APPROACH FOR THE IDENTIFICATION OF HYDRAULIC DRIVE SYSTEMS WITH DIGITAL CONTROL ACTUATOR

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ABSTRACT

This paper shows an approach for the identification of hydraulic drive system with digital control through numerical approximation of dynamic processes. Dynamic processes in the form of transient characteristics are obtained on the basis of known from previous studies nonlinear mathematical simulation model of the experimental setup consisting mainly of two parallel loop powered, each containing three-way, two-position hydraulic digital control valve and output of pipeline. Two parallel loops driven double acting actuator. Identification is made on the basis of synthesized linear mathematical simulation model allowing to approximate with maximum accuracy the variation of velocity of the actuator at constant values of frequency of the input control signal and different values of actuators stroke.

Keywords: Hydraulic System, Digital Control, Actuator, Transient Processes, Identification

1. INTRODUCTION

The continuous development of digital hydraulics is mainly aimed at two main directions. On the one hand, the development and improvement of hydraulic fast switching hydraulic valves and other hand synthesis and analysis of systems built from these devices used for pilot hydraulic control of different size hydraulic capacities. As all contemporary engineering applications and these hydraulic systems require useful mathematical simulation models used for in-depth investigation of the influence not only of the construction parameters, but the parameters of their control. In many cases, however, the synthesis of both the newly designed system and in solving problems related to existing information is necessary to develop a simulation model, based on the obtained experimental or verified simulation data. Then resorting to means and methods of identification systems that solves the issue of the receipt of these models. In its meaning the identification provides the theoretical background and practical means when building mathematical models of systems (processes, objects) based on measured information to convert the signal in these systems. Meanwhile, the development of software products make identification methods and their instruments daily tool to address issues not only practical, but research interest.

As a consequence of a series of simulation studies [1] concerning the hydraulic drive system with digital control actuator in this paper shows an approach for the identification of the system based on already obtained transient processes of an variation of velocity of the actuator. Identification of the experimental system consists primarily in the preparation of linear mathematical simulation model for a given selection of values of time constants and transmission coefficients of its constituent units to achieve maximum approximation of the original set transitional process. Furthermore, the selection of these values itself becomes a visual approximation to (in real time) by developed optimization procedure.

The main objective is that the results of this identification to make it possible to sue for effect of transient processes on the control signal from the viewpoint of moving of the test device, which are already assessed in [2], in terms of quality of regulation. Furthermore, performance of the identification system by transient processes will serve as a basis for further research aimed at determine the transfer function of the system and hence can assess about behavior of the system by means of the frequency characteristics.

2. SCHEME OF THE EXPERIMENTAL SETUP AND SYSTEM

Fig.1 is a diagram of the simulated experimental system, which is described in detail in [2].
3. MATHEMATICAL SIMULATION MODEL OF TRANSIENT RESPONSE

Nonlinear relationships constituting the mathematical model of transient processes velocity and moving the actuator are described in detail in [1]. The mathematical simulation model is implemented in the environment of the software Matlab / Simulink, through block modeling of building experimental system (Fig. 1) units. Figure 2 and Figure 3 shows a structured model of building blocks having non-linear behavior.

Figure 1 Experimental Installation Lay-out

Figure 2 Simulation model of experimental system Matlab / Simulink [1]

Figure 3 Subsystem modeling hydraulic actuator device and measuring equipment
4. IDENTIFICATION OF THE SYSTEM THROUGH THE DYNAMIC CHARACTERISTICS

The developed simulation model of study hydraulic drive system with digital control actuator allows to measure dynamic performance simulation in the form of transient response and velocity of movement of the output implementation unit (actuator) in different design and the tuning parameters of the individual components. Previous studies analyzed the response of this type of actuator - double-acting hydraulic cylinder with equal area and relatively small sizes, for various values of the stroke and at the different frequencies of the input digital signal. Figure 4 shows transient response of the actuator at 80Hz frequency and the corresponding values of the stroke in the range 5 ÷ 20mm, taking into account performed in [2] frequency analysis of the input signal.

From the results shown graphically (Fig. 4) clearly seen that the transient response respectively at 5, 10, 15 and 20mm have fluctuating subsiding behavior. This behavior can be described accurately enough by a polynomial of the sixteenth row. This has been established from the initial approach to identification based on approximation by polynomial significantly higher (Fig. 5) and inconvenient for further working order, which requires a change of approach for the identification of the test system.

One of the approaches commonly used for the identification of systems by nonparametric transient characteristics of the object is based on the optimization method. In this sense his approach is to determine the coefficients in a particular parametric model, based on requirements from evaluations transient model (weight function) to be as close to the reference (experimentally or verified simulation) characteristic under the same conditions for forming them. In this particular case the parametric model is a linear model composed enabling optimization procedure by sequentially searching the pattern settings (gain coefficient and time constants) that implement mentioned distance. This approach is very illustrative, since it allows to be monitored in real time the variation optimized parameters with respect to the capabilities of the software used - Matlab / Simulink. For the test a hydraulic system with digital control is more
appropriate that the linear model to match the transient response of the velocity of movement of the actuator for the movement according to the power in one direction, until it reaches the preset stroke (indicated in Figure 6) in accordance with transient response of the movement (Fig. 4).

Figure 6 Transient processes of velocity

The structural diagram of a linear model is shown in Fig. 7. Another advantage of this approach is that based on the data sample throughout the corresponding iterations of the procedure identification velocity structure can be significantly simplified model by which to obtain data for identification of transition process of movement through integration. This model is shown in Fig. 8.

Optimization procedure is performed based on the method of nonlinear least-squares in the following mathematical description [4]:

$$\min \left[ f(x) \right] = \min(f_1(x)^2 + f_2(x)^2 + \ldots + f_n(x)^2),$$

where \( x \) is a vector of independent variables \( x_1, x_2, x_n \).

Figure 7 Linear model

Figure 8 Model for velocity integrating

The results of the identifications of the transition process of velocity and the variation of the parameters \( T1, T2 \) and \( k \) as a function of iterations of the procedure for different values of \( S \) stroke the actuator in the range \( 5 \div 20 \) mm, are shown in Fig. 9 and Fig. 10.

Figure 11 shows the results after integrating data from identifications on velocity, which represent the response of the actuator according to the approach adopted for identification.
Figure 9 Results of identification of velocity for different strokes of the actuator

Figure 10 Variation of parameters throughout on the optimization procedure
5. ANALYSIS OF THE IDENTIFICATION RESULTS

The analysis of the results of the identification is made on the basis the variation of throughout the cost function of the separate iterations until a local minimum of the used in this case optimization procedure based on the method of nonlinear least-squares. The variation of the cost function in form without dimensions of the different values during the stroke of hydraulic actuator device, generally indicates the deviation of the linear model from the initial time until the limit of the conditions (a local minimum) for a match between both of transient responses. Fig. 12 shows the cost function for the four cases of stroke of the actuator.

The graphic result clearly shows that the variation of cost function in logarithmic coordinates, indicating a relatively high accuracy of approximation between the predetermined by the nonlinear model and describe it based on a linear model transient response. At 20 mm stroke actuator cost function varies in the range $80 \div 0.03$, and at 5 mm stroke actuator function vary in range $12.5 \div 0.007$ and the number of iterations decreases from 15 to 10.

Quantification of this coincidence is described precisely enough for the purposes of identification with the relative error (proximity) of the cost function change between the beginning and end of the realization procedure. In this regard, we obtain $99\%$ coincidence between both of transient responses, visualized in Fig 9.
6. CONCLUSIONS

Based on this proposed approach for the identification and due to the obtained results it summarized as follows:

- Composite linear mathematical simulation model by using, on which it is possible identification of the studied hydraulic drive system with digital control actuator by means approximation of the transitional processes a variation of velocity at different constructive and the tuning parameters. Approximation is made based on an optimization procedure that allows to monitor dynamically the variation of the parameters of the linear model.
- Based on the results of identification of the system transient response velocity carried out the identification of the reaction of the actuator in accordance with previously obtained transient responses.
- The implemented approach for identification will serve as a basis for further research aimed to study the dynamic behavior of the system and it is frequency characteristics based on transfer function of a composite in this work linear mathematical simulation model by introducing corrective units to improve the behavior of the system in a wider frequency range.

REFERENCES


AUTHORS

Ilcho Ivanov Angelov received the M.S. degree in Mechanical Engineering from Technical University - Sofia in 1980. During 1980-1982, he worked as a senior constructor in factory of “Mir” Montana town (Bulgaria) in the field of hydraulic power systems. Since 1982 till now he worked consequently as an assistant, senior assistant and associate professor in Department of Hydroaerodynamics and Hydraulic Machines at Technical University – Sofia, Bulgaria. In 1991 took PhD thesis: “Research of the pilot operated two-way flow control valve by hydraulic drive system for automatically controlled forklift application”. Lecturer and experience in the field of “Control Theory and Applications of Hydraulic Drive Systems”, “Hydraulic Displacement Volume Machines and Devices” and “Hydraulic Power Control Systems”.


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