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EXPERIMENTAL RESULTS AND A DISCRETE DYNAMIC MODEL DETERMINATION OF AN ELECTRONICALLY CONTROLLED HYDROSTATIC TRANSMISSION

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ABSTRACT

The paper presents the experimental results of a research on a hydrostatic transmission with an electronically controlled variable displacement pump. A linear discrete dynamic model is identified and a model order and the z-transfer function parameters are estimated.

The mathematical model is realized trough a procedure of identification in the local operating point of hydraulic motor.

Keywords: hydrostatic transmission, electronically controlled pump, discrete model identification, z-transfer function, model order and parameter estimation

1. INTRODUCTION

The hydrostatic transmissions are widely used and well known transmission system [5-7]. Their main purpose is to transfer the mechanical input power as a mechanical output power, using a hydraulic system consisting of a hydraulic pump and motor. They are often used for their power density and capacity, accuracy, fast response and high operating efficiency. They are mainly an auxiliary system of some other system like mobile machinery and industrial process equipment and their performances are more and more important besides their energy consumption. The total efficiency could be highly improved when the variable displacement pump makes closed loop with the hydraulic motor [1]. The speed of the load is governed by controlling the flow of the pump with good response and accuracy.

2. THE PHYSICAL SYSTEM AND THE EXPERIMENT DESCRIPTION

The overall physical system consists of two subsystems (Fig. 1): the hydrostatic transmission circuit and the electronic measuring, data acquisition and processing subsystem.

The hydrostatic transmission circuit consists of an electronically controled variable displacement pump (1), a hydraulic motor (2), a charge pump (3), the pressure relief valves (4, 5) and the chock valves (6-9), as shown in Fig. 1. The pump and the motor make a closed hydraulic circuit and their drain connections are connected to the tank (10). The charge pump (3) refils the closed hydraulic circuit with additional cooled oil to keep its temperature and viscosity.

The electronic controller (11) drives the pump control servovalves and the measuring transducer, picks up the measuring data and performs the AD conversion. A test and a control computer (12) govern the testing process and execute the model identification and the estimation procedure.

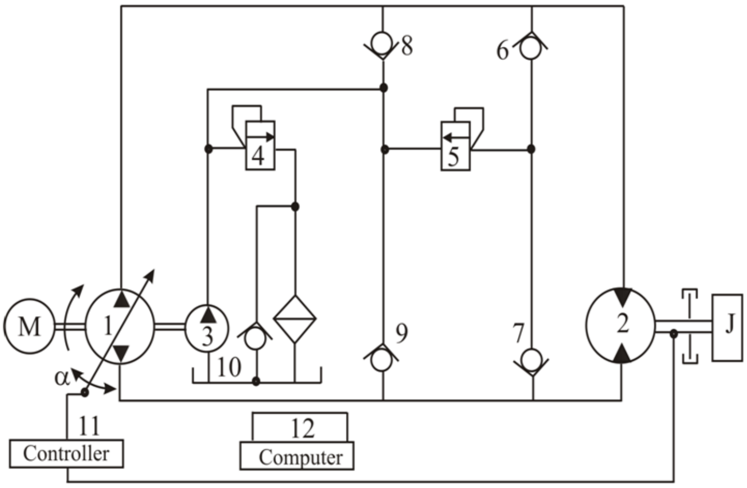

Fig. 1 The hydrostatic transmission

3. TESTING RESULTS AND ESTIMATED MODEL

The model estimation of the hydrostatic transmission is done in a general procedure of a system identification [2], such as data examination, model structure selection, model order and parameter estimation and validation.

For this paper the electrohydraulic system is considered as a SISO system. The input of the system is the voltage (u) which controls the supply pump servovalve to govern the angle of pump swash-plate motion. The output signal is the rotational speed (ω) picked up with the speed transducer on the hydromotor shaft. The system is preset at the nominal operating point A (Fig. 2), with a constant input signal U and excited too, with an additional test signal for the purpose of the system identification procedure [3].

In this work pseudo random binary sequences (PRBS) with white-noise-like properties [2] are used to excite the system. The input and output signals are shown in Figure 3.

All signals are sampled with a sampling interval of 0.01 second and the measurements are repeated. The data set for system identification is given by a 2N-dimensional vector of input-output measuring data:

$$Z^N = \{ u(1),\omega(1),...,u(N),\omega(N) \} \qquad (1)$$

where $N=600$ is the number of measuring data.

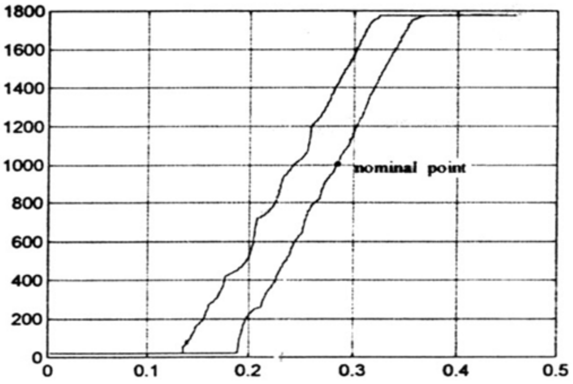

Fig. 2. The system preset at the nominal operating point

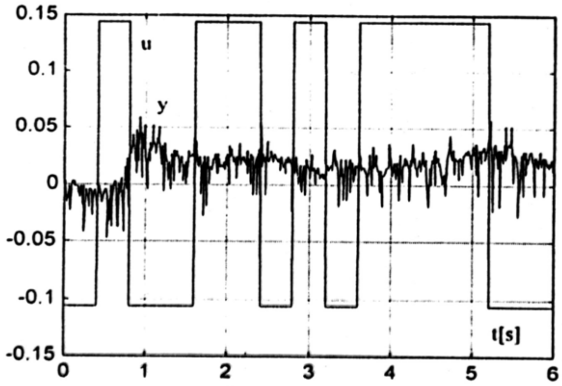

Fig. 3. The input and output signals

Using a general procedure of the system identification [3], an optimal model order $n=4$ is estimated [4] and the discrete z-transfer function is identified under the form

$$W(z) = \frac{b_1 z^3 + b_2 z^2 + b_3 z + b_4}{z^4 + a_1 z^3 + a_2 z^2 a_3 z + a_4} \tag{2}$$

Using the measuring data set Z^N, the prediction error vector $\boldsymbol{e}$, as the difference of system output ω and the model output ω_M, is computed in the next form

$$\boldsymbol{e} = \omega - \omega_M \tag{3}$$

where $\boldsymbol{\omega}$ and $\boldsymbol{\omega_M}$ are the N-dimensional vectors of the system output and model output data, respectively.

By minimizing the loss function E having the form:

$$E = \boldsymbol{e}^T \boldsymbol{I} \boldsymbol{e} \tag{4}$$

where $\boldsymbol{I}$ is the identity NxN matrix and using the last-squares estimator procedures [2], the discrete model parameters

$$\{a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4\} \tag{5}$$

are computed, and the z-transfer function $W_A(z)$ with these parameters (for constant speed $\Omega_0 = 1000\ min^{-1}$ in the nominal operating point A) is obtained in the final form:

$$W_A(z) = \frac{1}{100} \frac{0.94z^2 - 1.762z + 0.931}{z^4 - 0.2166z^3 - 0.2011z^2 - 0.2402z - 0.1956} \tag{6}$$

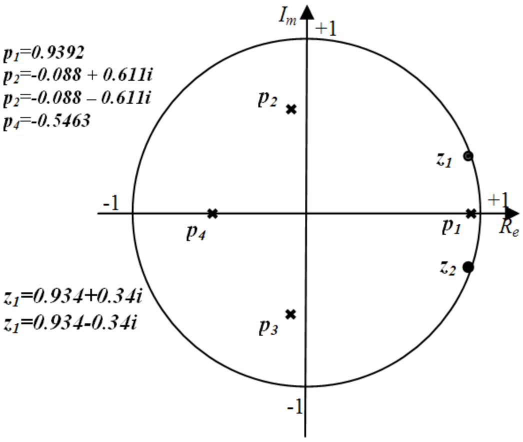

Fig. 4. the location of the poles and zeros of
the z-transfer function in a complex z-plane

Figure 4 shows the location of the poles and zeros of the z-transfer function in a complex z-plane. All poles and zeros are located inside the unit circle in z-plane. It means it is estimated the stable and minimum phase model of the system in the local operating point A. The above procedure of computing has been done by means of MATLAB soft.

4. CONCLUSION

The hydrostatic transmissions are widely used in different applications. Their operating efficiency and good performances are very important. These electrohydraulic systems are marked by nonlinear characteristic in different operating points and it is very important to know the actual dynamic properties and the model of the system in every operating conditions.

In this research is tested dynamic behavior of the electronically controlled hydrostatic transmission for the whole operating state of the output hydro motor and the local linear discrete model is estimated in the target operating points. This paper presents the experimental testing results and it estimated a linear model for one of operating points.

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