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IDENTIFICATION OF PARAMETERS OF PID CONTROLLER OF AGRICULTURAL MACHINES DRIVES OPERATION

Summary

The article describes the determination and verification of regulator PID coefficients exampled by regulator which is a part of the control system of pumps for liquids. To implement the identification process we used functions available in Matlab. Obtained in the simulation result amounted to 93.59% of setpoint. The effectiveness of the method is illustrated by the graph allowing comparison of the preset value of the variable capacity of the pump operation with the results obtained from the simulation of the arrangement: the control system - the pump.
***Key words**: PID, controller, setting of coefficients*

IDENTYFIKACJA PARAMETRÓW REGULATORA PID STERUJĄCEGO PRACĄ NAPĘDÓW W MASZYNIE ROLNICZEJ

Streszczenie

W artykule przedstawiono opis wyznaczenia i weryfikacji współczynników regulatora PID na przykładzie regulatora w układzie sterującym pompy do substancji płynnych. Do realizacji procesu identyfikacji zastosowano funkcje dostępne w środowisku Matlab. Otrzymany w procesie symulacji wynik wyniósł 93,59% nastawy. Skuteczność metody zilustrowano za pomocą wykresu umożliwiającego porównanie zadanych zmiennych wartości wydajności pracy pompy z wynikami uzyskanymi z symulacji pracy układu: system sterujący – pompa.
***Słowa kluczowe**: PID, regulator, nastawy współczynników*

1. Introduction

Modern agricultural machines increasingly are equipped with electronic control systems. These machines use a number of sensors recording the current physical condition of the device. Thanks to systems of automatic control and the information obtained from the sensors, it is possible to control the individual drives. Regulators are elements belonging to the control circuit. Their function is to generate a suitable control signal so that the controlled object behaves in a desired way, for example, bringing the object to a specific state or improving the unfavorable properties of the object. The controller can also improve dynamics (for example, the engine will sooner achieve the desired speed). Its inappropriate use can lead to instability in the control circuit. Most frequently, the controller goal is to keep the output value at a certain level, called the setpoint. PID controllers are widely distributed and used in industrial control systems. They meet the needs of approximately 90% of all installations of automation [2].

2. The principle of operation of the PID controller

Controller type should be chosen individually for given system, depending on the complexity of the control and on control mode as well. An important issue is to choose properly parameters, since both too small and too large values do not allow the desired quality regulation. For small setting, system can too slowly respond to a signal change and not reach a specific value within a suitably short period of time. The overshoot can lead to instability of the system. In response we obtain non faded oscillations or chaotic values. As a result, it can lead to damage to the whole team. The calculation algorithm of PID regulator contains three separate fixed parameters and therefore is sometimes called a regulator with three members: proportional, integrating and derivative, marked off [2]:

Kp - gain, called the proportional band,

Ti - doubled time is the time required for doubling the output signal values in relation to the initial signal caused by the proportional action, it causes integral effect,

Td - Anticipation time, after which the signal associated with proportional action will be levelled with the signal deriving from the differentiate.

Figure 1 contains a block diagram of used automatic control. This system consists of a comparator, a regulator, actuator (engine), the controlled object and a sensor (flowmeter). Element comparator calculates the difference between the value of preset signal w(t) and the value of the signal v(t) obtained by the closed loop feedback via the measuring element measuring the output signal y(t).

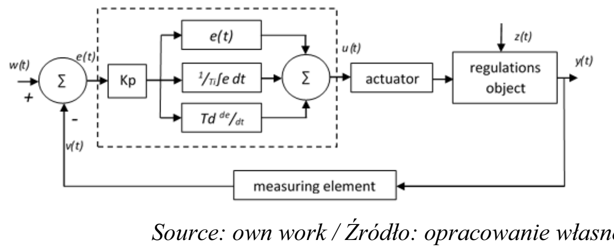

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Fig. 1. Block diagram of the object control by a PID controller

Rys. 1. Schemat blokowy sterowania obiektu z wykorzystaniem regulatora PID

The error e(t) is transmitted to the controller, which using the coefficients, determines the control signal u(t) of the actuator, thus affects object with the use the so-called extortion. Adjustable object can be affected by disturbance z(t).

3. Construction of regulation system

The solved problem concerned the control system of the pump in applicator of liquid fertilizer type EM to the soil. The purpose of regulation system was to maintain a constant dose of fluid per unit area taking into account variable linear speed of the machine. Therefore, the measuring wheel to measure the actual speed was installed. A membrane pump was the controlled system. It is a pump used to dispensing a liquid fertilizers. It is used in various kinds of sprayers and soil-applied applicators. The pump was connected to the DC motor, powered from a 12 V battery. It is shown in Figure 2. In the figure we can see also flow-meter acting as sensing element, through which the controller receives information about the current flow, allowing the implementation of feedback.

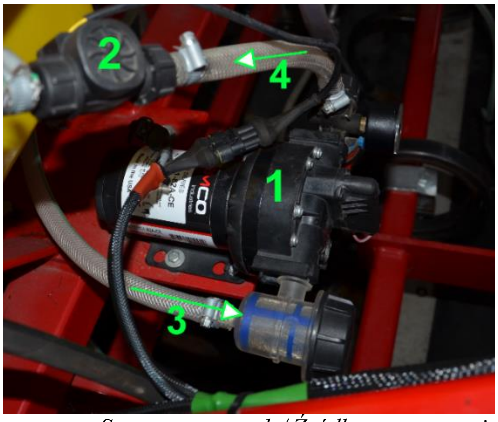

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Fig. 2. The pump and components of the control system: 1– membrane pump; 2– flow-meter; 3– the suction pipe; 4– a discharge pipe

Rys. 2. Pompa oraz elementy wchodzące w skład układu regulacji: 1– pompa membranowa; 2– przepływomierz; 3– przewód ssący; 4– przewód tłoczący

In Figure 2, there is indicated the direction of sucking the liquid from the tank and the direction in which the liquid is pumped. The regulation system (Fig. 3) was designed to control unit controller.

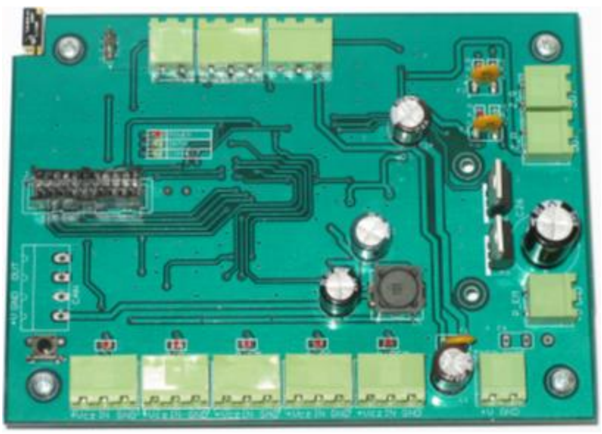

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Fig. 3. Driver control system

Rys. 3. Sterownik układu regulacji

The control program of a pump has been implemented in the controller. Informations on the current flow and values of machine speed also are transmitted to the controller.

4. The concept of the solution

In order to determine the causal model that reflects the dosing process behavior, it was necessary to carry out an identification experiment. The aim of the experiment was to collect data describing how the examined system acts under the influence of external influences. This was done by observing the output values when the analyzed system was stimulated by known values of input signal. To proper pump motor control, modulation of pulse width (PWM) in the range (0-3600) was used. It is a method of adjusting the current or voltage signals, with constant amplitude and frequency, which consists in changing the duty ratio of the signal [1]. The setting value of PWM determine the percentage of current capacity. The setting value of PWM determines the percentage of current efficiency. The value 3600 represents 100% of current efficiency which controls pump operation. In the first stage of the experiment, work flow of the pump was controlled by values of input function increased by steps of value 200 units in the range 0-3600 in a fixed time interval (Fig. 4a). At the same time, the response was recorded (Fig. 4b). As you can see in Figure 4, the value of system answer increases while increasing extortion value.

Then, based on the results of the identification experiment, the choice of the type and form of the model was done. The mathematical model necessary to predictive simulation of dispensing system was based on the transfer function. In the literature, the process of model selection is called estimation process [5]. The resulting waveform was used as parameters of *ident* function, whereby the transfer function was determined.

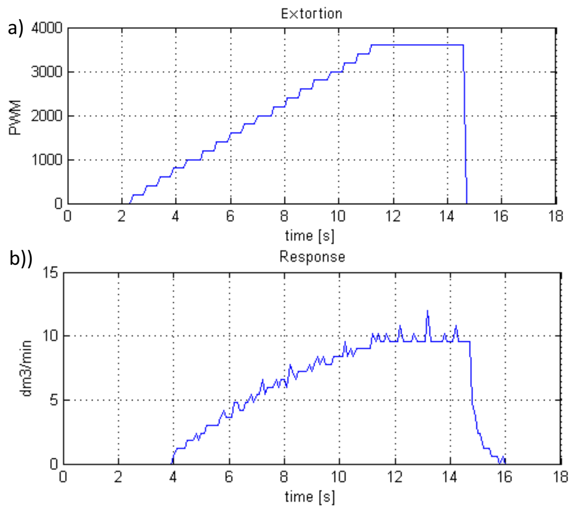

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Fig. 4. Graphical representation of data entered into the procedure Matlab; a) extortion; b) system response

Rys. 4. Graficzne przedstawienie danych wprowadzonych do procedury Matlaba; a) wymuszenie; b) odpowiedź układu

It is a tool of Matlab environment, which allows the identification of parameters of dynamic systems on the base of the measured input and output data. Parameters identification uses the established form of transfer function - the user specifies the number of zeros and poles of the system.

The process of finding the values of model parameters by means of the function *ident* from System Identification Toolbox consists in minimizing loss function describing the deviation of output values obtained on the basis of measurements and results from identified model. To conduct the identification calculations the test function was used. In order to minimize the loss function it uses a non-linear optimization algorithm [3].

After identifying and obtaining coefficients of transfer function describing the operation of the dispensing system (pump), we carried out a verification of the obtained results. It consisted in comparison of the actual response of the system with simulation results obtained on the basis of the determined transfer function. Compliance was achieved at the level of 86.75%. These waveforms are compared in Figure 5 where a value of 10 000 imp min^{-1} is equivalent to 10 dm^3 of water.

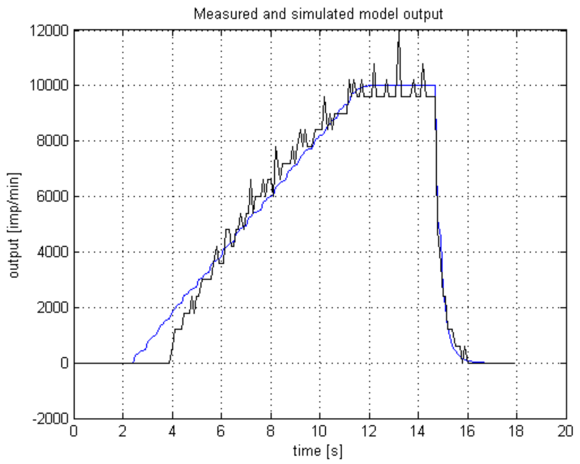

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Fig. 5. Comparison of the measured response of the pump with the simulation results

Rys. 5. Porównanie zmierzonej odpowiedzi pompy z wynikiem obliczeń symulacyjnych

In the next stage, in the Simulink system [4] (Matlab module), a mathematical model of the regulator and controlled facility (pumps) working in closed loop (shown in Figure 6) was developed. In order to determine sought controller parameter settings Ziegler-Nichols method was used. It involves measuring the size of the oscillations. In this method, you must designate critical to strengthen the Kc of system and the oscillation period Tc. For this purpose, we used developed mathematical model.

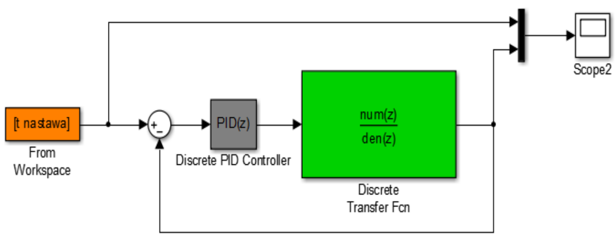

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Fig. 6. The mathematical model in Simulink

Rys. 6. Model matematyczny w Simulink

To determine the critical circuit gain Kc assumed zero values for the coefficients Ki and Kd, and the proportional coefficient Kp was increased to the point where the output signal oscillates with a constant amplitude. The value of the proportional element is determined by the critical circuit gain Kc = 1.0255 in this case. Figure 7 shows the system step response during the designation of critical strengthening of the system. The value of the oscillation period Tc = 0.4 s was read from the graph [2].

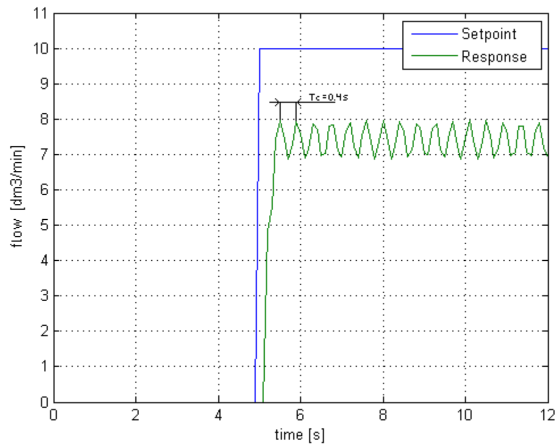

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Fig. 7. The waveform of signal during the designation of critical strengthen Kc

Rys. 7. Przebieg sygnału podczas wyznaczania krytycznego wzmocnienia układu „Kc"

The values of the PID set by the formulas shown in Table 1.

Table 1.Tuning method of Ziegler-Nichols [2]

Tab. 1. Dobór nastaw metoda Ziglera-Nicholsa [2]

	Kp	Ki	Kd
P	0.5 Kc		
PI	0.45 Kc	1.2 Kp / Tc	
PID	0.6 Kc	2 Kp / Tc	Kp Tc / 8

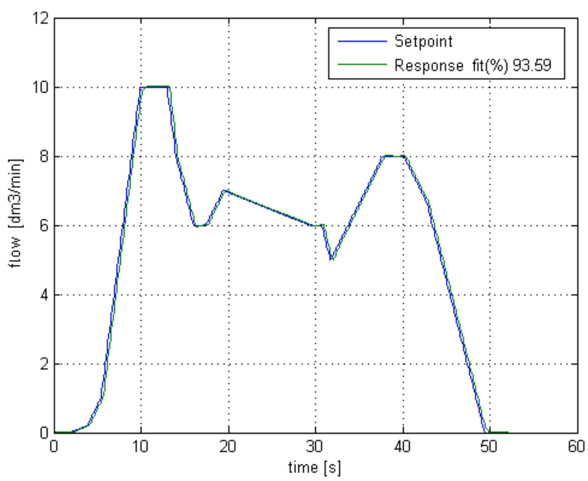

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Fig. 8. Comparison of pump efficiency set values with the results obtained from simulation of the pump

Rys. 8. Porównanie wartości nastaw wydajności pompy z otrzymanymi wynikami symulacji pracy pompy

The control system should react to a change in dosage resulting from the variable speed of the agricultural machine and various set point values. To test this, the simulation was carried out, in which the course of flow in the range of 0-10 dm^3 min^{-1} was the input signal. In the model of PID controller obtained earlier coefficients were used. Operation of the dispensing system is described using the transfer function determined earlier. Graphic comparison of the setpoint values with the results of simulation calculations of the pump is shown in Figure 8.

As the chart shows (Figure 8), the control system responds correctly to setpoint values change, with a view to their alignment, thus minimizing the error value. This system also has a certain inaccuracy at level 6%. It is so small that the operation of regulation system was found correct.

5. Summary

The presented method of determining coefficients of the regulator proved to be an effective solution. Accuracy of the result obtained from the simulation in relation to the setting amounted to 93.59%, which is a satisfactory result. Determined in this way the coefficients were introduced into the control algorithm implemented in the physical driver of the dispensing system. After laboratory verification of the control system on the real object and affirming its correct operation we received functional controller, which precisely and reliably dispenses the optimum dose of biological or chemical agents.

6. References

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