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SIMULATION STUDIES OF VANE PUMP CHARACTERISTICS WITH A FUZZY CONTROLLER

BADANIA SYMULACYJNE CHARAKTERYSTYK POMPY ŁOPATKOWEJ Z REGULATOREM FLC

A b s t r a c t

This paper presents the results of simulations of vane pump static characteristics with a fuzzy controller. The controller was designed for controlling the flow rate of the vane pump. The results confirm, that the control quality is slightly better than with the PID controller, especially at low loads and rapid changes of the system load.

Keywords: *hydraulic system*, *flow control*, *fuzzy logic controller*, *vane pump*

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań symulacyjnych charakterystyk statycznych pompy łopatkowej z dodatkowym regulatorem rozmytym. Regulator zaprojektowano dla sterowania wydajnością pompy łopatkowej. Uzyskane wyniki potwierdzają jakość sterowania nieco lepszą niż regulatorów typu PID zwłaszcza w zakresie małych obciążeń i szybkich zmian obciążenia układu.

Słowa kluczowe: *układ hydrauliczny*, *regulacja wydajności*, *regulator rozmyty*, *pompa łopatkowa*

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1. Introduction

One of the most important elements of a hydraulic system is a pump. Performance characteristics of a pump should be matched to the changes of the system needs. These capabilities, maintaining the high efficiency of the system, can be provided only by a variable pump delivery. In this area piston pumps and vane pumps are commonly used. In this paper are presented results of simulation studies of a vane pump equipped with an extra controller.

Control systems used in vane pumps do not provide maintenance of the adjustable delivery in the whole range of operating pressures coming from the system load. With the increase of the pressure, the flow rate declines as shown in Figure 1. Delivery Q is not only function of control signal k but additionally depends on pressure p in hydraulic circuit. The main reasons for the flow rate drop are: an increase of leakage in the pump and the need to power the control system using the pump. Application of eccentricity measurement system, used in solutions of companies like Bosch, Berarma or Parker does not prevent this phenomenon, because in order to maintain constant performance, information about the current real flow rate is needed. For this purpose, system for measuring the volumetric flow rate in the outlet channel of the pump must be used. Furthermore, an additional pump controller based on the control signal from the flow sensor should be applied. In order to obtain a high control accuracy and maintain ease of tuning, application of a fuzzy controller (FLC) and a PID controller to compare the control quality was proposed [1–5, 7, 8].

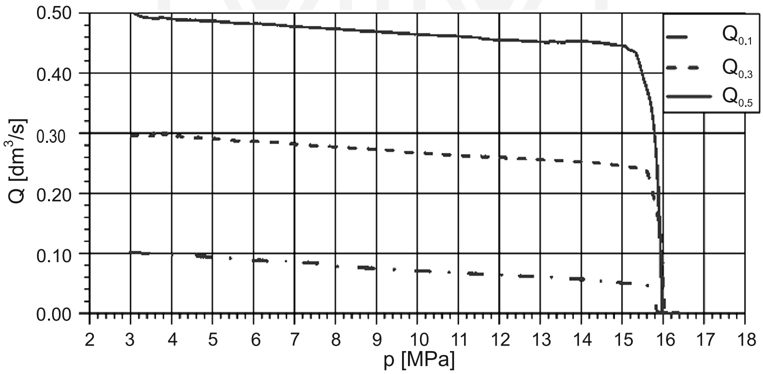

Fig. 1. Static flow rate characteristics of pump model for adjusted delivery 0.1, 0.3, 0.5 dm³/s without additional control system

Rys. 1. Charakterystyki statyczne modelu pompy przy nastawionych wydajnościach 0.1, 0.3, 0.5 dm³/s bez układu regulacji wydajności

2. Object of research

Model of hydraulic vane pump was built in 20sim program. Block diagrams created in this program are presented in Figure 2. The system consists of a supply unit 1, an additional supply of the load pressure control system 2, double-acting actuator with a rod on both sides 3, an inertial load of the cylinder 4, pressure control system and the pump 5, a load pressure control system 6, direction change system of a rod movement 7. Supply block consists of: vane pump with variable displacement 8, hydraulic fluid reservoir 9, drive pump system 10 and check valve 11. The system is additionally equipped with a controller 15 (PID or fuzzy). Rod position signal comes from sensor 17. Position signal is converted to the volumetric flow rate in block 14 and transmitted to the controller 15. Block 16 generates a control signal for the system. To control the hydraulic system, a fuzzy controller (FLC) and a digital PID controller were used. Parameters of both PID and FLC were adjusted by optimizing the ratio which involved minimization of the IAE (Integral of Absolute Error) on the test model [2, 3, 6].

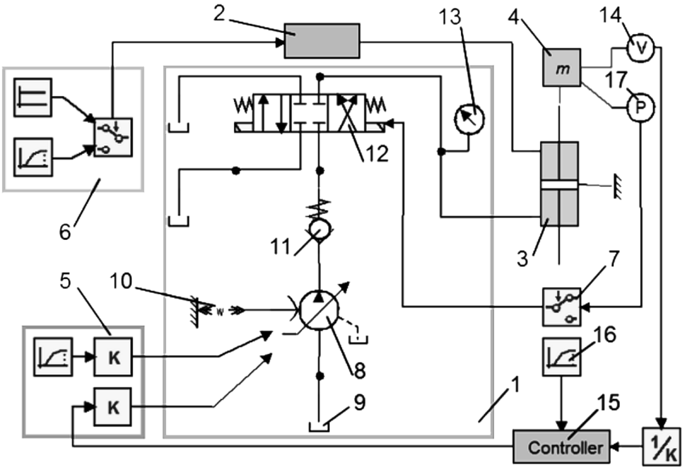

Fig. 2. Model of the system in 20-sim in the form of the block diagram

Rys. 2. Model układu w programie 20-sim w postaci blokowej

3. Development of a fuzzy logic controller

In previous studies, i.e. presented in [2], analysis of the structure of fuzzy controller based on PI controller input error e and error change Δe was carried out. In those studies, influence of the Δe on the control signal was insignificant. Furthermore, due to the large number of rules of 45, controller tuning process was very time consuming. It was observed that at low flow rates the system was characterized by a greater tendency to fall into oscillations than at the medium and high flow rates. Therefore, an alternative model of fuzzy logic with two inputs was made. In the alternative model the error change signal Δe was replaced by a flow rate signal.

At the beginning of building a fuzzification block, two input signals were adopted: a pump delivery error e and a flow rate Q. The delivery error was normalized to the range [–1, 1], while the flow rate was normalized to the range [0, 1]. In the fuzzification block, input signals were transformed into fuzzy sets using a piecewise linear membership function. The error signal was divided into seven sets, while the flow rate signal was divided into to three sets.

Diagrams of fuzzy sets of input signals are shown in Figures 3 and 4, while diagram of the output signal is presented in Figure 5.

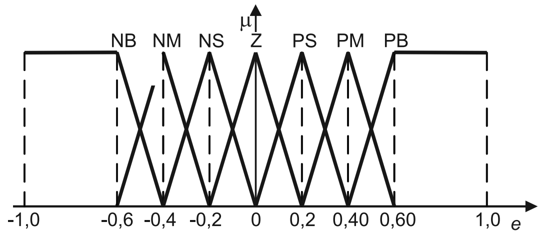

Fig. 3. Fuzzy sets of the error signal *e* of the FLC controller

Rys. 3. Rozmyte przedziały sygnału błędu *e* regulatora FLC

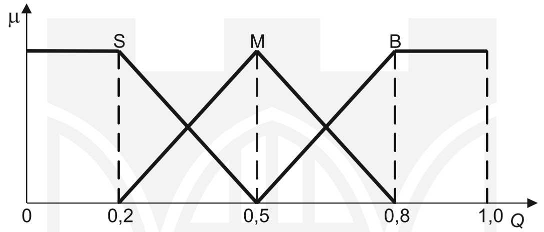

Fig. 4. Fuzzy sets of the flow rate signal *Q* of FLC controller

Rys. 4. Rozmyte przedziały sygnału wydajności *Q* regulatora FLC

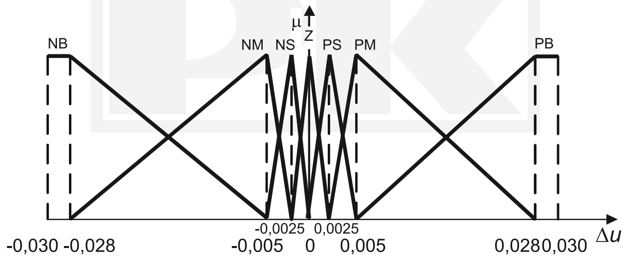

Fig. 5. Fuzzy intervals Δ*u* increase in signal of the FLC controller

Rys. 5. Rozmyte przedziały przyrostu sygnału sterującego Δ*u* regulatora FLC

4. Results of investigations

Prior to carrying out investigations, the plan of experiments was prepared. A complete plan scheme [2] was applied. Next, simulation studies of the control system performance for various values of the required flow rate at different speeds of the pressure increase were carried out. The usage of the measurement system and the controller allowed to obtain the characteristics in which the output flow rate was maintained throughout the whole range of allowable pressures for the pump. Figures 6 and 7 show constant flow rate characteristics, which were obtained using the PID and FLC, respectively.

Presented simulation results indicate, that the application of any of tested controllers allows to obtain the pump delivery closer to the required value than in the system without the regulator. The volumetric flow rates controlled by both controllers (curves: Q_{PID}, Q_{FLC}) were maintained much closer the required value than in the system with no additional control (curve Q). Furthermore, the system with a fuzzy controller was characterized by better work at higher increase speed of the pressure in the system.

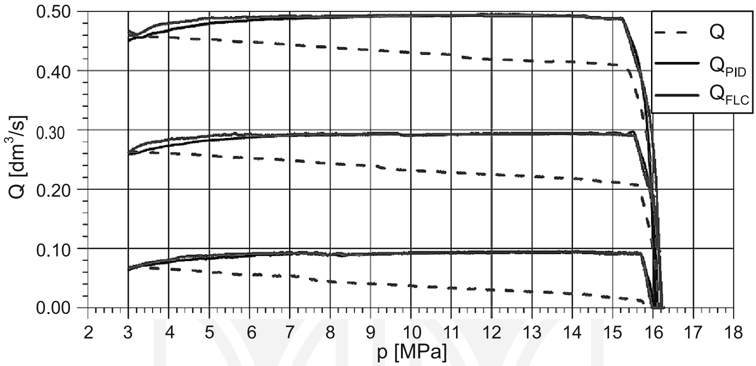

Fig. 6. Static flow rate characteristics of the pump model without the control, with PID and FLC; linear increase of the pressure at 10 MPa/s

Rys. 6. Charakterystyki stałej wydajności modelu pompy bez układu regulacji oraz z regulatorami PID i FLC; ciśnienie narastające liniowo z prędkością 10 MPa/s

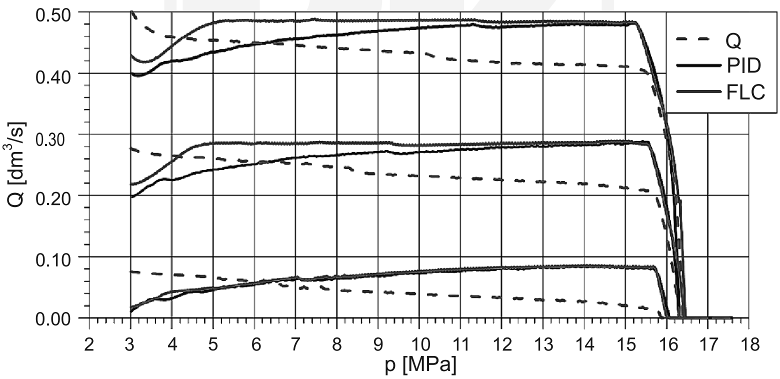

Fig. 7. Static flow rate characteristics of the pump model without the control, with PID and FLC; linear increase of the pressure at 20 MPa/s

Rys. 7. Charakterystyki stałej wydajności modelu pompy bez układu regulacji oraz z regulatorami PID i FLC; ciśnienie narastające liniowo z prędkością 20 MPa/s

5. Conclusions

Based on the obtained characteristics of vane pump, the ability to achieve improved quality control using a fuzzy controller has been demonstrated. Particularly at small and medium loads, the system with the fuzzy controller was characterized by the accurate maintenance of the required pressure value. In the case of the large load, results obtained with the FLC and the PID were similar. Additionally, it was observed during the research, that the FLC controller was characterized by increased ability to suppress the oscillations comparing to the PID.

With the ability to change the structure of the FLC input, further improvement of this controller is possible. In further studies, the behavior of the controller can be included depending on the delivery of the pump or the pressure in the system so as to improve its properties particularly for large loads.

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