

## NUMERICAL SIMULATION OF THE MECHANICAL FEEDBACK SERVOPUMPS BY AMESIM

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*The paper presents the mathematical modeling, and the numerical simulation of the dynamics of a swashplate servopump with mechanical feedback. The servomechanism controlling the pump displacement is supplied by a low pressure gear pump, and includes oversized pistons for rejecting the high frequency tilting force. The response time is controlled by the diameter of a metering orifice sited on the supply port. The theoretical performance of the servopump is found in good agreement with the manufacturer specifications.*

**Keywords:** servopump, servomechanism, numerical simulation, dynamics

### 1. Mechanical feedback servopumps structure

The mobile hydrostatic transmissions include hydro mechanical servos with lever feedback and centering springs sited in the cylinders (fig.1).

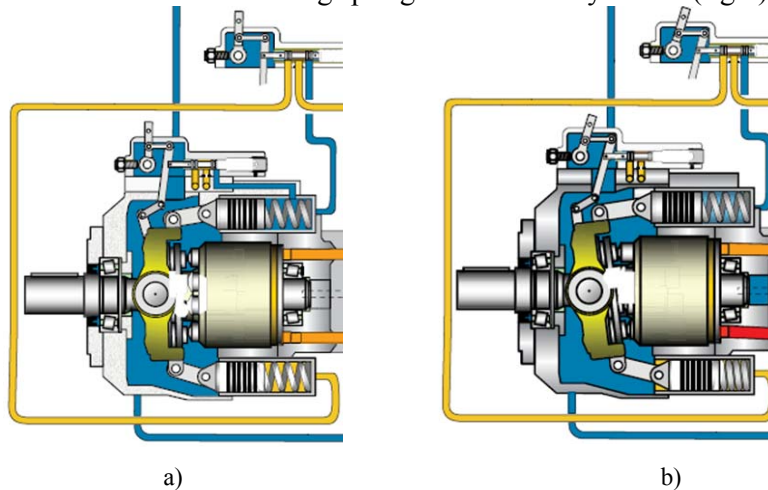


Fig.1.EATON Servopump: a)neutral swashplate position; b) with active servomechanism [1]

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The security offered by these servos is one of the main quality needed by the mobile equipmentsoperating in extreme environmental conditions. In the last decade the mechanical feedback became a hybrid one: the input lever is controlled by two position proportional solenoids, for the two flow direction. These devices are replacing the manual direct input by a joystick.

The last type of the displacement control system is a pure electrohydraulic servomechanism controlled by a "CAN Electronic Displacement Control"[1,2] The centering springs are acting directly on the hydraulic cylinder controlling the pump piston's stroke.

This paper is devoted to the modeling and simulation of the mechanical servopump by the aid of AMESIM simulation language. Common components from the dedicated libraries are used. The servos controlling the pump displacement (fig.2) has in input lever 4 actuating one end of the error bar 5.

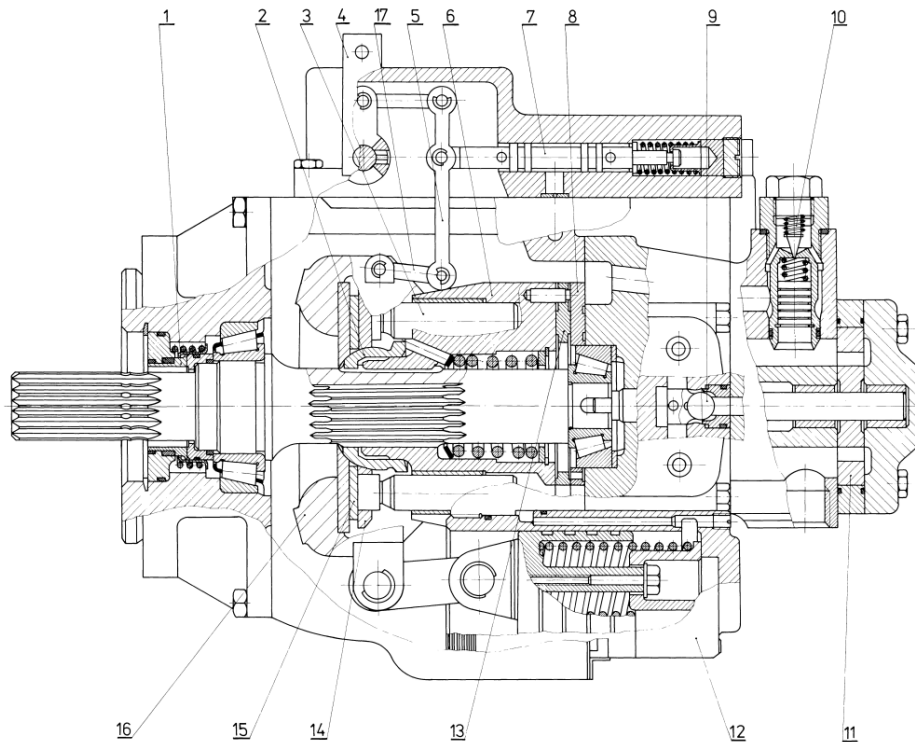


Fig. 2. Mechanical feedback servopumpwith swashplate:

- 1-shaft mechanical sealing; 2-spherical bush; 3-piston; 4-input lever; 5-errorbar; 6-barrel; 7-spool; 8-fixed valve plate; 9-check valve; 10-pressure relief valve; 11-auxiliary pump; 12-hydraulic cylinder spring centered; 13-mobile valve plate; 14-hydrostatic shoes retainer; 15-hydrostaticshoes; 16-swashplate; 17-feedback lever.

The other end of this bar is connected to the feedback lever 17. The positioning error is fed to the spool valve with a ratio of 1/2, improving the stability of the whole control system [1,2,3]. The spool underlap of about 1 mm introduces a dead band of about  $\pm 2,5^\circ$  at the level of input lever. The neutral position of the swashplate is automatically obtained by releasing the input lever: a centering spring is sending the spool in the neutral position from any stroke.

The stability and the response time of the servomechanism are controlled by the aid of a sharp edge metering orifice. The orifice size is established according to the customer demand. The usual diameter is about 1 mm, non dangerous from the obliteration point of view [4]. The response time of the stroking system directly depends on the orifice diameter: between 0.71 and 2.59 mm, the time needed by pistons to accomplish the whole stroke stays in the range 0.29 and 7.48 s. The big values correspond to big displacement pumps ( $250\text{cm}^3/\text{rev}$ ). According to the numerical simulations and the experimental identifications [4], this is the simplest way of controlling the dynamic behavior of the hydraulic servomechanism.

## 2. Modeling the kinematics of the servomechanism

The mathematical model of the servomechanism contains a mechanical sequence including all the moving components. This part can be generated using the module PLMASSEMBLY from AMESIM (fig. 3, 4).

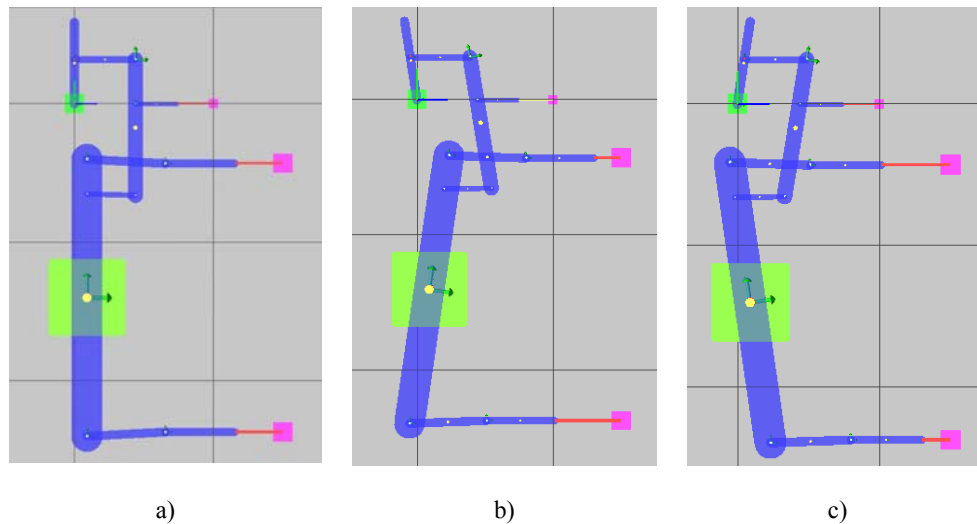


Fig. 3. The servopump servomechanism mechanical components in different steady-state situations (PLMASSEMBLY model from AMESIM): a) neutral position (no input); b) locked spool and constant force developed by the lower cylinder; c) locked spool and constant force developed by the upper cylinder.

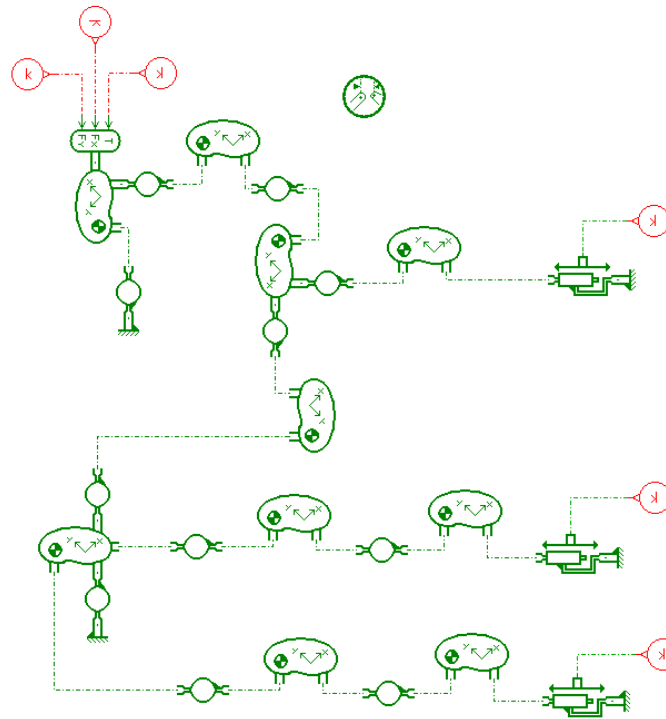


Fig. 4. Servomechanism simulation network developed in Planar Mechanical module from AMESIM

### 3. Modeling and simulation of the servomechanism dynamics

The mathematical model of the servomechanism set up in AMESIM language may be considered as a general one, but it reflects with accuracy the kinematic and the hydraulic structure of the studied system (fig.5). This model was used for simulating three linear inputs applied to the input (control) lever from zero to  $5^\circ$ ,  $10^\circ$  and  $15^\circ$  (fig.6). The main variables evolution is presented in the figures 7...12. The servomechanism is supplied by the auxiliary pump with hydraulic fluid under low pressure (16 bar). Consequently, the pressure drop across the metering orifice becomes very important during the transients, increasing the control system response time. This one matches the requirements of the mobile equipments with high inertia components. The servovalve opening reaches 4.3 mm for a negative lap of about 1 mm and round metering holes sited in the valve body. The maximum speed of the stroking piston reaches small values (15 mm/s). The time constant of the first order response can be adjusted between 0.8 and 2.2 s with damping orifices of 1.2...0.8 mm.

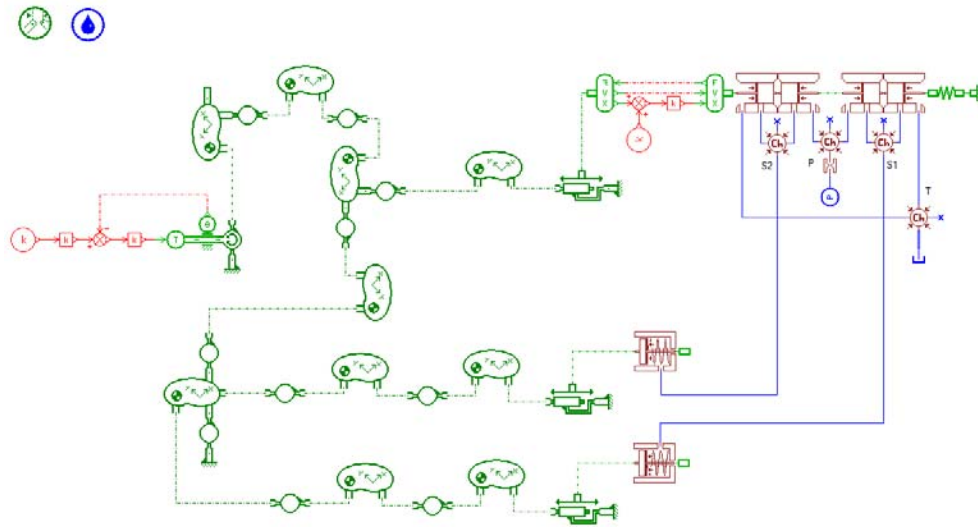


Fig. 5. AMESIM model of the servopump servomechanism with mechanical feedback

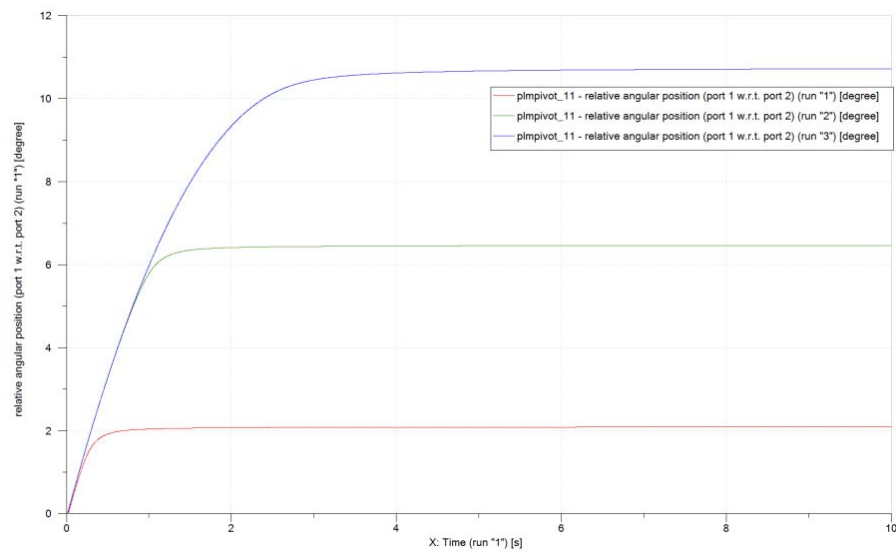


Fig. 6. Swashplate angle variation during the transients

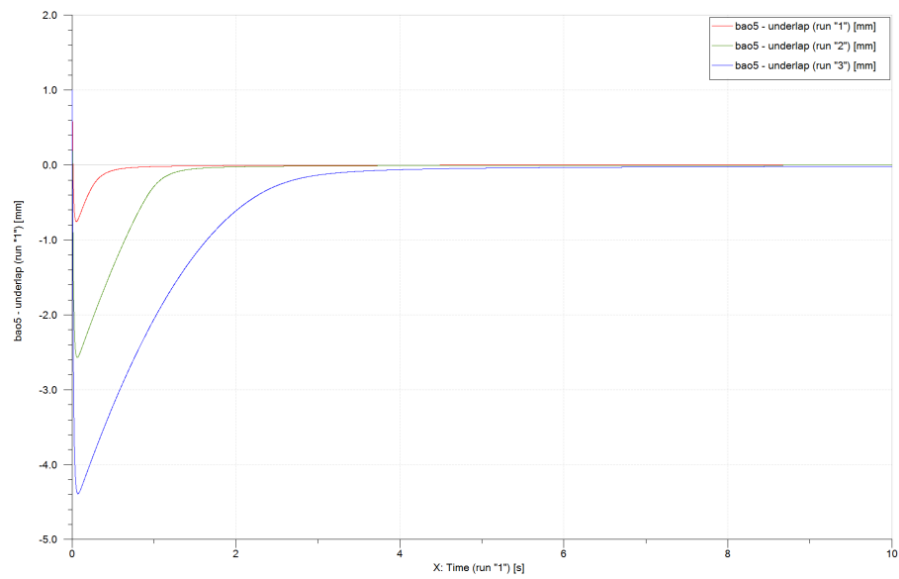


Fig. 7. Servovalve spool stroke variations during the transients

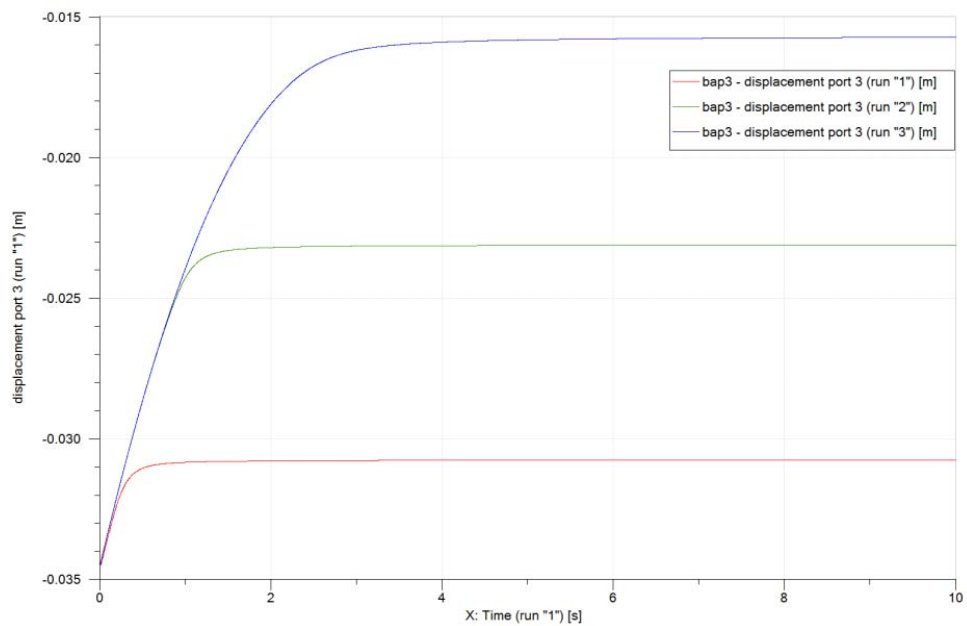


Fig. 8. Low piston displacements during the transients

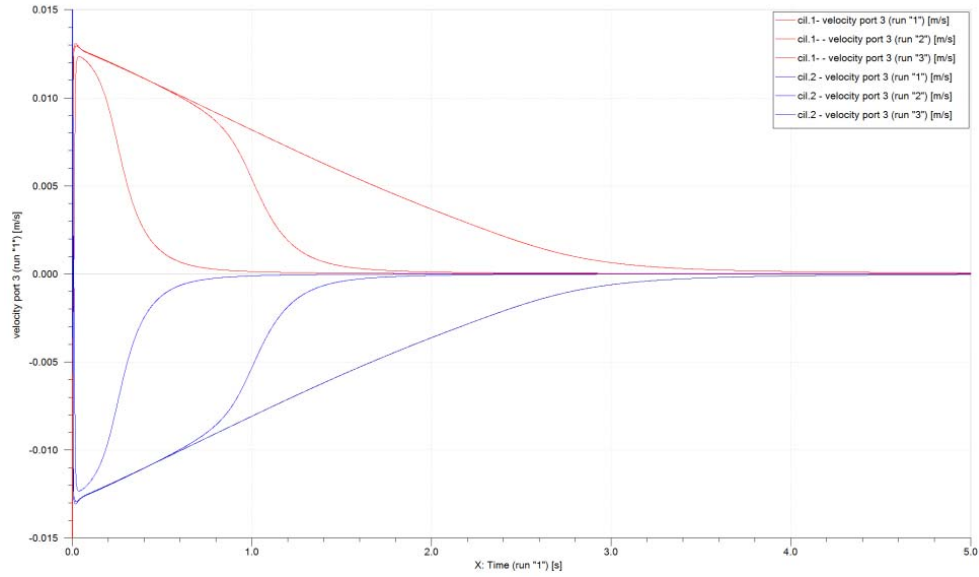


Fig. 9. Hydraulic cylinder pistons displacements during the transients

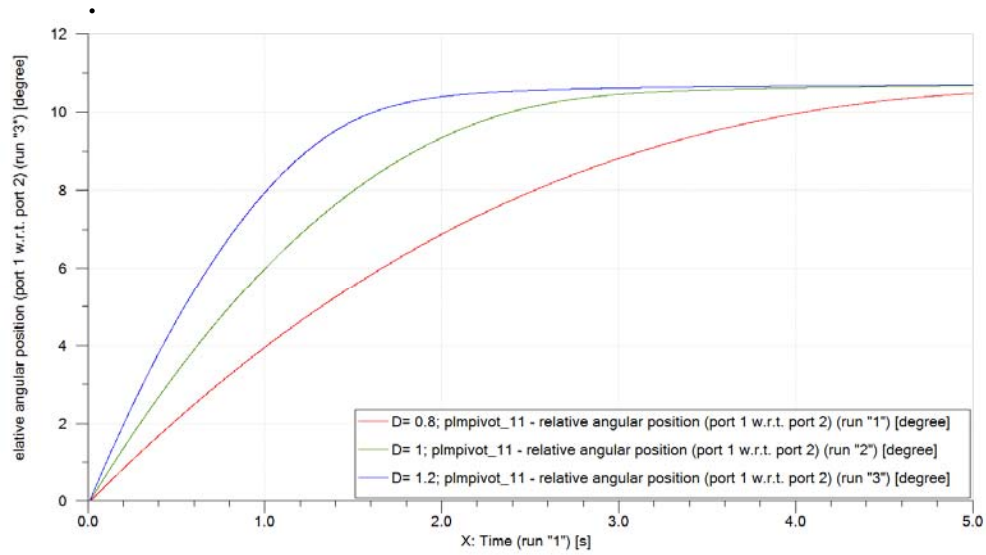


Fig. 10. The influence of the damping orifices diameter on the system response time for a step input of  $15^\circ$  introduced by the control lever

#### 4. Simulation model of the servopump dynamics

The complete AMESIM model of the studied axial piston servopump is presented in the figure 11.

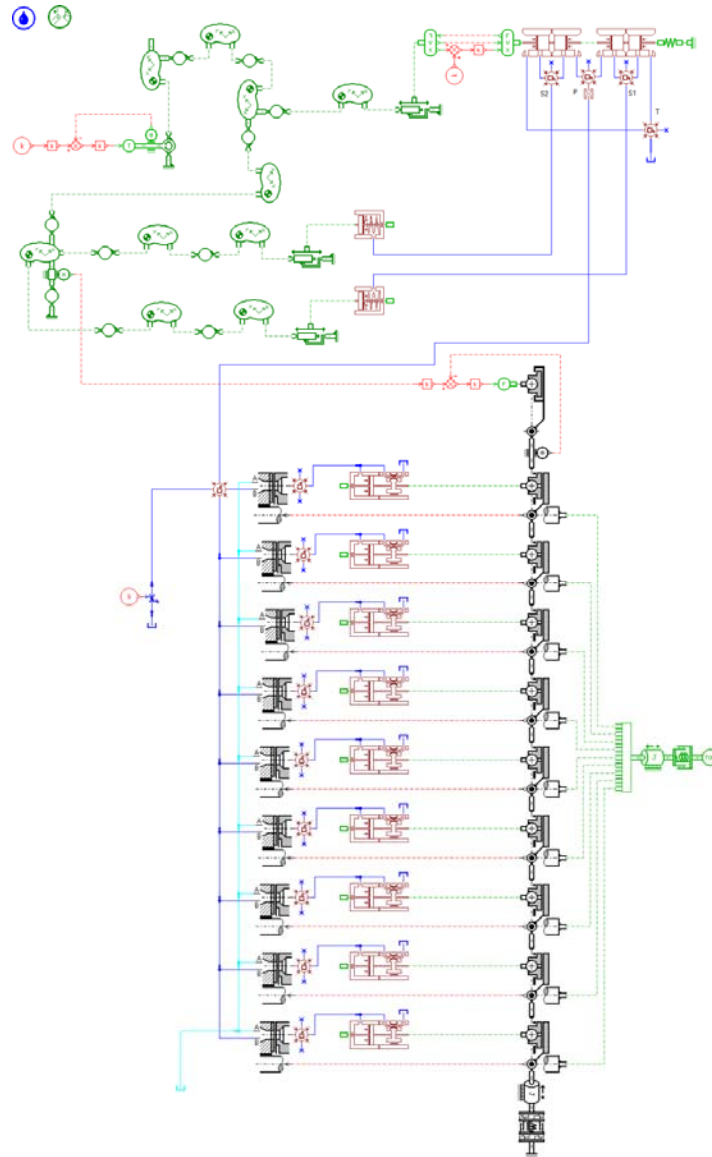


Fig.11. AMESIM model of a washplate servopump with 9 pistons supplying an orifice

Two different steps input applied on the input lever generates the flows presented in the figure 12. The output flow passes through an orifice. The flow irregularities (fig. 13) correspond to the pistons number (9) and to the shaft speed ( $25 \text{ s}^{-1}$ ).

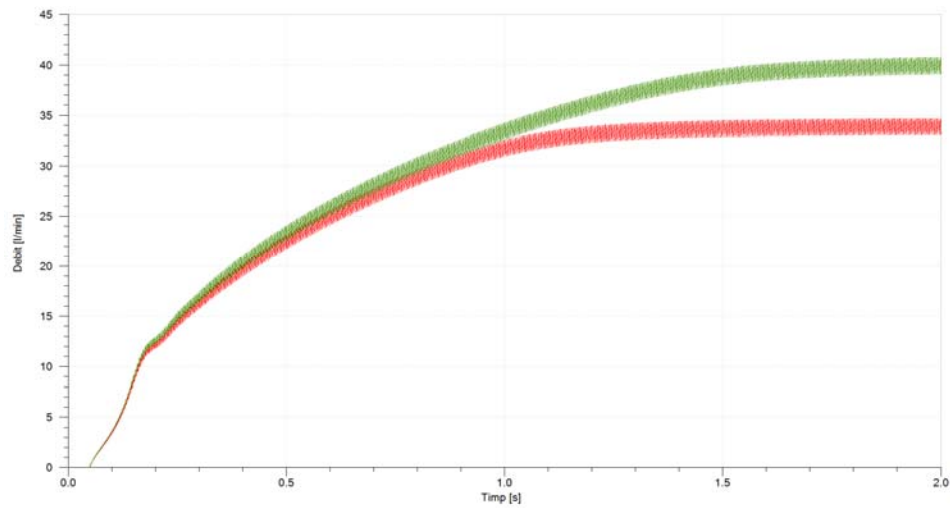


Fig. 12. Servo pump flow variations generated by two input signals

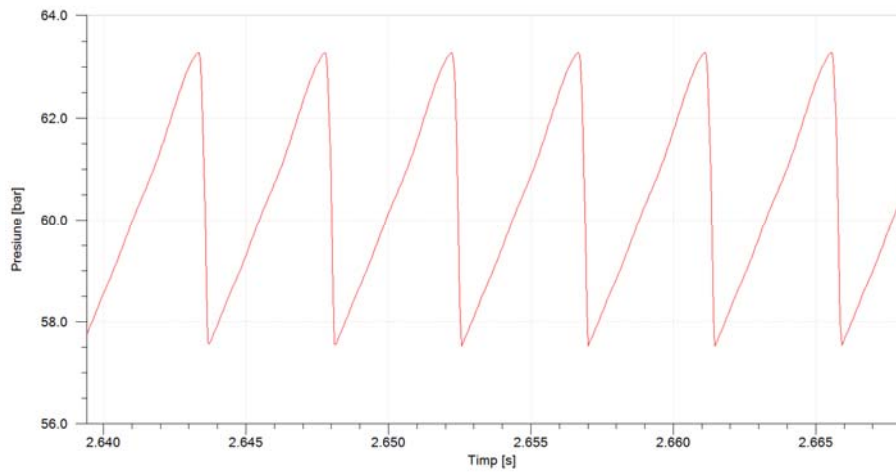


Fig. 13. Pressure variation at the servopump output for a constant input

## 6. Conclusions

The numerical simulations results obtained by AMESIM environment for the global parameters of the servopump displacement control are in good agreement with the manufacturer technical specifications. Other series of numerical simulations performed by general purpose languages like SIMULINK [1-3] or LabVIEW [8] are giving the same results. The servopump dynamic model will be included in the hydraulic library of the new release of AMESIM language [9-13]. The new mathematical model can be used in a wide category of applications, including the hydropower units speed governors [4-7].

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