MODERN INSTRUMENTS FOR ANALYSIS OF HYDROSTATIC TRANSMISSIONS

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Lucrarea abordează analiza unei transmisii hidrostatice cu reglaj mixt [2],[4], existentă în laboratorul INOE 2000-IHP Bucuresti, care contine în primar o servopompă MOOG şi secundar un servomotor BOSCH. Aspectele originale ale lucrării constau în:
- realizarea unor modele de simulare în AMESim [6], specifice servopompei şi transmisiei;
- realizarea unei interfețe virtuale pentru modelul de reglare al transmisiei;
- validarea modelului de reglare al transmisiei hidrostatice prin iteratii succesive de simulari numerice şi identificari experimentale, realizate prin cuplarea alternativă a interfeței virtuale la rețeaua numerică de simulare, respectiv la modelul fizic de laborator [1],[3].

This paper deals with the analysis of a hydrostatic transmission with mixed adjustment [2],[4], existent in the laboratory of INOE 2000-IHP Bucharest, which includes in its primary sector a MOOG servo pump, and in its secondary sector a BOSCH servo motor. The original aspects of the paper consist in:
- development of simulation models in AMESim [6], specific to pump and transmission;
- development of a virtual interface for the adjustment model of transmission;
- validation of the adjustment model of hydrostatic transmission through successive iterations of numerical simulations and experimental identifications, developed by alternative coupling of the virtual interface at the numerical simulation network, respectively at the physical laboratory model [1],[3].

Keywords: hydrostatic transmission, AMESim, LabVIEW

1. Introduction

Latest trends in modeling and simulation of dynamic systems regard new concepts, such as co-simulation and real-time simulation.

The concept of real-time simulation of dynamic systems allows simultaneous existence of both a part of a mathematical model, and a part of a

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physical model, thus obtaining a decrease of the degree of uncertainty, caused by certain phenomena neglected in the mathematical model [5].

Co-simulation involves simultaneous use of resources from multiple modeling /simulation environments, with the opportunity to enjoy maximum performance of each environment [7].

The article presents an actual example of achieving a numerical co-simulation network based on two programs: AMESim and LabVIEW. With AMESim program a hydrostatic transmission model was developed, while analysis of data obtained from simulations in AMESim has been performed with virtual instrumentation, by means of LabVIEW software.

Simultaneous use of the two simulation/ programming environments, AMESim and LabVIEW, can lead to the development of an advanced modeling / simulation network of electro hydraulic systems [8].

The objectives of this paper consist in development of the basic model of a simulation network for a hydrostatic transmission with mixed adjustment [9], development of simulation models for MOOG servo pump and hydrostatic transmission, integration of servo pump's model with the simulation model of hydrostatic transmission with mixed adjustment, development of virtual interface of the adjustment model of hydrostatic transmission, optimization and validation of the adjustment model of transmission through successive couplings of virtual interface to the modeling/simulation network and to the physical laboratory model.

The main characteristics of the two adjustable volumetric machines from the primary and secondary sectors of transmission are the following:

a) for the adjustable radial piston MOOG type pump within the primary sector of hydrostatic transmission: rotational speed n=1500rpm; interior radius of the adjustment ring R=0.155m; radius of the cylinder module r=0.15m; excentricity e=0..5mm; diameter of a radial small piston d_p=20mm; maximum capacity $V_{p\ max}$ = 32 cm^3/rev.

b) for the hydraulic adjustment servomechanism of pump capacity: diameter of small piston d=25mm; diameter of large piston D=31.5mm; inertial mass of the two pistons and adjustment ring M_i=3Kg; minimum supply pressure of servomechanism P_{min}=20bar.

c) for BOSCH hydraulic servo motor within the secondary sector of hydrostatic transmission: minimum capacity $V_{m\ min}$ = 7 cm^3/rev; maximum capacity $V_{m\ max}$ = 28 cm^3/rev.

2. Basic model of a simulation network of hydrostatic transmission

Simulation model includes a numerical simulation network of a hydrostatic unit that operates as a pump (Moog - RKPD / radial piston pump) and a simulation network of a hydrostatic transmission in open circuit made of two units of adjustable capacity.

The analyzed hydrostatic transmission, with secondary adjustment, with single consumer of type rotary volumetric motor, adjustable, according to figure 1, includes:

- **in the primary sector**: a MOOG servo pump, place 1, with radial pistons and integrated electronics, with three loops of adjustment, that is in flow, in pressure, in flow and pressure; an electric motor for servo pump actuation, of constant rotary speed, place 2; a pressure limiting valve, place 3; a flow transducer, place 4; and a pressure transducer, place 5.
- **in the secondary sector:** a BOSCH servo motor, place 7, with axial pistons, tilted block and integrated electronics, a torque transducer place 8; a speed transducer, place 9; an axial piston pump, with tilted block and fixed capacity place 10, to simulate the load of hydraulic servo motor, two pressure transducers, place 11 and place 13; four way-valves, place 12, fitted on load suction / repression side of pump; a pressure adjustment valve, with electric control, place 14 for adjusting load of hydraulic servo motor.
- **a** PXI-NATIONAL INSTRUMENTS **block**, place 6, which provides a virtual interface of the adjustment process of capacity of the adjustable volumetric machines (LabVIEW / PXI).

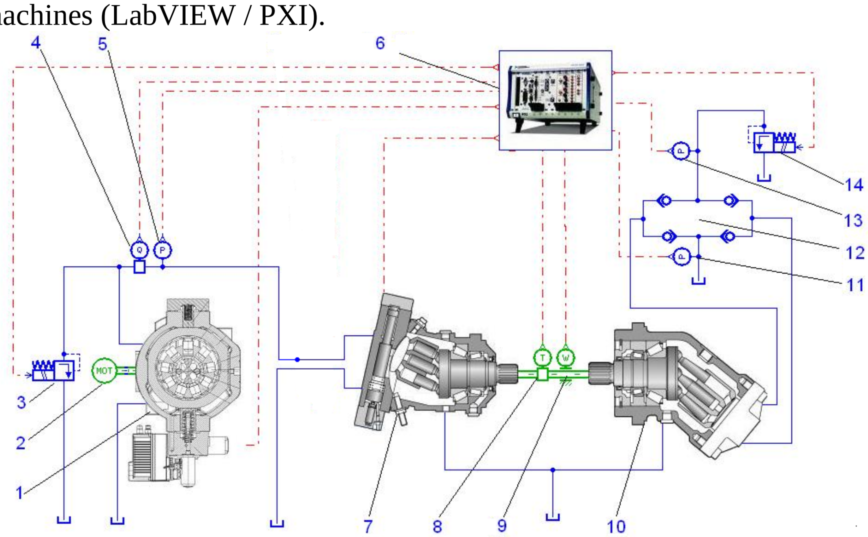


Fig. 1. Simulation network of a hydrostatic transmission – basic model.

3. Numerical simulation of radial piston pump type MOOG-RKP

Simulation model developed for the analysis of volumetric pump is shown in figure 2. It includes: the hydraulic servomechanism for prescribing the position of the adjustment ring; a module for calculating the relative position of small pistons as against to their angular position and the ordered eccentricity; the two small radial pistons of the pump; the distribution unit, controlled by the angular position of small pistons and the geometrical characteristics of the distribution flange.

By means of the modeling network developed, static characteristics were determined, Fig. 3, and dynamic ones, Figs. 4 and 5, of the servo motor that adjusts capacity of the analyzed radial piston pump. The model was excited with control signals (prescribing of eccentricity of the flow adjustment / control ring), sinusoidal, rectangular and ramp type signals, of various amplitudes and frequencies. The results are compared, simulated and experimentally shown. Simulation model has been "tuned" as a result of the comparative analysis between simulated and experimental response for a better accuracy of results.

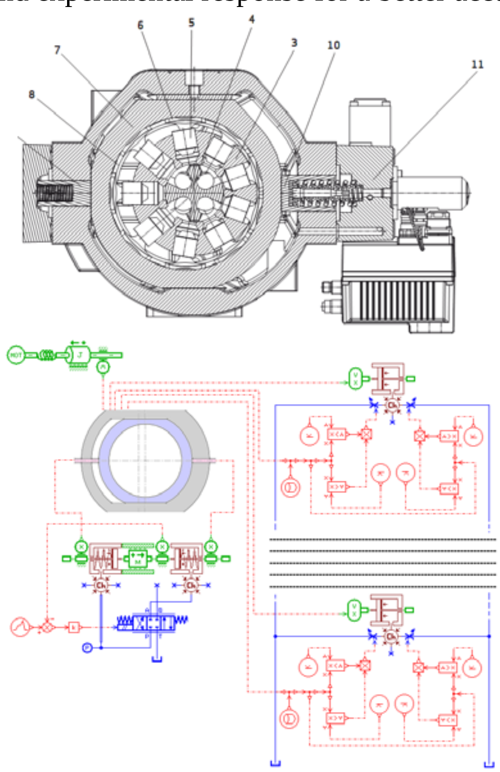


Fig. 2. Servo pump MOOG type RKP: above- cross-section; below- numerical simulation network.

Fig. 3 shows, in percentages, dependence between the input and output of the hydraulic servomechanism that adjusts pump capacity, respectively between the eccentricity developed and the one prescribed for the capacity adjustment ring. Curve 1 represents the stationary characteristic of the adjustment servomechanism obtained by numerical simulation, and curve 2 the same characteristic obtained on an experimental basis. Servomechanism was subjected to a control voltage (V), ramp type, with frequency of 0.05 Hz.

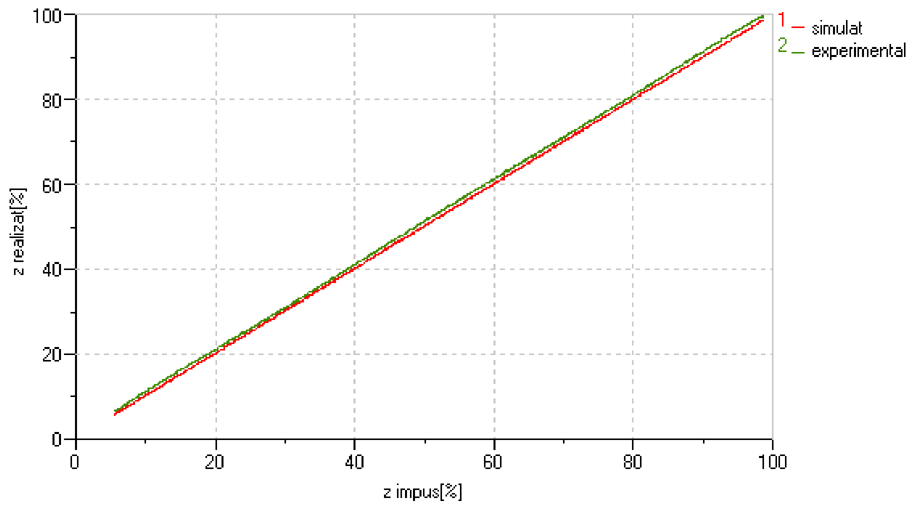
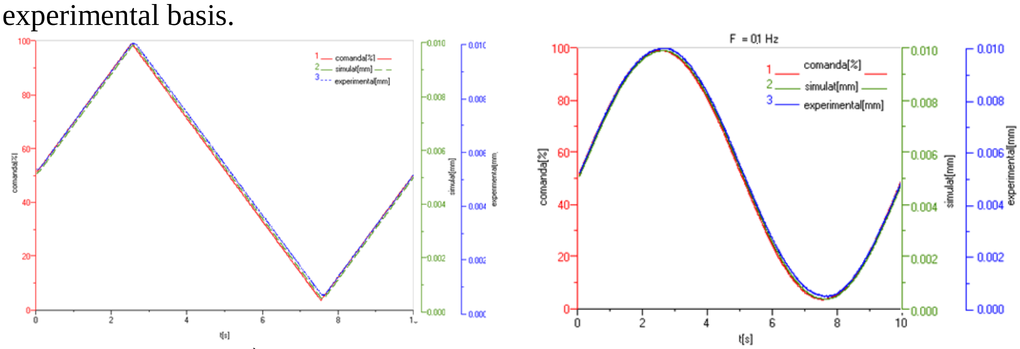


Fig. 3. Stationary characteristic of hydraulic servomechanism that adjusts capacity of pump MOOG-RKP.

In Figs. 4 and 5 curve 1 represents the control signal, curve 2 response of servomechanism that adjusts capacity, obtained through numerical simulation, and curve 3 response of servomechanism that adjusts capacity, obtained on an experimental basis.



a) b)

Fig. 4. Response of the adjustment servomechanism to control triangular, a) and sinusoidal, b) signals (f=0.1 Hz).

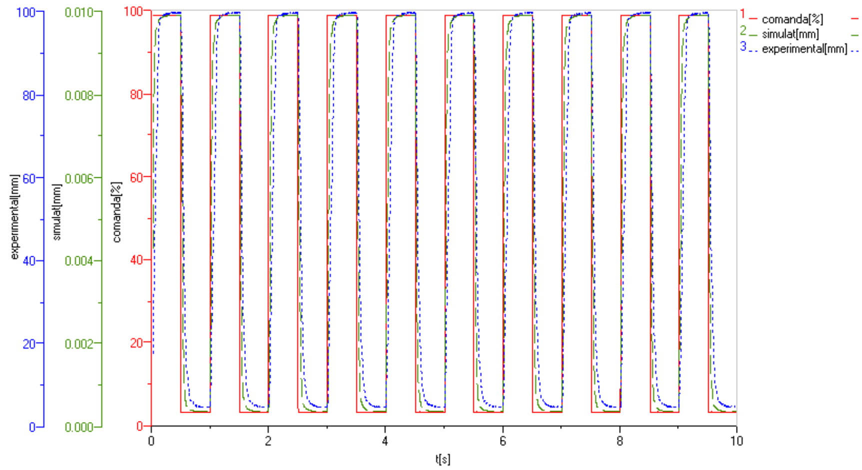


Fig. 5. Response of the adjustment servomechanism to control rectangular signal (f=1 Hz).

4. Detailed model of numerical simulation of a hydrosatic transmission; virtual interface of the adjustment model

Model of volumetric radial piston pump has been integrated to the simulation network of hydrostatic transmission. Transmission includes hydrostatic unit which operates as a pump, volumetric motor of adjustable capacity and module consisting of hydrostatic pump of fixed capacity, pressure limiting valve and block of way-valves, module which is used as hydrostatic load. The hydraulic system is controlled by the process computer NI-PXI. By means of this one various adjustment schemes of transmission parameters can be implemented. For the analyzed case a feed-forward compensator with inclusive correction has been used.

Application implemented on the digital system is a co-simulation model AMESim/ LabVIEW, model developed in AMESim by simulating hydraulic and mechanical components of the process, and the software component – the numerical adjustment part. Co-simulation process allows coupling of the software control component to the simulated model of the process for a preliminary tuning of regulator parameters, these being still used as reference sizes for the stage of fine-tuning performed on the experimental stand.

Fig. 6 shows the detailed model of numerical simulation network for mixed adjustment hydrostatic transmission, developed by means of AMESim program, and in Fig. 7 virtual interface of the adjustment model of transmission, developed using LabVIEW software and a PXI-NATIONAL INSTRUMENTS module.

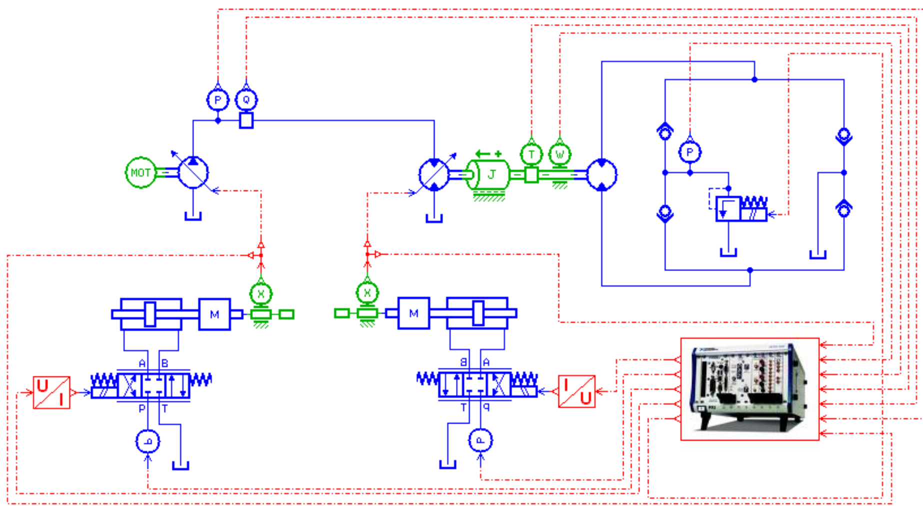


Fig. 6. Numerical simulation network of hydrostatic transmission – detailed model.

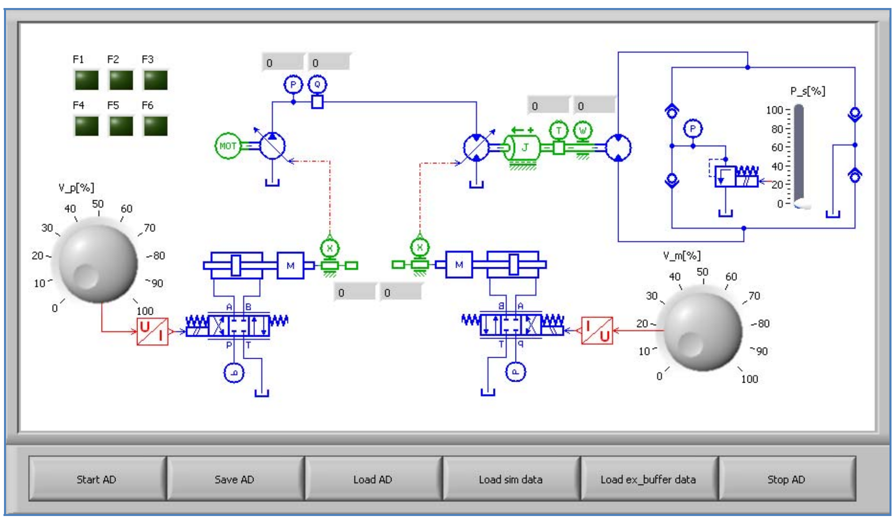


Fig. 7. Virtual interface of the adjustment model (LabVIEW / PXI).

The software application contains a module for conveying experimental results collected on the stand via the Internet using a web page. The online application also allows control of process parameters, capacity of volumetric pump, motor capacity and pressure within the load circuit. Fig. 8 shows the web interface for the adjustment model of transmission with mixed adjustment, and in Figs. 9, 10 and 11 components of the laboratory model on which experimental measurements have been performed.

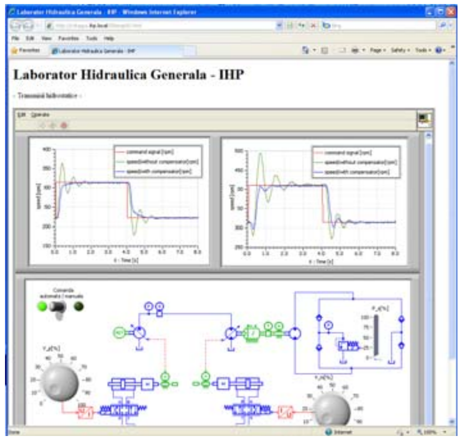


Fig. 8. Web interface of the adjustment model (LabVIEW / PXI).

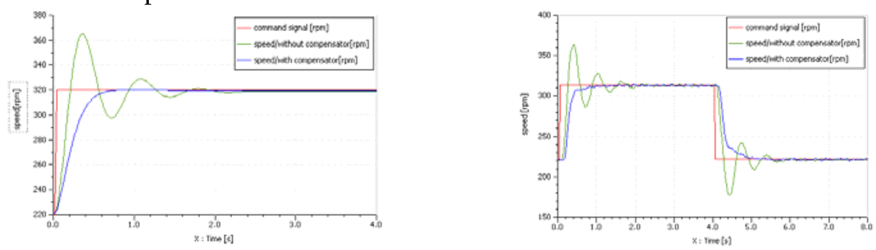
Fig. 9. Fixed pump for load simulation and Bosch adjustable motor within the secondary sector of hydrostatic transmission.

Fig. 10. Servo pump MOOG within the primary sector of hydrostatic transmission.

Fig. 11. Secondary sector of hydrostatic transmission – laboratory model.

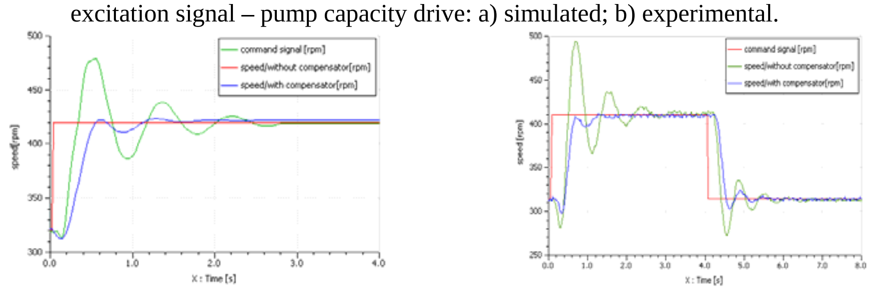
5. Validation of the adjustment model of mixed adjustment hydrostatic transmission

Validation of the adjustment model is confirmed by the shape of characteristic curves experimentally raised, by coupling LabVIEW/ PXI virtual interface to a physical model developed in the laboratory, equivalent to AMESim simulation model. One can notice comparable dynamics, theoretically and experimentally identified, of the adjustment system of hydraulic transmission. Obtaining adjustment models for other configurations of hydraulic transmissions, with primary, secondary or mixed adjustment, can be treated as a customization of this model developed.



a) b)

Fig. 12. Response of the adjustment system of rotational speed of hydraulic motor to step type excitation signal – pump capacity drive: a) simulated; b) experimental.



a) b)

Fig. 13. Response of the adjustment system of rotational speed of hydraulic motor to step type excitation signal – motor capacity drive: a) simulated; b) experimental.

Figure 12 shows comparatively the responses of the adjustment system of rotational speed of hydraulic motor Bosch within the secondary sector of hydrostatic transmission with mixed adjustment to a step-type excitation signal, when the command is applied to the hydraulic servomechanism that adjusts capacity of MOOG pump within the primary sector of transmission, responses obtained by numerical simulation and on an experimental basis, with and without error compensation.

Figure 13 shows comparatively the responses of the adjustment system of rotational speed of hydraulic motor Bosch within the secondary sector of hydrostatic transmission with mixed adjustment to a step-type excitation signal, when the command is applied to the hydraulic servomechanism that adjusts capacity of this motor, responses obtained by numerical simulation and on an experimental basis, with and without error compensation.

6. Conclusions

a) The application was performed by co-simulation, modern concept that uses simultaneously multiple modeling languages within the same simulation network.

b) Use of this method of analysis is particularly useful in the development and design stages of complex automated systems, providing a rapid solution to identify characteristics of analyzed system.
c) By using advanced modeling and experimental identification procedures superior dynamic performance can be obtained for hydrostatic transmissions.
d) Virtual interface of the adjustment model (LabVIEW / PXI) of hydrostatic transmission allows tuning of the system by successive iterations of simulations performed in AMESim, and data processing, performed in LabVIEW. It can alternatively be coupled to the laboratory physical model or to the simulation network in AMESim.
e) Web interface of the adjustment model (LabVIEW / PXI) allows remote control of hydrostatic transmission, i.e. laboratory testing of transmission also by persons outside the testing laboratory.

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