A NEW GENERATION OF HYDRAULIC PRESSES WITH ELECTROHYDRAULIC SERVOPUMPS

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The paper presents the transition from the high accuracy hydraulic press controlled by electrohydraulic proportional servovalves to a new generation of high efficiency digital hydraulic presses controlled by electrohydraulic servopumps. A modern digital electrohydraulic deep drawing press used for shaping high accuracy aerospace components is considered as a reference type for identifying the advantages of eliminating the servovalves supplied by an axial pistons pump with two stages pressure compensator. Few types of hydraulic press with servopumps are presented for different kind of press operations. The dynamic performances of a universal purpose servopress type are studied by numerical simulation, showing the possibility of rising the oil pressure only at the real level needed to accomplish the operation cycle phases.

Keywords: hydraulic presses, electrohydraulic servopumps, energy saving, simulations of the active phase

1. The peculiarities of the actuation system of a high accuracy hydraulic press

The modern manufacturing processes involving both high forces and a high accuracy of the tools motion need a lot of energy for supplying the servovalves of different hydraulic servomotors. A typical example of such a process from the aerospace field is the plastic deformation of a high-alloyed steel ring in order to obtain a nozzle for a turbojet (Figs. 1 and 2). The continuity of the metal structure and thickness needs a very accurate motion of the profiled tool, controlled by two-stages servovalves with a special shape of the laminating edges of the cylindrical spool shoulders. The complex hydraulic presses have always a main variable displacement axial (or radial) pistons pump with pressure compensator (Fig. 3). It is possible to control the pump displacement during the process, (Fig. 4) but the mixed control needs many simulations and very expensive practical attempts.

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Fig. 1 Typical deep well press of 5MN with proportional servovalves [1]

Fig. 2 The hydraulic oil supply system and the flows control section: the oil tank, the servopump Parker PV046R1, the Parker proportional servovalves block, and the auxiliary electropump [1]

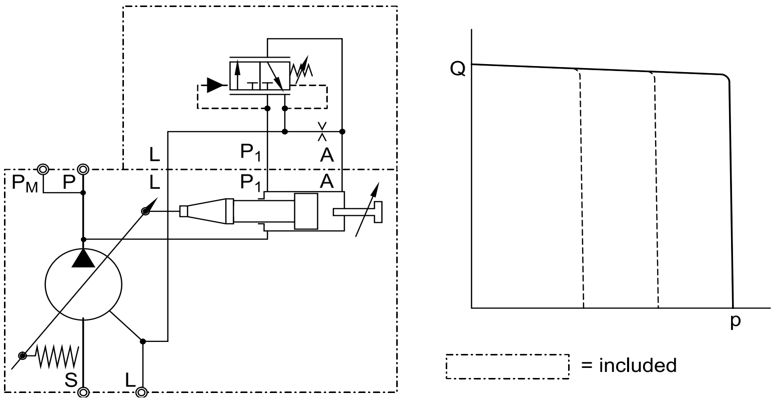

Fig. 3 Hydraulic diagram and the steady-state characteristics of the servopump PV046R1 with mechanical pressure compensator [2]

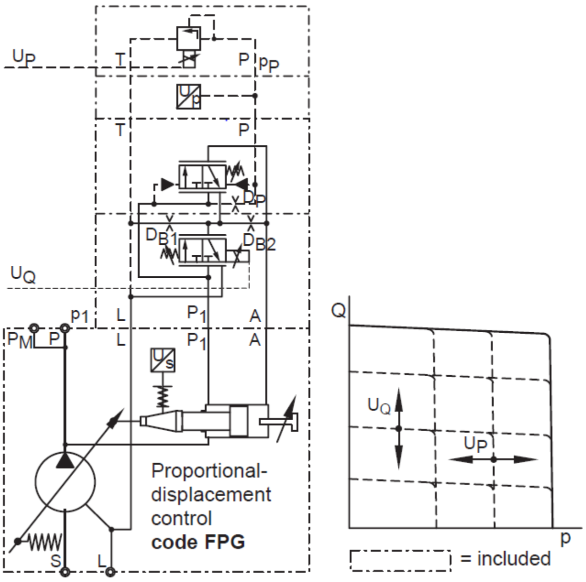

Fig. 4 Complete hydraulic scheme of the servopump PV046R1K1T1NUPG, including the flow rate servomechanism and the pressure compensator

The response time of this type of servopump is small enough (about 80ms) for avoiding to disturbe the servovalve controlling the motion of the main hydraulic cylinder during the process of pressing the sheet of alloyed steel in the die [3].

The hydraulic scheme of the press (Fig. 5) shows a complex control system of the main hydraulic cylinder motion, designed to avoid any uncontrolled position change of the sheet of metal turned into a complex nozzle. The top die motion is always combined with the die cushion adjust according the nozzle profile in order to obtain the shape and the thickness variation demanded by the user.

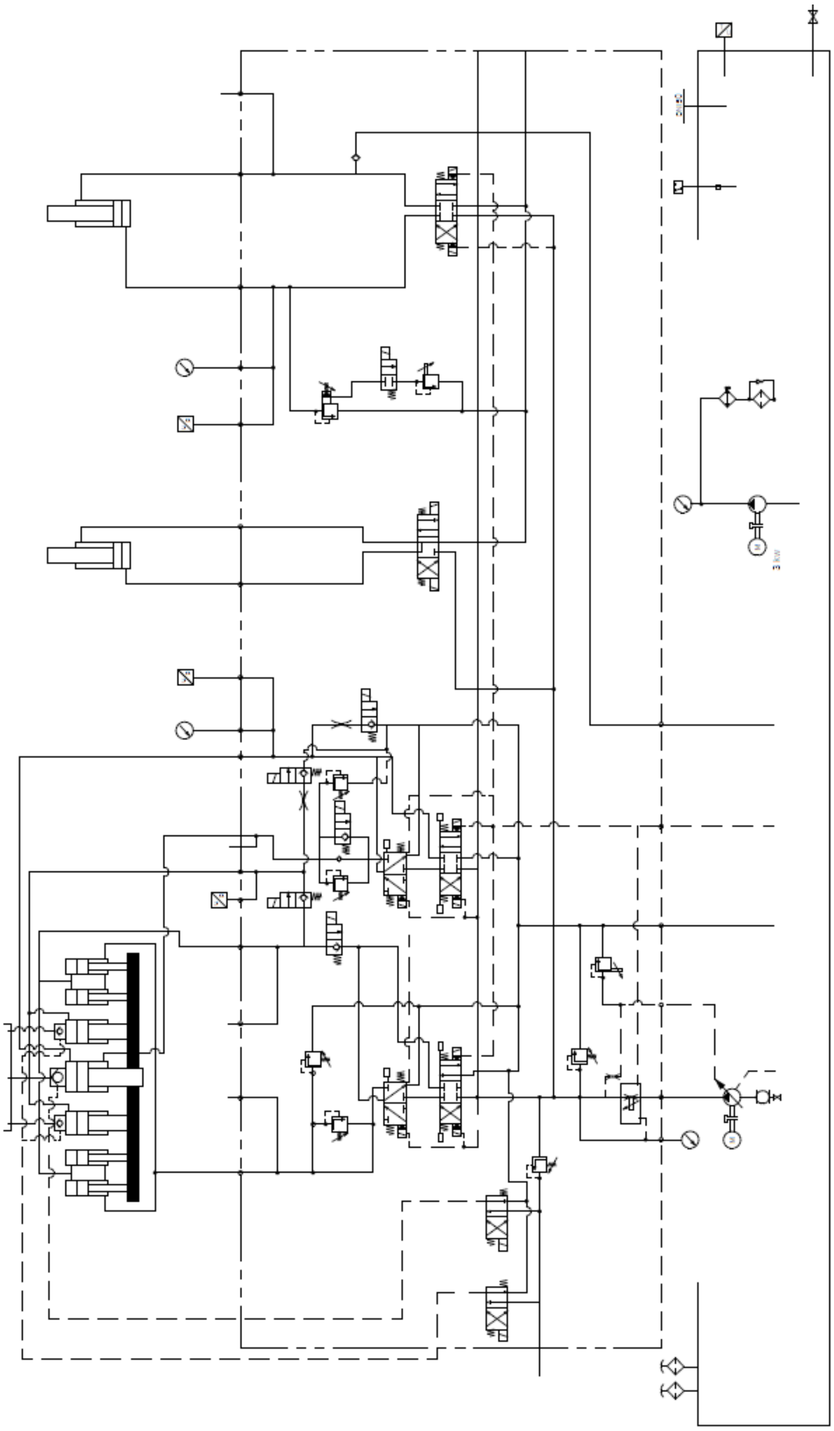

Fig. 5 Hydraulic scheme of a deep well electrohydraulic press [4-5]

The overal power consumption of the press for controlling nine hydraulic cylinders is about 55 kW. Most of this power is turned into heat by the servovalves, which is eliminated by a systems of heat exchangers.

2. Energy saving replacing the servovalves by speed controlled pumps

Some advanced press companies decided to eliminate the constant speed induction motors by much smaller brushless servo motors for driving dual displacement radial piston pumps or speed controlled constant displacement pumps [6-8]. This changes saves energy particularly when the system is working under partial load, or working in "standby mode". By including the servomotor in a modular multi-axis motion control drive, the energy efficiency can be higher, especially when the machine works under partial load. Figure 6 shows the structure of a die cushion press which incorporates this new technology [9].

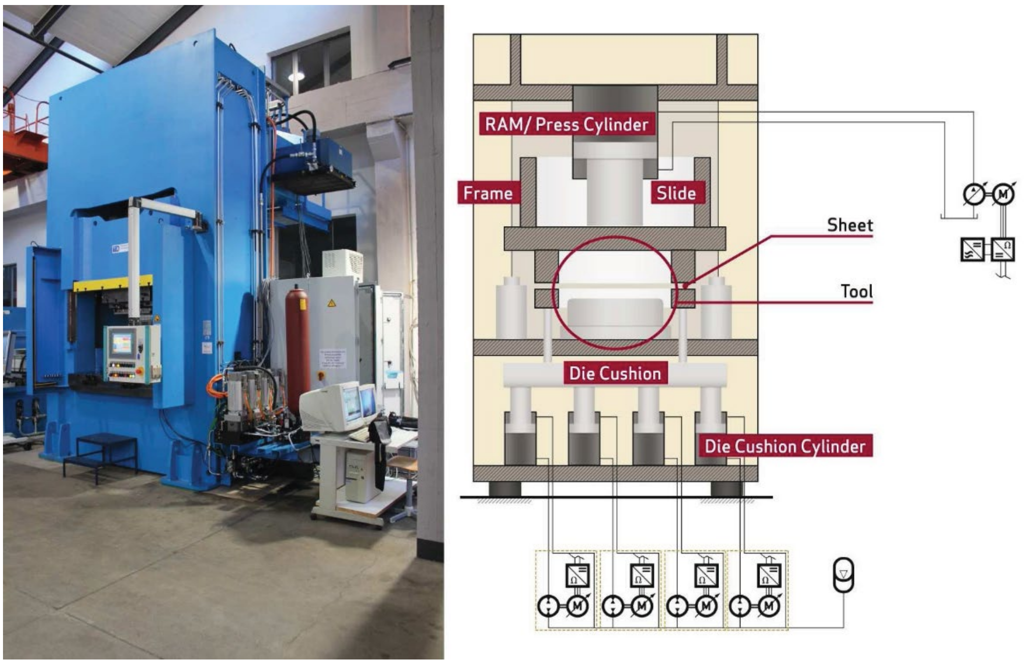

Fig. 6 The experimental deep drawing press with Moog electro-hydrostatic actuators

The research was performed by Moog Inc. and the Fluid Power Institute of Dresden University. A conventional press machine with a die cushion with four separate cylinders was modified by replacing the servovalves contolling the four die cushion with electrohydraulic actuators (EHA). The servo drive alowed to recovere energy from the die cushion to the ram actuator. While maintaining comparable dynamics and pressure control functionality, energy savings during a complete machine cycle of 30% could be achieved during tests, explaining the great interest of the users of electrohydraulic press for the electro hydrostatic actuators (SHA). Moog Inc. studied different schemes for the hybrid actuators used for different kind and size of applications (Fig. 7). Some of them were already applied both in aerospace application (as "flight-by-wire" actuators), and in industrial manufacturing process, for saving large amount of energy.

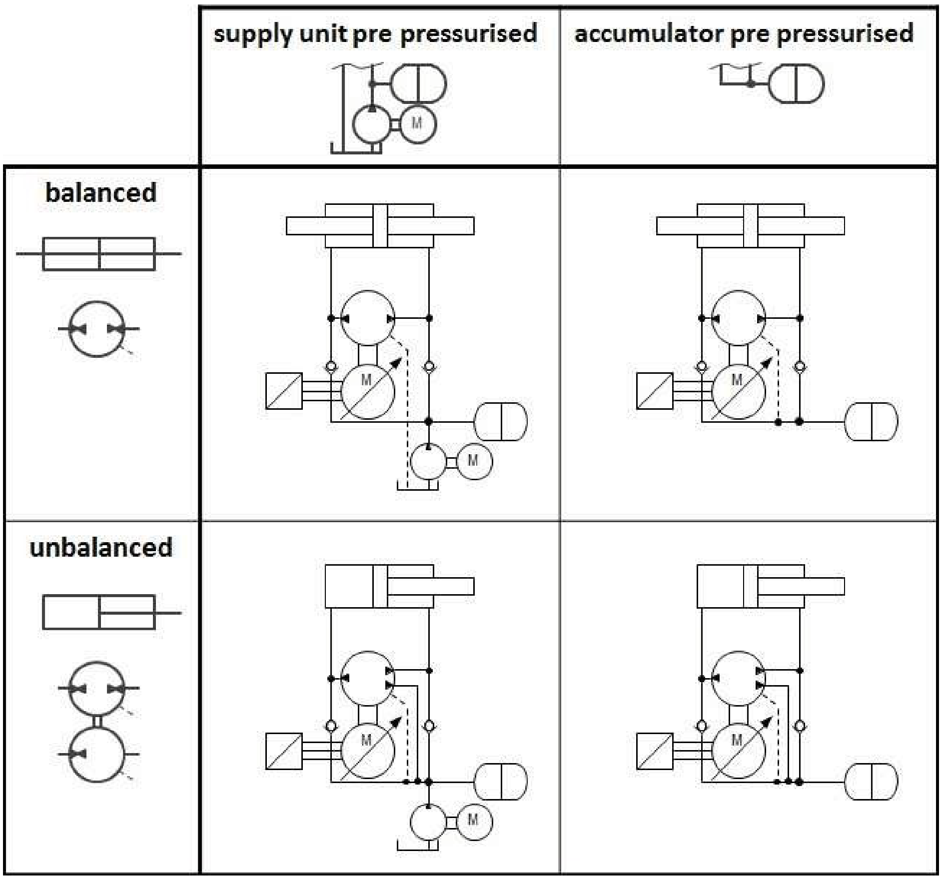

Fig. 7 Characteristic base circuits for MOOG electro hydrostatic actuators (EHA)

The normal operation tests in common industrial processes have shown a good expectation of life, reaching 20,000 hours [10]. However, the wide investigations of the researches from advanced fields have underlined the need of use the best quality components and materials for avoiding any intervention in complex conditions as aerospace ones. [11]

The modular design of the EHA and SHA offers many advantages. The design can be "integrated", (Fig. 8a), "compact" (Fig. 8b) or distributed. The complete integration of the cylinder and the motor/pump unit into a hydraulic manifold offers an optimum way for reduce installation space. The complete or partial integration of the cylinder and the motor/pump unit into the hydraulic manifold allows the optimization of the installation space.

a)

b)

Fig. 8 Designs of Rexroth SHA: a) integrated; b) compact.

The SHA offer a lot of advantages, combining hydraulics and electrics: ready-to-install solution pre-assembled, oil filled and with minimum amount of defined interfaces; easy startup – plug & run; low maintenance expenditure, diagnoseable; energy – efficient operation iving power on demand; I4.0 capability; self - contained, separated from any central hydraulics (flexibility); the same origin key components connected within the system. There are a lot of user benefits: time savings – fast and easy installation and startup; high machine uptime; reduced operating and maintenance costs – energy and insurance; cost savings – open standards in the control concept; efficient engineering – construction kit principle.

3. Design, modeling and simulation of a new servopress

A useful step in designing a servopress (PSH) need to define the press destination. The simplest configuration, developed by VOITH (Figs. 9 and 10) includes two servopumps which control the two variable volume chambers of a hydraulic cylinder. Thanks to this drive system, the user can significantly reduce the life-cycle costs (LCC) of the press, while at the same time boosting the productivity of your production process and increasing the quality of your products. The PSH is suitable for new systems but can also be retrofitted to modernize existing presses. The PSH system uses two servo pumps instead of conventional valve control technology. This concept simplifies the design of the press drive, while still providing an excellent level of functionality and performance. [12]

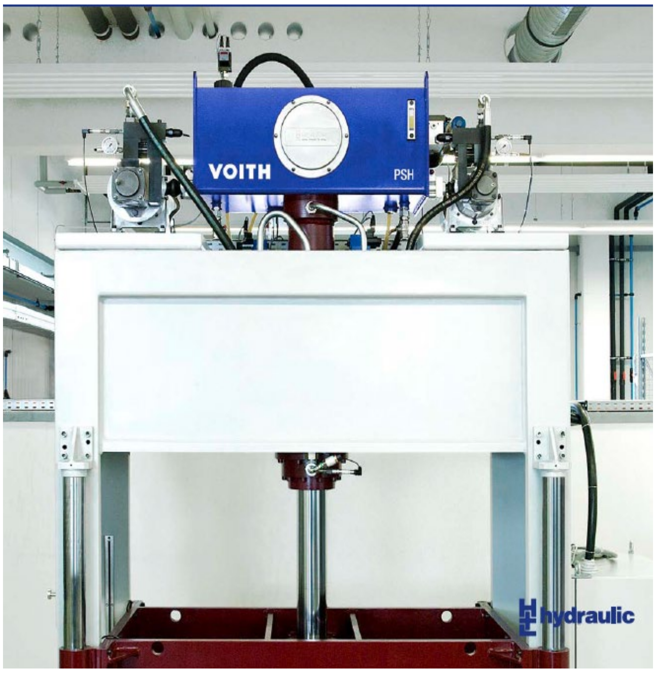

Fig. 9 Front view of the VOITH PSH hydraulic press drive

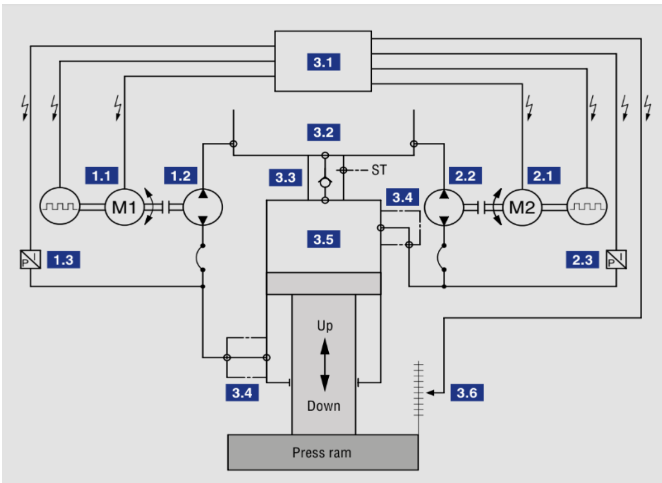

Fig. 10 Schematic diagram of the VOITH PSH: 1.1 and 2.1-Servo motor; 1.2 and 2.2-Internal gear reversibele crescent pump; 1.3 and 2.3-Pressure sensor; 3.1-Electronic control system; 3.2-Oil reservoir; 3.3-Inlet valve with ST control cable; 3.4-Pressure safety control; 3.5-Operating cylinder; 3.6-Position sensor

The PSH hydraulic press drive operation principle was patented in 2010, in close connection with the progess in power electronics, digital controllers’ fieldbus and servopumps (Figs. 11 and 12). Thanks to this drive system, the indestry can significantly reduce the life-cycle costs (LCC) of the press, while at the same time boosting the productivity of the production process and increasing the quality of the products.

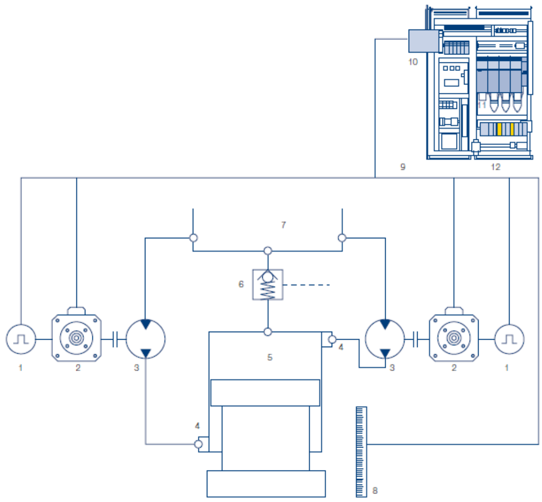

Fig. 11 PSH schematic operation principle

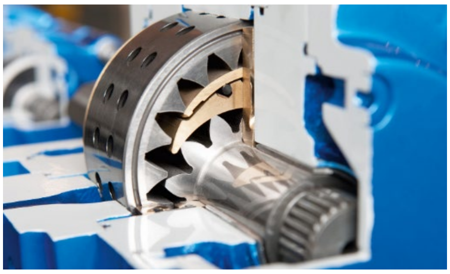

Fig. 12 Cut view of a modern reversible high pressure crescent servopump (REXROTH)

The last implementations of the PHS include the digital die hybrid control, with a strong impact in aerospace and automotive industries due to the big amount of energy recover (Fig. 13). The users of the new principle of PSH are pointing out many favourable features: conventional valve control technology not required; active real time servo pump control; excellent energy efficiency; modular design; few components; simple drive system with excellent functionality of power, speed and position regulated by the servo pump; accurate reproducibility in terms of speed, power and cycle number; improved thermal efficiency; smaller oil tank; sensors for parameter monitoring in established diagnostic functionality.

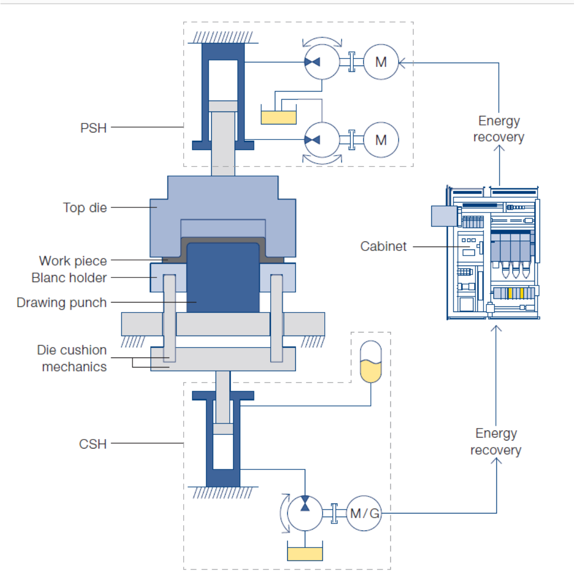

Fig.13 VOITH PHS with energy recovery by the concept CSH (cushion by servopump)

4. Numerical simulation of a PSH

The simplest simulation of the PSH dynamics can be performed with AMESIM software, taking into account the minimim controller structure (Fig.14). The active phase of the press process is considered only.

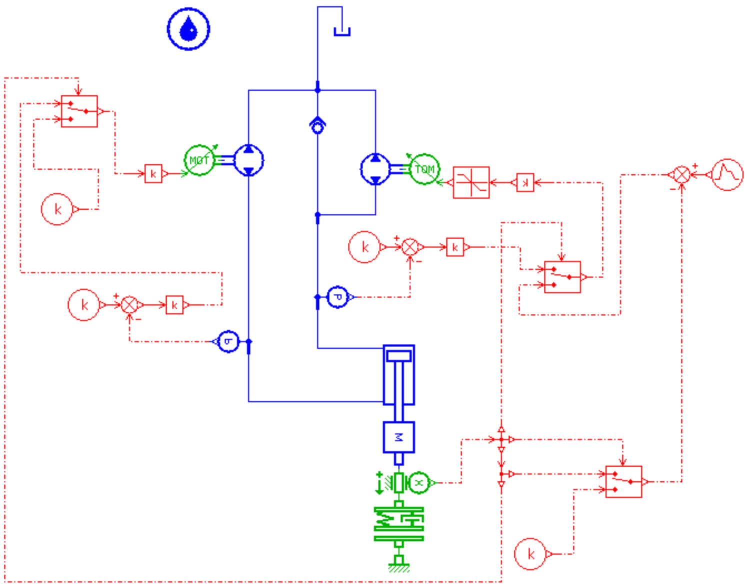

Fig. 14 Basic simulation network for the active phase of the press process

The time evolution of the main state variables of the press is presented bellow (Figs. 15-22).

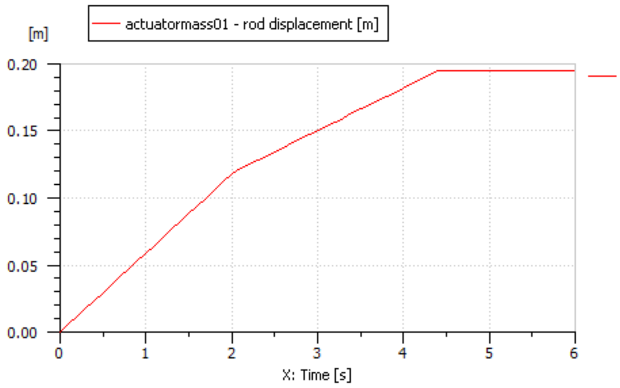

Fig. 15 Hydraulic cylinder rod displacement during active (press) stroke

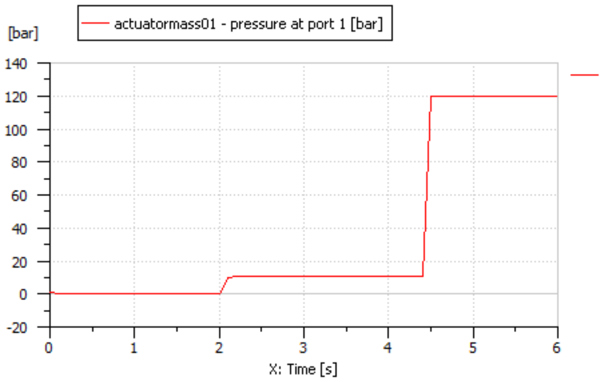

Fig. 16 Pressure variation at upper input port of the hydraulic cylinder

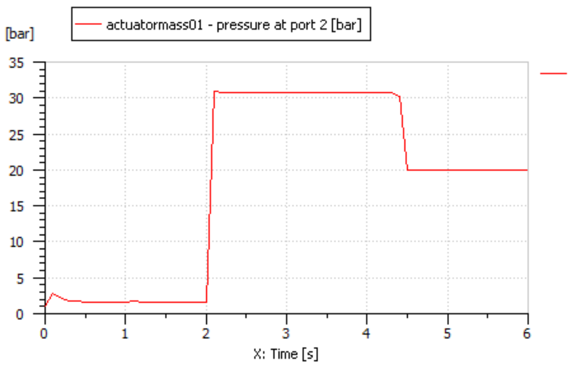

Fig. 17 Pressure variation at output port of the hydraulic cylinder during active stroke

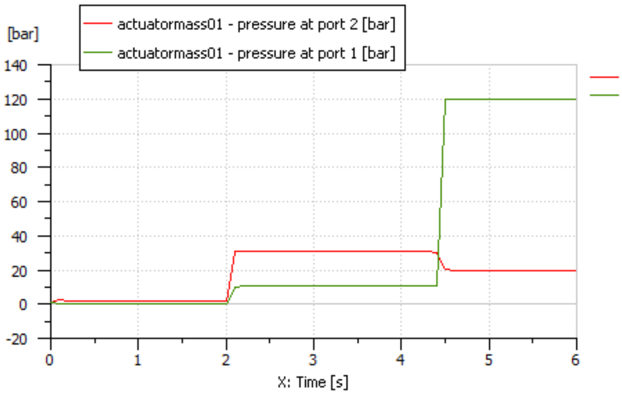

Fig. 18 Pressure variations into the chambers of the hydraulic cylinder during press phase

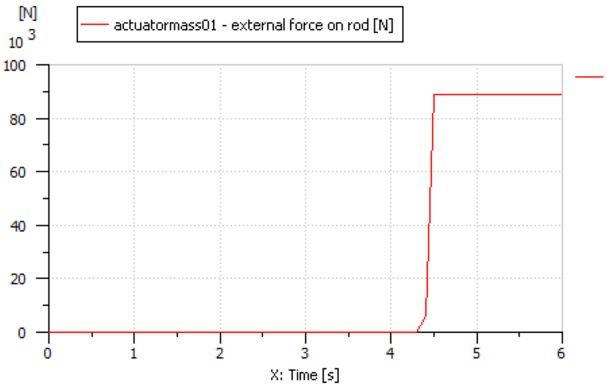

Fig.19 Variation of the hydraulic force on the cylinder rod

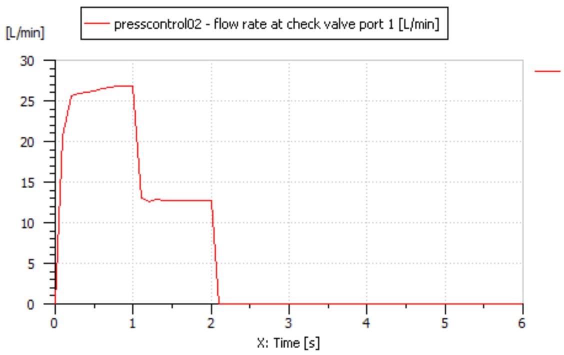

Fig.20 Variation of the flow rate passing through the check valve

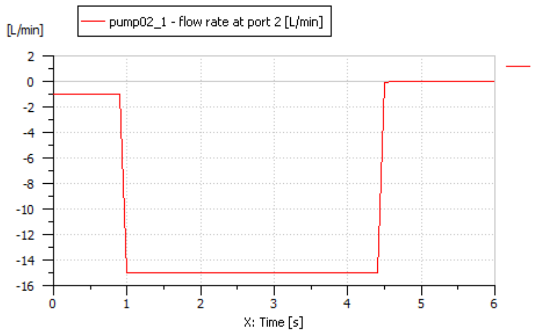

Fig. 21 The flow rate variation at the second pump input port

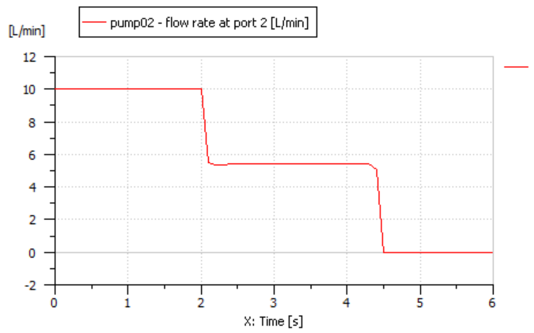

Fig. 22 The flow rate variation at the second pump output port

5. Conclusions

The information included in this paper have to be regarded as introductory only for realistic predictions on the future of the digital hydraulic control systems. The huge amount of possible applications of the digital hybrid servosystems shows the need of "hybrid" research team, oriented to the different kind of optimizations: mechanical, thermal, hydraulic, digital communications and control etc. [13]

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