fig. 5).
2. Curve after the theoretical relationship (Fig. 5).

Changes in cupping pressure depending on a range of the mould bottom.

In the case of cylinder-shaped pieces (Fig. 3) cupping pressure is influenced by the range of connecting vertical wall and the bottom part (r_d)

From the experimental results presented in Fig. 4, shows that the cupping pressure varies inversely proportional to the radius of the mould bottom fund and for the values $r_d < (10 - 15)\, g$ cupping pressure takes great values, beyond the limits currently used in hydraulics.

$$p = \frac{g}{r_d} \cdot \sigma_r \, . \qquad (1)$$

3. Curve after the theoretical relationship (Fig. 5)

$$p = 5 \times \frac{g}{r_d} \frac{h}{d} \cdot \sigma_r \qquad (2)$$

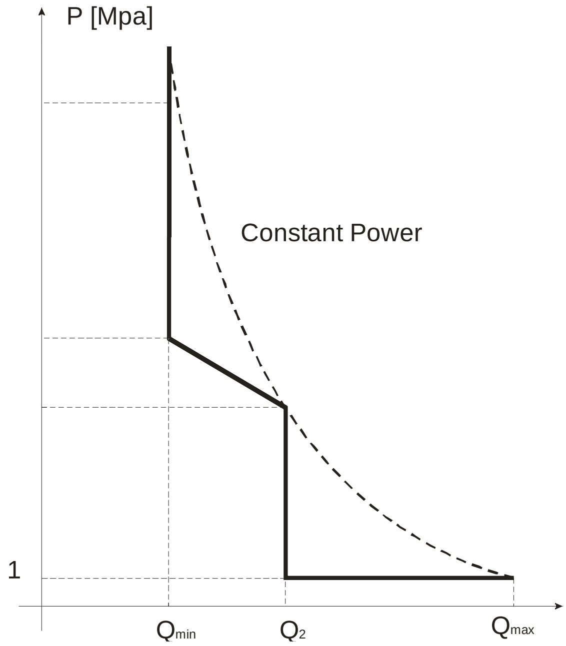

Fig. 6. Chart operating at a constant power hydraulic multiplier.

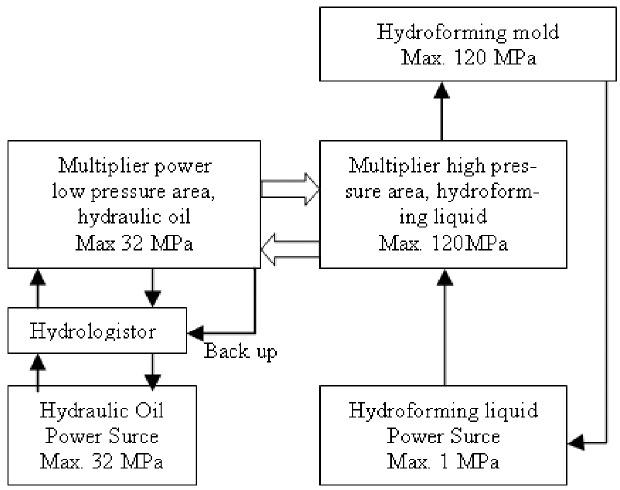

Fig. 7. Hydraulic diagram of the multiplier system.

The chart diagram of the multiplier system is presented in the Fig. 6.

The multiplier has a piston with multiple sections. The main one is Sa the section which generates the pressure which is multiplied. The difference between [$Sa - (S_1 1 + S_1 2)$] generates the multiplying rapport 2 to 1.

S_1 and S_2 are two surfaces used to generates those to desired flows at specified pressures.

When the pressure reaches the medium value programmed the spring x is compressed and for the final deforming process is used only the S_2 surface and the multiplying ratio groves to 4 to 1.

This action generate the maximum pressure up to 128 MPa.

To simplify the operation and to increase the reliability of hydraulic system was used in the automation of a multiplier a hydro-logistor H.

This hydro-logistor has 3 / 2 ways and connect the multiplier at Sa chamber alternatively to the pressure gauge and to the tank gauge.

The working frequency is dictated by a loop created with a connection line to the command area of the hydro-logistor.

At the command areas of the hydro-logistor act two different pressures, one from the pressure line and the second from the loop.

When the orifice of the loop is closed the pressure in the loop circuit getting down till the hydro-logistor change his position to tank.

At that moment the pressure in the multiplier goes to zero and the piston coming back to initial position and opens the loop channel.

The pressure grows to nominal, the hydro-logistor change again and assures pressure to multiplier piston. In this way the circle on auto-oscillating is closed and the system generates high pressure.

For the hydro-formatting process we need a minimum pressure to engage the system.

In the diagram the Hydro-formatting liquid pump generates a 1 MPa pressure which opens the one way valves and fills the mold with liquids in the first stage.

The used hydro-forming liquid must be recycled and proper flirted and stored for continuous operation.

The system needs an accumulator for inhale the pulses and protect the power system. The accumulator also amplifies the energy in the loop system and grows the general performance.

5. METHODS USED

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To establish the main characteristics for design the all system we make a working simulation in Mathlab.

The main equations which characterize the dynamic function of the system are:

The frequency of the auto-oscillation of the system:

$$\omega = \frac{k_j \sqrt{S(p_0 - p_r) - R_0}}{(S_A - S_B)\sqrt{(S_A - S_B)}} \left(1 - 0{,}255 \frac{k_j^2 Mj}{(S_A - S_B)^3} - 0{,}065 \frac{k_j^2 M^2 j^2}{(S_A - S_B)^6} \ldots \right) \quad (3)$$

The amplitude of the auto-oscillation frequency:

$$2x_3 = 2j\left(1 + 0{,}255 \frac{k_1^2 Mj}{(S_A - S_B)^3} + 0{,}130 \frac{k_j M^2 j^2}{(S_A - S_B)^6} + \ldots \right) \quad (4)$$

Theoretical domain of the first frequency:

$$2H_1 = 2j\sqrt{1 + 1{,}020 \frac{k_j^2 Mj}{(S_A - S_B)^3} + \frac{k_j^4 M^2 j^2}{(S_A - S_B)^6} + \ldots} \quad (5)$$

The transfer functions of the system in close loop.

$$G(s)H(s) = \frac{k_q S_1 c_{12}}{m_1 m_2 \left(s^2 + 2\xi_2 \omega_{02}^2 + \omega_{02}^2 + \frac{c_{12}}{m_2} \right) \left[- \left[\frac{S^2 s}{m_1} + (k_c s + B)\left(s^2 + 2\xi_1 \omega_{01} s + \omega_{01}^2 \right) \right] \right]} \quad (6)$$

In figure link side of the plunger multiplier and distributor drawer are observed.

The link is hydrostatic; it sends a signal pressure from pressure to withdraw the plunger with a constant value to the command room of the hydro-logistor 3/2.

To optimize the operation of the dynamic multiplier the following parameters will be monitored (Figs. 8, 9 and 10):

- The balance of forces on the hydro-logistor drawer
- Move the command element of the hydro-logistor
- Piston movement generator
- Work performed by mechanical plunger multiplier (power consumed)
- Kinetic energy generated by multiplier piston
- The flow of oil consumed by the plunger generator

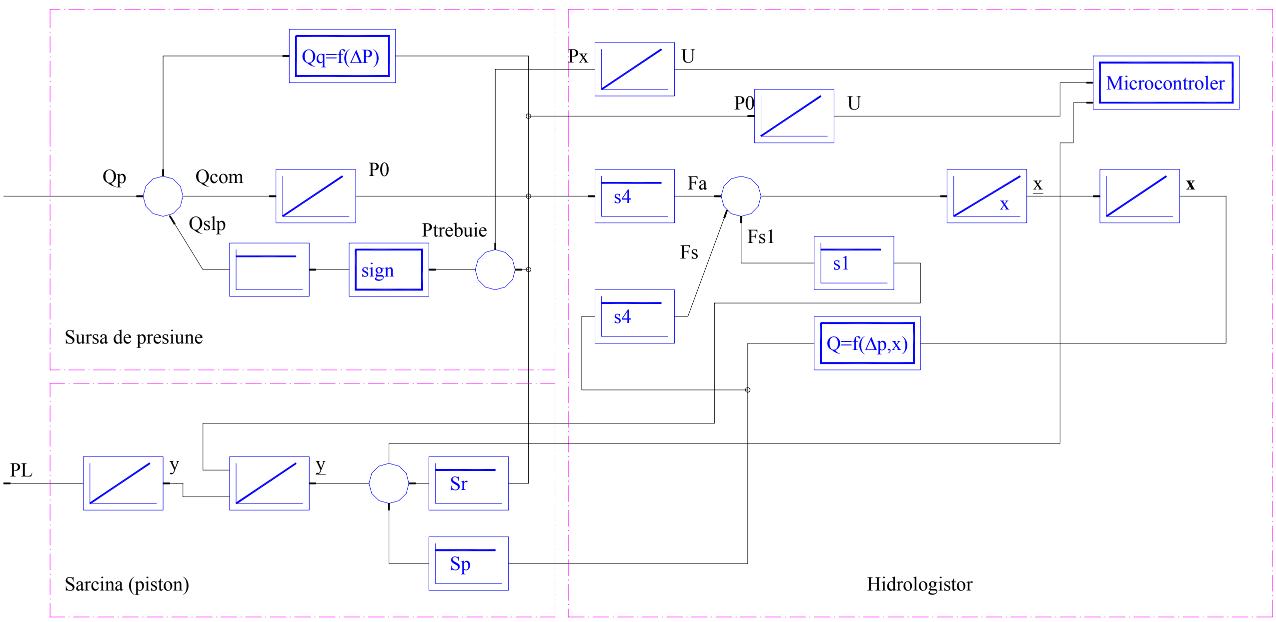

Fig. 8. Schedule block a hydraulic multiplier system.

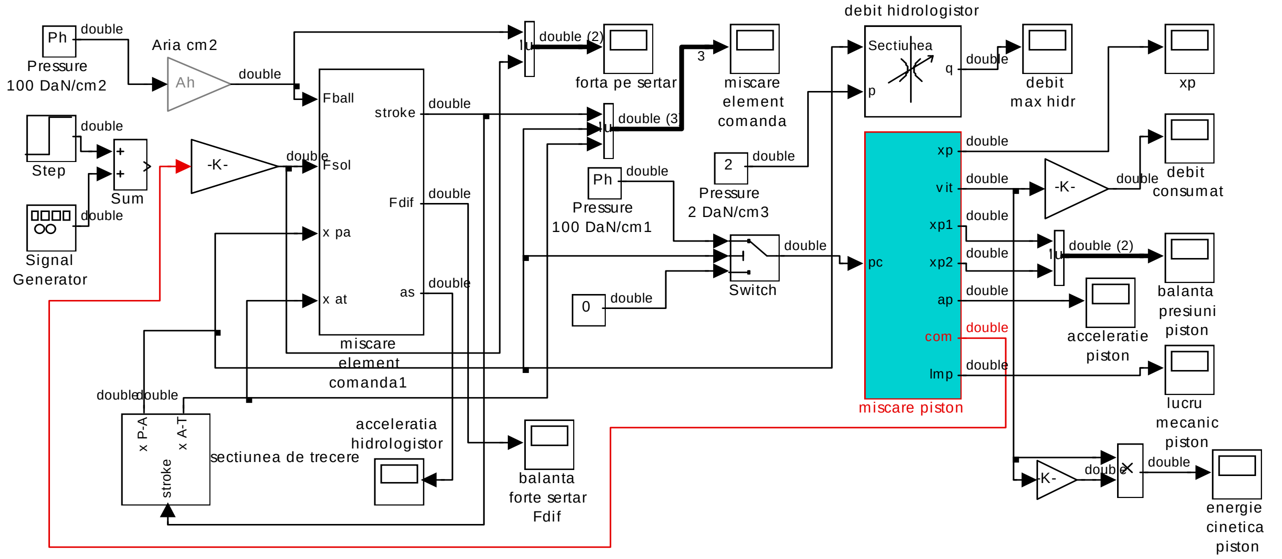

Fig. 9. Simulating diagram for the maximum frequency of the multiplier system.

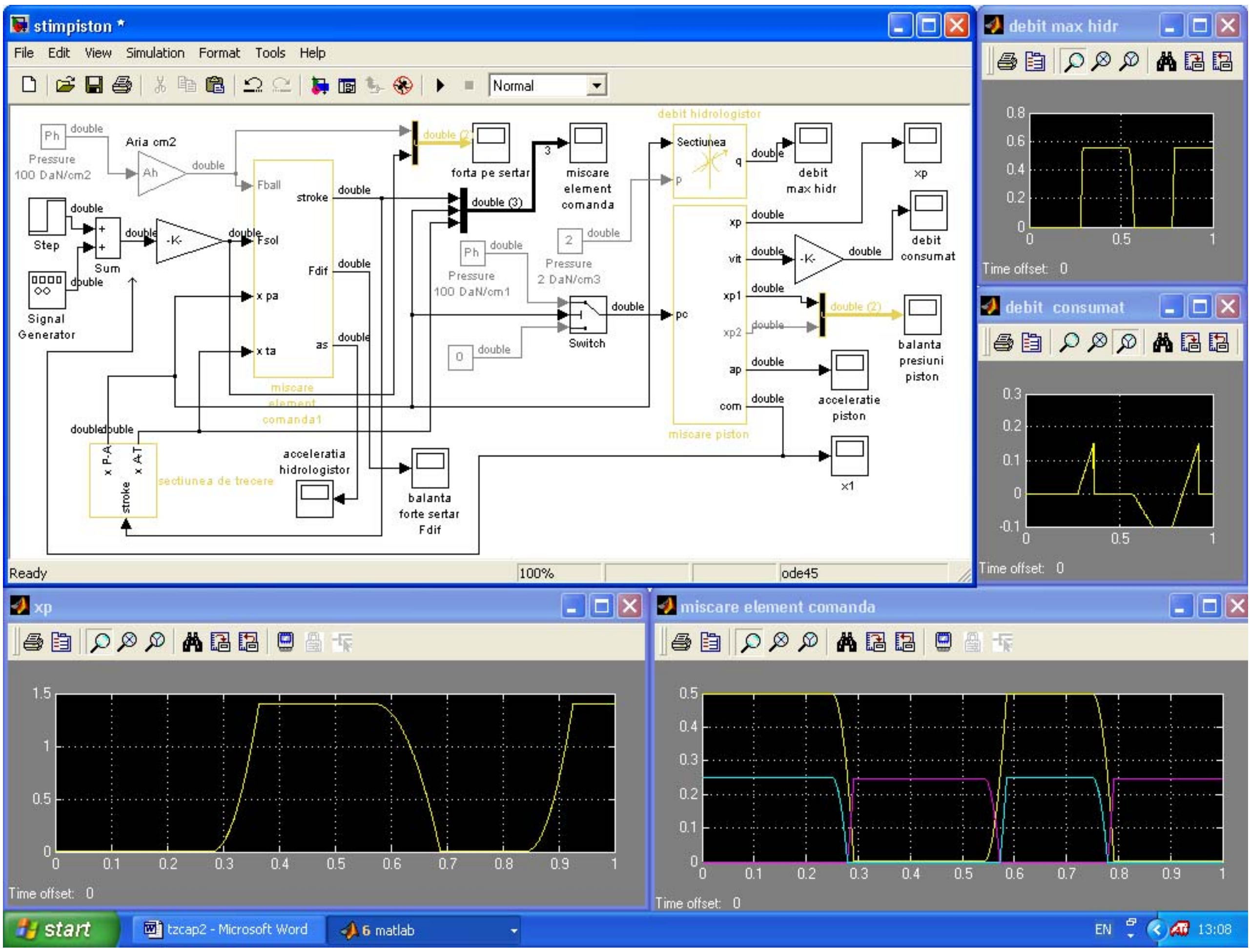

Fig. 10. The block diagram of the piston & hydrologistor working together.

6. RESULTS

In Fig. 11 it is observed form of kinetic energy of the piston generator, for course work and race for withdrawal, the amount reaching its theoretical value of 75 J for the course and 180 J for race return. This difference is explained by the fact that the withdrawal to achieve high frequencies is opting for small active area so for very high speed work. In practice this energy is absorbed by the pressure battery introduced into the work of the multiplier later used for the race, the difference being absorbed in the table multiplier.

Increased frequency of up to the limit of stability of the generator can be done by increasing pressure of work

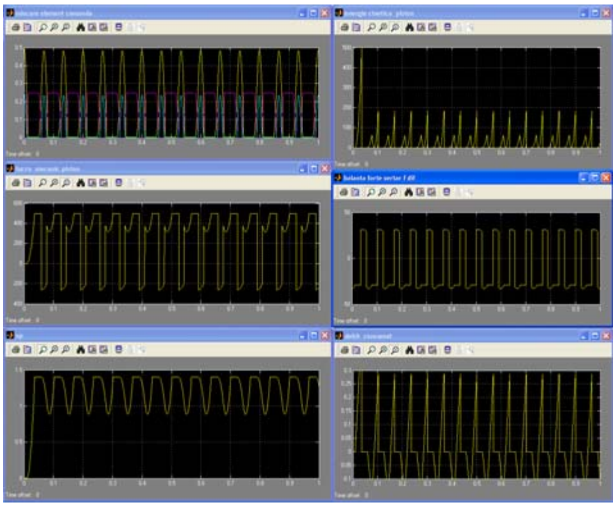

Fig. 11. Movement and energy.

to the value of 24 MPa, where the multiplier auto-oscillates at 22 Hz, consumes a yield of about 24 l / min, a swing of 6 mm but generate an impact energy of 120 J for the course. Basically the energy of impact can not be taken over by the mold, which was optimized the multiplier, so it is necessary to limit the pressure of work at a certain value.

7. FURTHER RESEARCH

We assume that the next step of the future research in to make a 3D functional model of the multiplier. Will be studied with the finite element analyses and optimized for a proper design. Regarding those great pressures a proper analyze for the pistons bodies, one way valves, and sealing system should be done.

Next step is functional model and experimental results. It will be tested the flow at different pressures, the power needed to generate flow and pressure and the form of the pressure signal at different regimes.

8. CONCLUSIONS

The purpose of this simulation was to create a mathematical model of hydraulic auto-oscillating multiplier. With this mathematical model can analyze and optimize dynamic behavior using different construction of hydro-logistors.

Hydro-logistors used in the construction of hydraulic multipliers was based on the commutations characteristics of these switching devices, ideal for working in the dynamic systems.

As demonstrated by the end of this chapter we have managed to achieve some theoretical high performance, comparable and sometimes over the performance of the multipliers produced so far on the world market.

When was chosen for field use with molds an alternative to more automation is required, which have a yield of more than 30% area with many practical uses, multipliers operated directly by the automation with very great practical applicability in hydro-formation work in the field of aviation and automotive design.

Besides the numbers used, with whom it has determined the outline dimensions for hydro-logistors and active components of the multipliers for simulation in the dynamic determination of the limits of stability in the functioning and the subsequent optimizing was used with good results environment programming Mathlab Symulink.

Numerical methods and exercises using computers were used alternately for each component in building the multiplier.

After optimizing operational parameters - the construction so that each component of the total multiplier can be exploited to their maximum to the past, in the second part of this work to the study of behavior in the whole dynamic of the entire hydraulic multiplier.

Analyzing the momentum and the kinetic energy and multiplier comparing it with data from manufacturers of such equipment is found on an overall decrease in the flow consumed by 10% to increase to 12% of the amount of kinetic energy of the multiplier piston, using the construction of pulse multipliers of hydrostatic hydro-logistors.

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