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APPLICATION OF FUZZY LOGIC CONTROLLER IN THE HYDRAULIC LUFFING SYSTEM OF THE SELF-PROPELLED CRANE JIB

1. Introduction

In hydraulic drive and control systems of the self-propelled cranes, braking valves are used to lower the load, or load-carrying structure. A hydraulic system must be supplied with the essential pressure to unlock mechanical and hydraulic locks [1]. As the velocity of the working motion increases, supply pressure increases, so that the supply energy rises. There are different solutions of the braking valves, for example with the load compensation [2,3]. These solutions make valve characteristics intependent of load and flow. This paper presents the lowering system, which is based on the overflow proportional valve applied as a braking valve (Fig.1). The overflow proportional valve is placed, where usually a braking valve is installed. Hydraulic command signals are changed into corresponding electical signals. A fuzzy logic controller was applied to control the proportional valve. A mathematical model of the system has been built, and simulation research has been carried out.

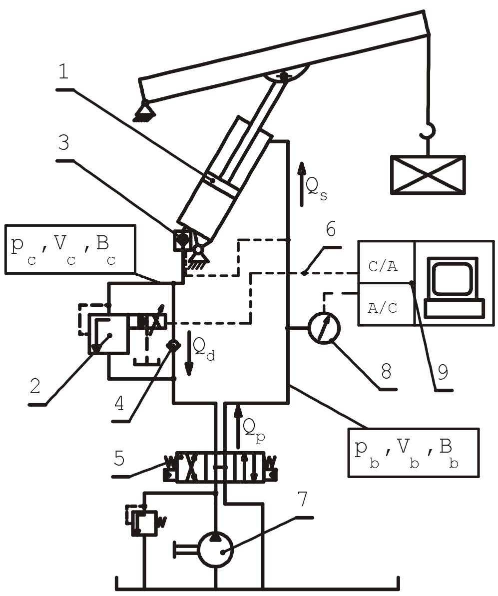

Fig. 1. Diagram of the hydraulic system changing the angle of the crane jib: 1-hydraulic cylinder, 2-proportional overflow valve, 3-controllable non-return valve, 4-non-return valve, 5-manipulator, 6-valve controlling signal, 7-pump, 8-pressure converter, 9-microprocessor system

2. Pressure Control System

The presented hydraulic system shows the strongly non-linear properties. When the PID controller was applied, there was a difficulty to achieve a stable state, thus the fuzzy logic controller has been applied (Fig.2). The pressure error signal, and the differential coefficient of this signal were used to control the system. The output signal is a change of the electromagnet force (current intensity in electromagnet) in the proportional valve.

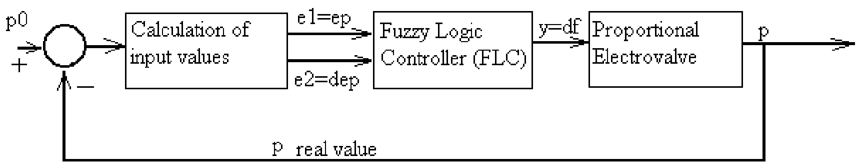

Fig. 2. Structure of the pressure regulator

The controller works in a feedback loop. The output signal is passed to the input of the controller. Calculated values of the pressure error (ep), and the difference between the current pressure value and the previous pressure value (dep) are the main data for the fuzzy controller. Fuzzy logic controller generates the output signal, which is an increment of the force acting on the electromagnet of the valve.

The fuzzy regulator has three modules: fuzzification, interference and defuzzification module. In the fuzzification module the input signals are normalized into range [-1, 1]. Then the values of the input singals are fuzzified, using the characteristic functions. In the given system there are triangular characteristic functions applied inside the range, and trapezoidal non-symmetrical ones on the edges [4].

In the interference module there is a rule database. On the basis of the affiliation rate of the input values into corresponding ranges, the rules from the database are launched. The pressure error signal was divided into five fuzzy ranges, and differential coefficient of the pressure error was divided into three fuzzy ranges. The rule database contains available output signals for all combinations of input signals, so there are fifteen rules in this system. The conclusion process allows to launch up to four rules at one time. Four affiliation rates determine the output value of the interference module.

The last module of the fuzzy logic controller is a defuzzification module. It calculates the final value of the output signal. The “Center of Sums” method was applied to receive a sharp value of the signal [4].

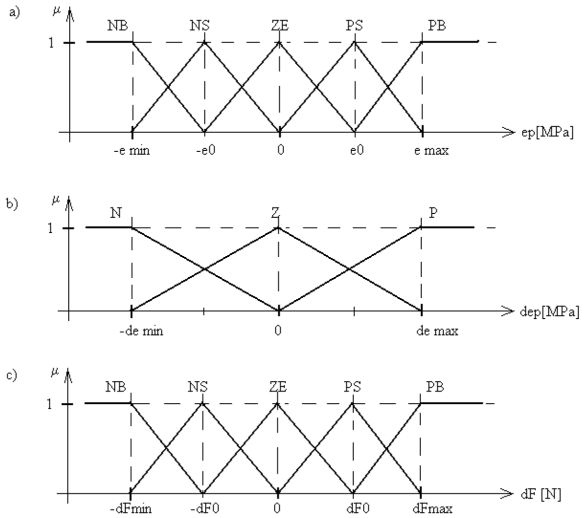

Fig. 3. Characteristic functions: (a) pressure error, (b) derivative of the pressure error, (c) force of the electromagnet

Pressure error values were divided into five intervals. The ranges of the signal are: Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS), and Positive Big (PB) (Fig.3a). Intervals haven’t got the same length, they are condensed near the zero value. Values of the derivative pressure error were divided into three intervals: Negative (N), Zero (Z), and Positive (P) (Fig.3b). Fuzzification of the output value (electromagnet force) was carried out with the use of a similar method, as the pressure error (Fig.3c).

The rule database is shown on the graphical diagram below (Fig.4). This database was applied for the fuzzy controller. For example, NB (Negative Big) value of the pressure error means that the pressure value is considerably bigger than the expected signal, and P (Positive) value of the derivative pressure error means that the signal is lower than it was during the last measurement. The conclusion is that the pressure is bigger than it should be, but it goes towards the correct value. Activated rule generates the output signal which has the value of: Negative Small (NS), so the control signal is lowered. The conclusion system consists of fifteen rules. The rules generate the output signal for all pressure error and derivate pressure error combinations.

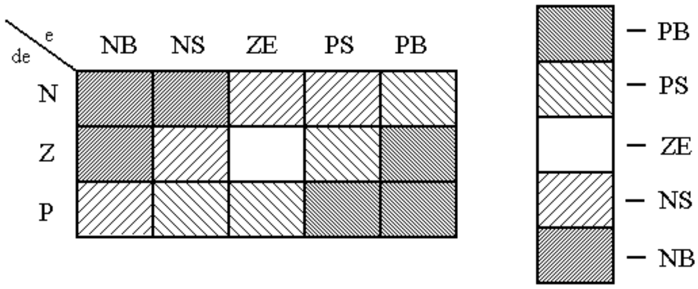

Fig. 4. Rule database

3. Summary

Simulation research was carried out using the simulation computer programme written in Borland Delphi 5.0. This programme includes a module for solving the system of differential equations, which describe the hydraulic system. The second module simulates fuzzy logic controller. It evaluates the value of the control signal.

The application of the fuzzy logic controller allowed to obtain of good static and dynamic characteristics of the system.

References:

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