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# Estimation Of The Accuracy Parameters Of Automatic Regulation Of The Flow Of Bulk Materials On Mobile Vehicles Under Random External Influences.

**Sergei Vladimirovich Mashkov[1]*, Mikhail Alexandrovich Kuznetsov[1], Marat Rafailevich Fatkhutdinov[1], Tatyana Sergeevna Gridneva[1], and Igor Viktorovich Yudaev[2].**

[1]Samara State Agricultural Academy, Uchebnaya str. 2, Kinel 446442, Samara Region, Russia
[2]Azov-Black Sea Engineering Institute Federal State Budget Educational Institution of Higher Education "Don State Agrarian University", Lenina str. 21, Zernograd 347740, Russia

## ABSTRACT

In determining the requirements for the accuracy of control, the duration of the control period is justified, in relation to which the specified accuracy must be maintained. As a theoretical prerequisite for analyzing the quality of control under the influence of a stochastic disturbance Q (t), the nature of the change in the value of the standard deviation of the volume of material in consecutive sections of the flow over time intervals Δt is considered. The optimum value, from the point of view of the quality of adjustment of the working section, is considered under the condition that a given function is fed to the inputs of the system $Q_{pre}$ (t) and random signal Q(t). The recommendations for the use of converters with small differentiation time $T_d$ are substantiated, which will allow to expand the bandwidth $\omega_b$.

**Keywords:** bandwidth, quality regulation, automatic control, adjustable feed, bulk materials.

**Corresponding author*

## INTRODUCTION

At present, precision farming technologies are widely used in world agriculture, which imply an individual approach to the processing or application of fertilizers of small individual sections of the field, depending on their initial state [1, 2]. The differentiated application of mineral fertilizers allows, according to the data received in real time (on-line), or on the basis of a preloaded map of the field characteristics (off-line), to apply optimal fertilizer doses depending on their need in one or another section of the field, by changes in the supply of fertilizers with the help of automatic devices and systems [3, 4, 5]. In this case, the operation of automatic devices should be based on the use of the most effective control algorithms for the controlled supply of fertilizers, the search for such algorithms is carried out with the improvement of automatic control systems.

When developing automatic systems for this purpose, one of the most bottlenecks is the step of converting the output signal into a change in the flow of matter. The conversion of the low-power output signal of the controller into a change in the flow of matter, regardless of the physical nature, is realized by multi-stage circuits containing local feedbacks. There are also various problems related to the technological process itself, as well as technological equipment (regulating and working bodies of automatic systems). Often, as actuators of automatic control systems, such technical means are chosen that, in their characteristics, not only do not improve the quality of control, but introduce additional errors, nonlinearities, delay, etc. [6].

Another reason for the variability of flow is the irregular collection of bulk material from the feeder-feeder, due to the dispersion of physical and mechanical properties, as well as random mechanical influences, for example, shocks accompanying the operation of machinery and the movement of the unit.

The task of the research is to determine the theoretical prerequisites for improving the quality of regulating bulk material (fertilizers), in order to maintain the supply of a given amount of material G (t) with deviations of not more than ± Δ, given for time intervals Δt, which would guarantee the stability of the automatic differential fertilizer application system.

## MATERIALS AND METHODS

Figure 1 shows the electric drive circuit of the developed automatic device for differential fertilization [5]. The on-board computer reads the data stored in the electronic card and generates commands for controlling the electric drive of the automatic device.

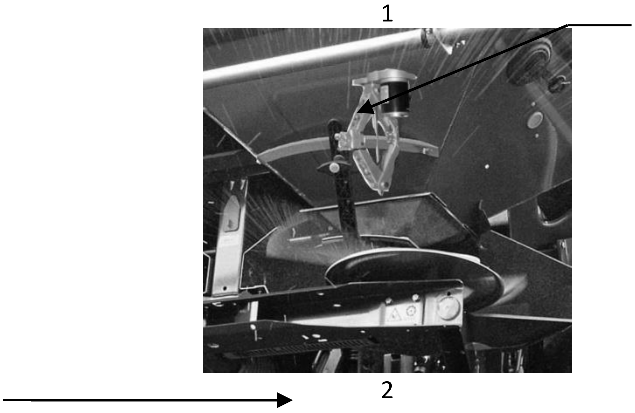

**Figure 1: Electric drive of an automatic device for differential fertilization:1 – reversible drive motor with gear;2 – diamond-shaped mechanism for moving the damper.**

The task of automatic control of the controlled flow of bulk materials is to provide flow with a controlled flow in order to maintain the supply of a predetermined amount of material G (t) with deviations of not more than ± Δ given for time intervals Δt [6].

$$G(t) = \int_t^{t+\Delta t} Q(t)\,dt, \qquad (1)$$

$$\int_t^{t+\Delta t} Q(t)\,dt - \int_t^{t+\Delta t} Q_{pre}(t)\,dt \le \pm\Delta, \qquad (2)$$

where $Q(t)$ – realization of the flow value in the interval $t_i$ - $(t_i + \Delta t)$;
$Q_{pre}(t)$ – flow setpoint;
Δ – allowable deviation.

To determine the theoretical prerequisites for analyzing the quality of regulation under the influence of a stochastic perturbation Q (t), we consider the tendency of a change in the value of the standard deviation of the material volume in consecutive sections of the flow in time intervals Δt. Assuming that the spectral density of the deviations S (ω) = $A^2$ (white noise) [7]:

$$\sigma = \sqrt{\frac{A^2}{\pi}\int_0^\infty \left(\frac{2Sn\frac{\omega\Delta t}{2}}{\omega}\right)^2 d\omega} = A\sqrt{\Delta t}, \qquad (3)$$

It is obvious that with increasing Δt the value of the coefficient of variation ν, which is used to estimate the accuracy, will have the form [8]:

$$\nu = \frac{A}{Q_{av}\ \sqrt{\Delta t}}, \qquad (4)$$

where $Q_{av}$ – average flow rate;
$A$ – random value.

## RESULTS AND DISCUSSION

Such an estimate of the Δt scale is in good agreement with the experimental data. When such a signal passes through an inertial link with K = Δt and T = 0.5 × Δt, the same result is obtained:

$$\sigma = \sqrt{\frac{1}{\pi}\int_0^\infty \left(\frac{K}{\sqrt{T^2\,\omega^2+1}}\right)^2 S(\omega)d\omega} = A\sqrt{\Delta t}, \qquad (5)$$

The identity of the results (3) and (5) makes it possible to use approximating values of the transfer functions for the response of control systems to random perturbations.

Proceeding from formulas (3), (5) it can be concluded that when assigning requirements to the accuracy of regulation, it is necessary to justify the duration of the interval, in relation to which a given accuracy should be provided [5].

The analysis of the quality of regulation for a stochastic disturbance is made provided that the system is stable. Consider the structural diagram of our system (Figure 2).

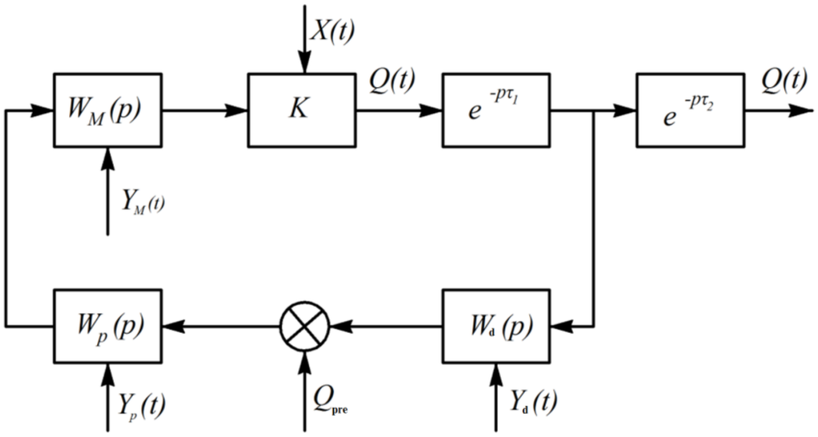

**Figure 2: Structural diagram for adjusting the working cross-section of the dispenser of an automatic device for differential fertilizer application**

The optimum choice, from the point of view of the quality of the adjustment of the working cross-section, should be considered under the condition that a given function is fed to the inputs of the system $Q_{pre}$(t) and random signal Q(t).

When passing a random signal through a system with a transfer function [5]

$$W(p) = \frac{Ke^{-p\tau}}{T_p+1}, \tag{6}$$

there is a significant weakening of high-frequency components. To characterize the degree of attenuation, it is necessary to use the effective bandwidth:

$$\omega_b = \frac{1}{W^2\ (0)} \int_0^\infty |W(J\omega)|^2\ d\omega = \frac{\pi}{2T_d}, \tag{7}$$

Signals with ω >$\omega_b$ practically do not pass through the system and do not affect the process. Thus, under the conditions set, $\sigma$ at a given $\Delta t_{pre}$ it is necessary that:

$$T_0 \ll \Delta t_{pre} \frac{D_{pre}}{D_f}, \tag{8}$$

where $\Delta t_{pre}$ –given time interval at which the variance is not greater than $D_{pre}$;
$D_f$ – variance at the same interval without auto-correction.

At high requirements to the accuracy of dosing, corresponding to formula (2) and at $\Delta t_{pre} \leq 10\frac{\pi}{\omega_f}$, as can be seen, it is necessary to use transducers with small values $T_d$ (time of differentiation), which will allow us to expand $\omega_b$. Then, in order to comply with condition (2), it is necessary to increase the speed of other links, which will lead to an increase in $K_o$ $K_p$ and a decrease $\frac{T_i}{\tau}$ and as a result, to a decrease in the stability margin of the system. However, the value of τ in our scheme is the interval through which the regulating effect affects the flow of material. Then, to ensure condition (2), it is necessary that $\tau \ll \Delta t_{pre}$. The effective bandwidth in this case will be:

$$\omega_b = \frac{\int_0^\infty \left(\frac{85n^2\frac{\omega\tau}{4}}{\tau\omega^2}\right)^2 d\omega}{\left(\frac{\tau}{2}\right)^2} = \frac{4\pi}{3\tau}. \tag{9}$$

Comparison of (7) and (9) shows that in the latter case, the effective bandwidth is 2.5 times larger. This circumstance is very important for the solution of the task at hand.

## CONCLUSION

In conclusion, we note that the tendency to change the value of the root-mean-square deviation of the material volume in consecutive sections of the flow for time intervals Δt is considered as a hypothesis of the analysis of the quality of regulation under the influence of the stochastic perturbation Q (t). The estimation of the quality of the working cross-section adjustment should be determined provided that a given function $Q_{pre}$ (t) and a random signal Q (t) are fed to the system inputs. When assigning requirements to the accuracy of system regulation, the duration of the interval through which the regulatory influence affects the flow of material with respect to which a given accuracy is to be provided is justified. It is necessary to use transducers with small differentiation time $T_d$, which will allow to extend the bandwidth $\omega_b$. Effective bandwidth, which guarantees the stability of the system, will be $\omega_b = \frac{4\pi}{3\tau}$.

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