PID controller in the steering unit with the Ackermann principle

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Abstract. The scientific article offers a model of a commutator motor control based on the study of actual data received from the shaft position sensor. As a result of theoretical research, the feedback control of the electric motor was realized. The tractor steering system was studied to adjust the steering shaft position correctly in real time. It should be noted that the error of angular velocity control was less than 2%.

1. Introduction
A modern steering system of a robotic tractor provides manual and automated control along parallel (straight) or curved paths. Simplicity and reliability make automatic control attractive for precision farming [1-6]. Now due to additional settings for steering systems automatic control is available for practically all popular models of agricultural machinery. The vehicle will automatically maintain its best position along the desired route. At the end of the path, the operator can easily disable the automatic steering system (by pressing an additional pedal or a button) and make a turn manually. Then the operator gives the autopilot a command (by pressing the pedal or button) and the automatic system quickly brings the tractor to the desired path. Automatic driving mode switches off automatically in case of failures or significant deviations in technological process in crop production.

One of the problems of mechatronic systems operating in aggressive environments is the short life of feedback systems [7, 8]. One of these systems is the feedback system in the steering mechanism. The solution to this problem is to use electric motors with an encoder based on the Hall Effect. The weak point in controlling such a system is turning the motor shaft to the desired angle [9]. The system’s failure makes the steering wheel rotation control and determining the movement direction impossible [10, 11].

The purpose of this work is to study algorithms for automatic adjustment of the PID controller coefficients for controlling the commutator motor.

2. Materials and methods
To solve this problem, you need to use the PID controller. The function describing the work of the PID controller consists of three components – proportional, integral and derivative parts (formula 1).

\[ U(n) = K_p E(n) + K_i \text{discr} \sum_{k=0}^{n} E(k) + K_d \text{discr} (E(n) - E(n - 1)) \]  \hspace{1cm} (1)

Mathematical meaning:
the proportional part of $E(n)$ is proportional to the output value of the controller and the deviation of the system; the integral part $\sum_{k=0}^{n} E(k)$ - the sum of all deviations of the system from the required value; the derivative part $(E(n) - E(n - 1))$ - in the difference between two adjacent deviations of the system [12].

The PID controller has three coefficients that affect the impact "force" of a particular part of the controller. To simplify the selection of coefficients, you can use auto-selection of coefficients. There are several methods used in algorithms for auto-selection coefficients. One of these methods is the "relay" method [10, 12], which has the following algorithm (figure 1):

- we send a control signal and wait for the value from the sensor to stabilize;
- we change the signal by a certain value ("step");
- we wait for the given period and change the signal by the same "step", but in different direction;
- we start to oscillate the system - when the value from the sensor passes the stabilization value, the signal switches again;
- we analyze the oscillation period and its amplitude; we calculate the recommended coefficients based on these data.

![Image](image_url)

Figure 1. Illustration of the auto-setting algorithm.

3. Results and discussion
The obtained results of function of the algorithm for automatic calculation of the coefficients: $K_p = 0.1$; $K_i = 0.05$; $K_d = 0.01$. 
Figure 2. Readings of actual angular velocity at a given value of 200 degrees/sec.

The graph analysis (figure 2) shows that the derivative coefficient must be reduced to remove unwanted oscillation of the system.

Figure 3. Readings of actual angular velocity at a given value of 50 degrees/sec.

The graph (figure 3) shows that the system is no longer oscillating. The next step is to test the system at a considerable setting change. This step will allow you to analyze the coefficient of the integral part.

Figure 4. Comparison of the actual angular velocity value when changing the setting from 50 to 800 degrees/sec with a different coefficient Ki.
The graph (figure 4) shows that increasing the integral part coefficient from Ki = 0.05 to Ki = 0.03 greatly increased the system response to a considerable setting change.

4. Conclusions
A model of a commutator motor control was developed based on the study of actual data received from the shaft position sensor; as a result, the control of the electric motor with feedback was realized. In practice, this system can be used, for example, in tractor steering to adjust the steering shaft position correctly in real time. It should be noted that the angular velocity control error was less than 2%.

Acknowledgment
The article was prepared under the financial support of the Russian grant Chuvash State University named after I.N. Ulyanov.

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