SIMULATION OF IMPACT SENSORS FOR PRECISION AGRICULTURE

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Abstract. The system of precision agriculture is based on a precise and targeted application of specific measures in the exact spatial arrangement. This method, however, can not only meet the traditional equipment of machines, but provides a scope for more complex control structures. Such structures are systems that process the input information and make the action of the output. The input blocks of the control system are sensors that convert, in our case, the electrical quantity of physical quantity. The value can be change in the distance, change the size of forces, acceleration, pressure, speed, etc.Various types of sensors that expand the opportunities for application, regulation, measurement and recording of data in technology lines are used in the precision agriculture system. Already for a longer time, the machine sensitive technique has not been limited just to contact measurement but has been aimed at contactless information processing. A control system allows controlling machines on broader basis. The article shows impacts and practical implications of imperfect measurement of input variables on machine behavior. In the MATLAB Simulink is a simulation of the influence sensing element. The paper shows the need to pay attention to the regulatory units and input systems of the control system.

Keywords: mechanical inverters, sensor applications, influence on sensor operation, measuring element.

Introduction

The input blocks of the control system consist of sensors which convert a physical variable into an electric variable.

The input variable is sensed more or less in a contact way. Other sensors or measurement devices may be realized by image processing cameras. That is used, e.g., in guiding a machine into a row, operations of automatic sorting, as well as in other operations where detection and change of image can be used. The camera system has a number of advantages, but it comes up against some considerable difficulties, e.g., changed lighting intensity, change of reflectance of the investigated material, impact of humidity, etc. This restriction makes the system inapplicable in a number of applications, in particular agricultural ones [1].

In the control system, the obtained information (the measured variable) is one of the most important parts, since without precisely measured data no precise intervention by control elements would be possible. Attention should not focus just on electric parts of the input blocks, but it must also focus on mechanical transducers located in coupling with the contact sensor; a defect of this part of the device is quite likely to impact other parts of the system. For example, friction in the hinged mounting will affect the inertia of the system and thus the quality of the transmitted information.

These problems are addressed in particular in agriculture, where working conditions are often worsened, e.g., due to dust, increased humidity and vibrations.

Materials and methods

Sensors and converters

Mechanical converters are a part of measuring elements which are in direct contact with the measured object. They include converters of linear movement into rotating movement or of pendulous motion into rotating movement. An example of a mechanical converter is shown in Fig. 1, which depicts sensing of the swiveling angle of the swivel of inclined conveyor (reaping/mowing adapter housing) [2].

The next example (Fig. 2) illustrates a mechanical converter of the height of the mowing adapter which also consists of a lever element and an adjusted segment moving over the ground surface. The mechanical system appears to be a potential source of errors, while adverse conditions bring about error states of the evaluation system. A failure condition may occur when the mechanism grating is clogged with cropping and soil deposits.

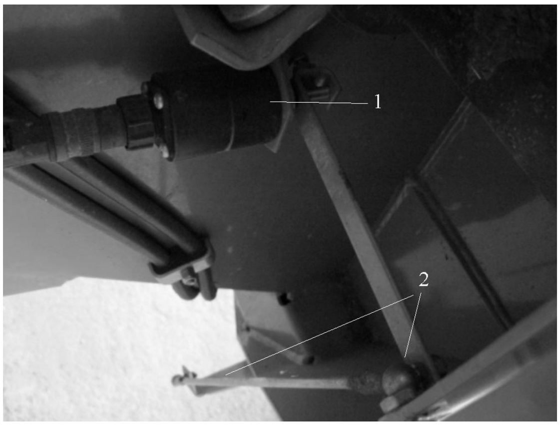

Fig. 1. **Sensor and converter:**
1 – sensor; 2 – converters

Fig. 2. **Sensor and converter:**
1 – sensor; 2 – converters

Structure of the control system

The general structure of the control system is composed of a control unit, sensors, actuators, and periphery (display screen, memory). The sensors may communicate with the control unit in one or both directions. During one-way communication, only the measured data are transmitted; during communication in both directions, also the sensor is being controlled. The sensor may be controlled only in special types of intelligent sensors which can adjust or calibrate their characteristics. This approach simplifies the work of the control unit, which would otherwise have to do such operations.

The two-way communication approach is also used during communication of a system through the used data bus, in particular for driving application machines.

A practical example of a control unit of a harvesting thrasher is shown in Fig. 3. To avoid damaging components of the control unit, the unit is protected by a dust and humidity proof casing.

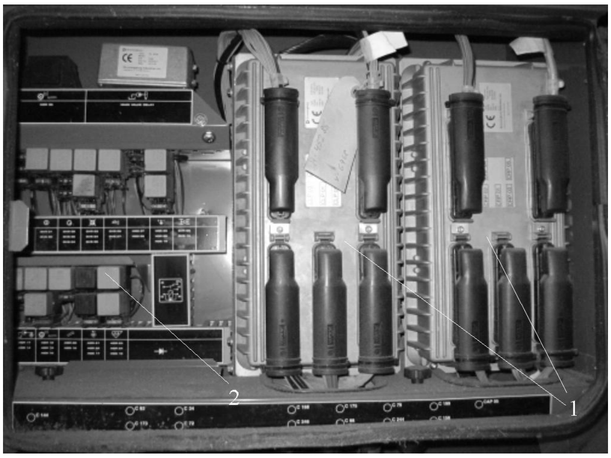

Fig. 3. **Control unit of harvesting thrasher:** 1 – control unit; 2 – relay block

Figure 4 shows a flowchart of the entire control circuit with feedback. The flowchart shows system transmission (transfer function) of the system $F_S(s)$, regulator transmission $F_R(s)$, disturbance variable transmission $F_{SV}(s)$ and measuring element transmission $F_M(s)$ [3].

The control circuit flowchart generally also contains actuator transmission, but the above flowchart is sufficient for the purposes of this paper. Together with the place of possible error occurrence, the flowchart shows a failure on the action variable and a failure on/of the controlled variable. A failure on the controlled variable is conveyed through the transmission block, which determines the possible character of failure impact.

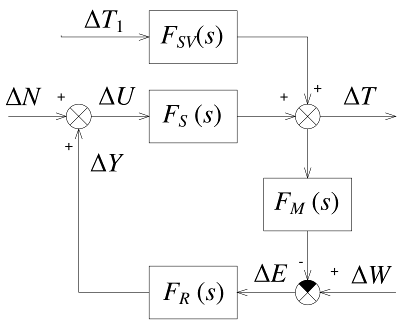

Fig. 4. **Flowchart of control circuit**

For further processing, transmission of the measuring element (1) is important, while the possible impacts of such transmission on the control process are compared.

$$F_M(s) = \frac{b}{(1+a_2 s)(1+a_1 s)} \tag{1}$$

Simulation of the practical influence of the employed measuring element was carried out in the MATLAB Simulink program. MATLAB – Simulink with its system modeling and simulation capabilities is an appropriate tool for such experiments.

Results and discussion

Impact of the input element on the control system

The impact of inertia of the sensor proper does not have to be significant in slow processes, but the impact of slackness or elasticity of mechanical parts of converters is important.

Figure 5 shows the least favorable system behavior where the presented course of the measured variables is displayed by the indexes 2 and 3, while the real course by the index 1. Distortion of the real course is shown clearly, while the control system is getting information considerably changed, i.e., with half amplitude and with delay doubling the duration of the original course. Distortion is dangerous in particular in circuits controlling, e.g., stubble height for the harvesting thrasher where the system is sometimes being adjusted even when no change is detected any more. The failure impact results in imperfect guiding of tools along the surface of the field and deterioration in the quality of automatic control. At the very most, some parts of tools may be damaged.

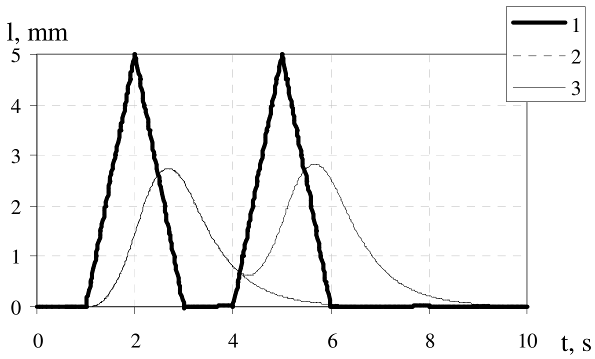

Fig. 5. **Impact of inappropriately chosen or damaged input element of measuring system:**
1 – real signal; 2 – measured signal; 3 – measured a periodic signal

Fig. 6 below shows the course in case of a better solution of the measuring circuit, which is sufficient, since 100% dynamic accuracy can never be reached; all that can be reached is an optimum or sufficient accuracy. Such accuracy depends on the speed of the possible changes of the analyzed variable. In case of stubble height control for the harvesting thrasher working under optimum conditions and with standing crop, a larger time constant of the measuring element and/or measurement chain suffice. Conversely, under adverse conditions, e.g., with crop varyingly standing, flattened or in between, more flexible control intervention is required [4].

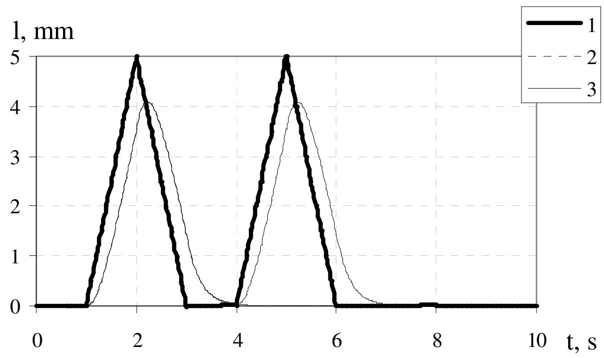

Fig. 6. **Impact of appropriately chosen input element of measuring system:**
1 – real signal; 2 – measured signal; 3 – measured a periodic signal

Fig. 7 below shows a part of dynamic behavior, where the sinusoidal course of deviation is the input signal, and the measured signal, significantly distorted due to the used inertia, is the output signal.

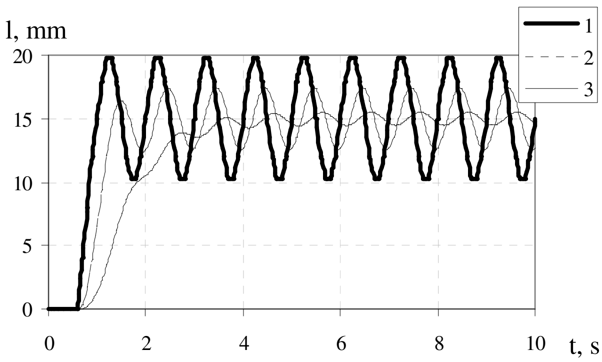

Fig. 7. **Impact of inappropriately chosen or damaged input element of measuring system:**
1 – real signal; 2 – measured signal; 3 – measured periodic signal

The measured signal is reaching its average value approximately in the third period of the input signal. As soon as the average value has been reached, it shall be constant together with the changed phase of the course [4].

Dynamic change occurs usually more frequently than static loading, however, assessment of dynamic change is more difficult. The cited case may arise, e.g., due to inappropriately chosen period of sampling of the measured variable.

Simulation of practical influence of employed measuring element

In order to compare the practical influence of the employed measuring element in simulation, sensors with higher and lower time constants connected in the control circuit were chosen. Figure 8 shows the control circuit. The partial transmissions of individual sensors with converters are calculated according to formulas (2) and (3) [5].

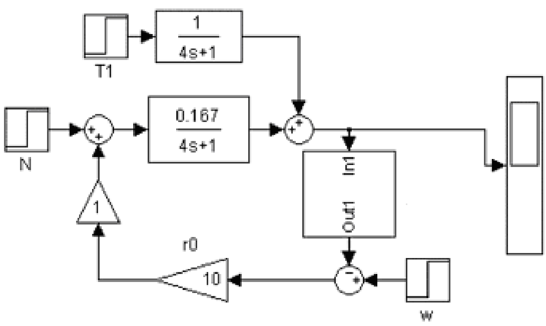

Fig. 8. **Flowchart of the control circuit**

$$F_M(s) = \frac{1.299\ s^2 + 4.541 \cdot 10^4 s + 4.058 \cdot 10^7}{s^3 + 1218\ s^2 + 2.852 \cdot 10^6 s + 4.117 \cdot 10^7} \tag{2}$$

$$F_M(s) = \frac{1}{(1 + 0.7s)(1 + 0.05s)} \tag{3}$$

The control circuit was set to regulation to a constant value w=50 mm, without impact of failure N on the action variable and without impact of failure T_1 on the controlled variable. A failure on the action value may be due to imperfect hydraulic control; such failure is expected to occur less often. There are several factors influencing the controlled variable, from uneven land surface (due to, e.g., ruts after application of machines) through to the elastic segments of the mowing adapter housing.

The type P proportional regulator, the amplification of which may be set to r_0=10, 20, 30, 40 and 80, is used for the regulation in question. The controlled variables for the individual cases are mentioned in Fig. 9 and 10.

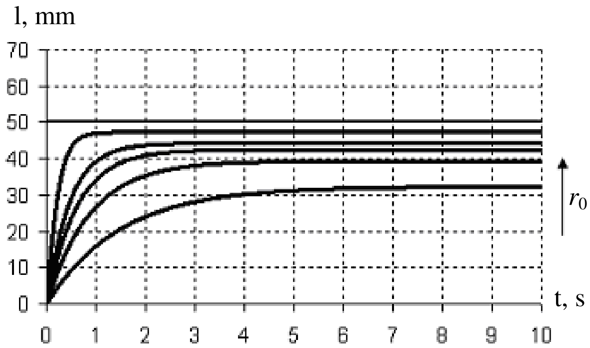

Fig. 9. **Regulation with use of measuring element with transmission according to (2)**

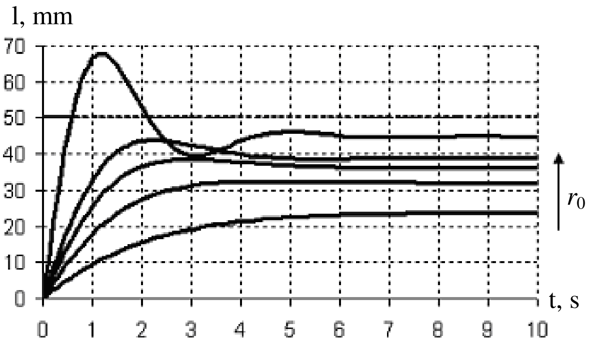

Fig. 10. **Regulation with use of measuring element with transmission according to (3)**

Conclusions

Problems with using converters may be partially eliminated by using a more suitable construction of converters or by using a completely different system, e.g., a system with contactless measurement.

If follows from our paper that attention should be paid to creation of a qualitative and accurate input system of regulation/control units of the control system. Figure 5 shows that the badly designed the converter dynamic error may be up to 50 %. Figure 7 shows the phase shift measured course and the mean value 15 % of maximum.

By optimizing the input units, precision agriculture can dramatically improve the economic results. That means a systematic trend of information technology application in agriculture.

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