Journal of Engineering and Applied Sciences 12 (Special Issue 10): 8819-8824, 2017
ISSN: 1816-949X

Microprocessor Control System of the Productivity for the Small Size Feed-Processing Plant

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Abstract: The urgency of increasing the efficiency of a small size feed-processing plant by automating the control of its productivity is shown in this study. The development results of the corresponding microprocessor system are presented with the control of the feed material flow by means of a typical damper with an individual electric drive. The control is based on the current of drive motor crusher. The functional scheme of the proposed automatic control system is presented. The indicators of the control system necessary for the development of the control system algorithm are determined. The results of laboratory tests on the operation of the automation system are given. Comparative production tests of the crusher with manual and automatic load control were carried out. It is shown that, the automatic control system significantly influences the uniformity of the crusher loading, improves the power parameters of the plant, productivity and quality of crushing. According to the mentioned, it is necessary to implement some plans in way of use of nature of clean energies with approach of sustainable development.

Key words: Small size feed-processing plant, microprocessor control system of the productivity, functional scheme, indicators of the control system, experimental studies

INTRODUCTION

Currently in the Republic of Kazakhstan more than 80% of the cattle population and other farm animals are in small farms and households. For these farms, a number of small size feed-processing plants, universal crushers and crusher-choppers of feed have been developed. They are cheap and reliable and sold on the market. The small size feed-processing plant DU-11 (Fig. 1) on the basis of which the studies were carried out is intended for chopping all types of stems and grain feeds, corn cobs and also for preparing complete feed and feed mixtures from coarse forages and silage or haylage.

The plant is transferred to various types of operations by simply replacing the devices included in its kit and the engine's reverse. In Fig. 1, solid lines show the set of the plant when chopping grain forage dotted lines show the chopping of corn cobs and simple chopping of coarse forage. In the case of preparing the complete feed, the ingredients are mixed in a mixing screw.

The disadvantage of the machine when chopping grain is the need for manual adjustment of its productivity by means of a damper which narrows or widens the hole through which the flow of grain materials enters the working organ. Manual control as a rule, leads to incomplete loading or overloading of the plant. In this case as the practice of operating shows, most of the working time the electric drive operates under an unloaded state and vice versa, cases of switching off the electric drive due to engine overload are not uncommon. This involves constant control over the operation of the machine, reduction in the machine energy efficiency and the quality of the product (Ghasemi, 2017).

The purpose of the research is to increase the efficiency of using the small size feed-processing plant by developing an automation system that allows to control the productivity of the plant by changing the flow of feed material entering the machine's working organ.

The goal is achieved by integrating into the plant a damper with individual electric drive for controlling the loading of the hammer rotor. In this case, the load control will be carried out according to the current of the hammer drive motor crusher.

The results of the research will increase the technical level and competitiveness of the small size feed-processing plant and will be used in the design of other similar feed-processing plants and machines.

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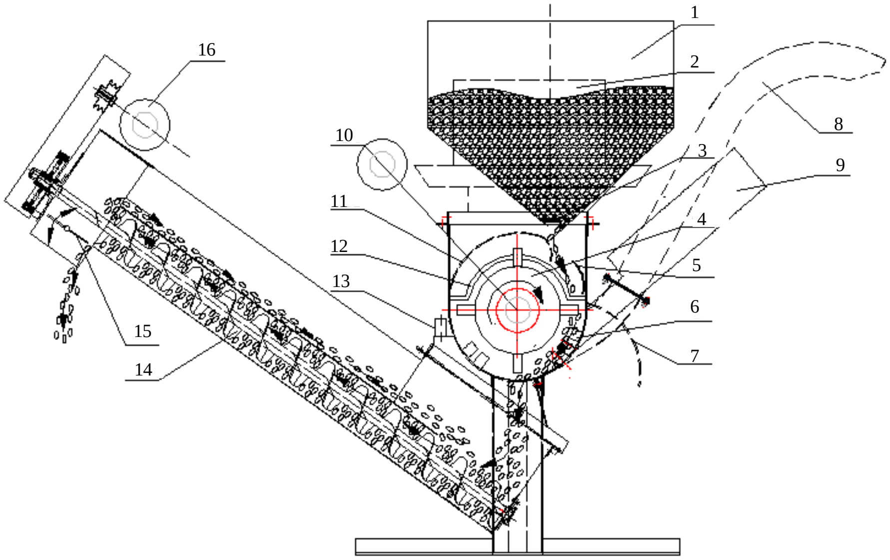

Fig. 1: Scheme of universal small size feed-processing plant: 1-Grain bunker; 2-Hay bunker; 3-Damper; 4-Hammer rotor; 5-Rotor; 6-Deck; 7-Reflector; 8-Deflector; 9-Chute; 10-Rotor electromotor; 11-Cutter; 12-Lifter; 13-Frame; 14-Mixing screw; 15 -Screw damper; 16-Mixing screw electromotor

MATERIALS AND METHODS

Experimental studies: The research on the development of automatic control systems to increase the productivity of choppers and crushers used in various industries is carried out by scientists and engineers from a number of countries.

For example, a mini flour mill (Kawuyo *et al*., 2014) and a hammer mill with a supply control device are known. Work has been done to improve the efficiency of the crushing process by developing PID controllers that enable rapid monitoring of the process parameters (Chai *et al*., 2011), controlling of the crusher operation in accordance with the prescribed rule (Williams, 2002), splitting the crushing process into a number of events in mathematical modeling (Evertsson, 2000; Lee and Evertsson, 2008, 2009), monitoring the characteristics of the raw material (Niemczyk and Bendtsen, 2011), recording the time of the dependent variables in the control of the crushers and the dynamic control of the cone crushers (Bearman and Briggs, 1998; Hulthun, 2008), dynamic wear compensation of the crushers lining (Tahmassebpour, 2017).

Also, there is an intelligent control system for coarse coal crushers based on the developed algorithm for comparing the image of a pre-treated material with the given image an automatic system with an electronic sensor for measuring the pressure in a powder chamber of a crusher, directly transmitting digital information to a control computer is developed. There is another intelligent cone crusher system for improved stability and dynamic system characteristics, the way of online cone crushers optimization allowing to maximize the overall productivity of crushers by controlling the speed for unknown changes in characteristics (Lu *et al*., 2012; Tahmassebpour, 2016; Ailian and Feng, 2012; Atafar *et al*., 2013) (Fig. 2).

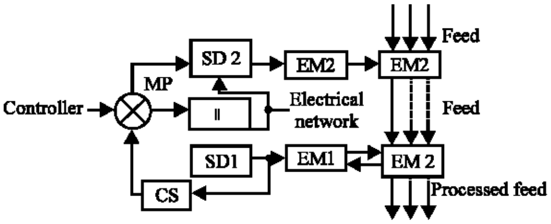

Fig. 2: Functional scheme of the control system: MC-Microcontroller; II-Indicating Instrument; CS-Current Sensor; SD1, SD2-Starting Device; EM1-Electromotor of working organ; EM2-Electromotor of damper; WO-Working Organ; BD-Bunker Damper

In the commercial mini crushers like auto loader, hopper, Sandvik, there are systems for automatic material shortage alarms, automatic crusher setting systems for supply conditions, engine protection.

In accordance with the given goal and taking into account the above-mentioned researchs, we developed an

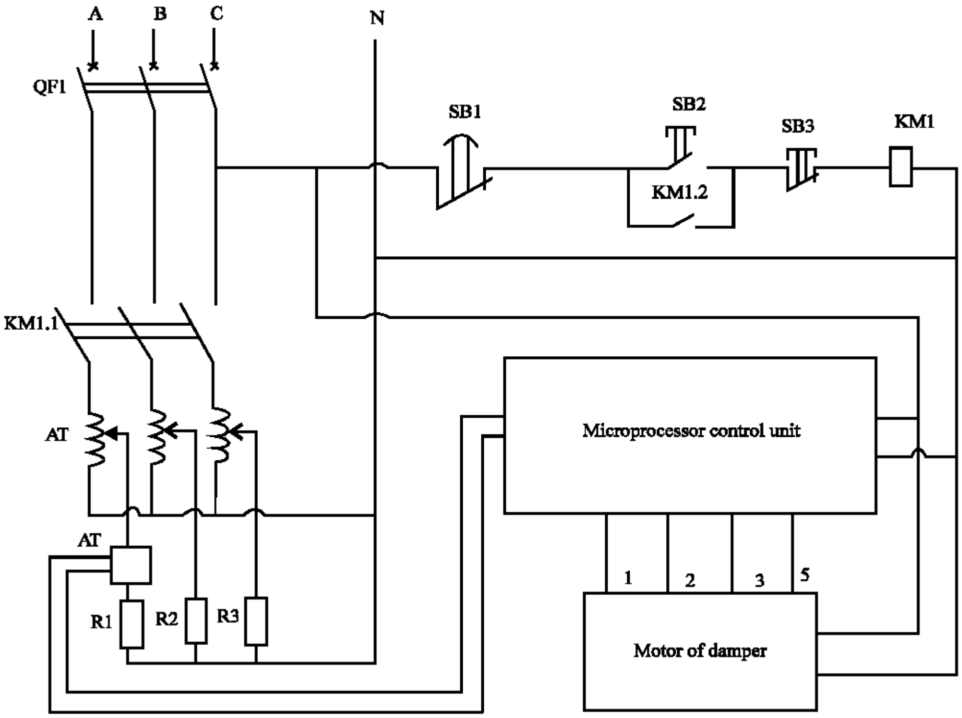

Fig. 3: Single line diagram of laboratory bench

automatic control system (Keshuov *et al*., 2016). The functional scheme of the control system is shown in Fig. 2. In the working part of the mechanical characteristic of asynchronous Motor (EM1) of the Working Organ (WO), the current is proportional to the magnitude of the torque on its shaft and consequently, the loading of the plant working organ. The value of the current through the Sensor CS which carries out feedback in the system is transferred to the Microprocessor MP which compare it with the set of current values in accordance with the algorithm of the control system and transmits the corresponding control signal to the Starting Device SD2 of the Motor EM2 of Bunker Damper BD. As a result, the damper opens or closes by regulating the flow of feed from the bunker to the working organ and accordingly, changing the motor current EM1. The Starting Device SD1 serves to control the motor EM1, the Indicating Instrument II shows the current value of the motor and the operating modes of the plant.

When developing the automation system, it is necessary to take into account the start time of the crusher motor. We have obtained starting diagrams for current and speed of the motor with an empty drum and with the presence of 2 and 4 kg of grain (barley) residue in the drum on the natural sample of the small size feed-processing plant (Fig. 3). The records were made using an oscilloscope DSO 3064, a shunt and velocity generator Tch-10R.

With an empty crusher drum the motor is loaded only with the moment of working organ no-load characteristic. It can be seen from the oscillograms that were recorded in this mode, the starting time of the crusher drive motor is $t_s = 2.0$ sec. If you have a grain in the crusher drum, there is a reliable start. In this case with the residue in the bunker of 2 kg of barley starting time is $t_s = 3.1$ sec with the residue in the bunker of 4 kg of $t_s = 6.0$ sec.

When developing a control system, it is important to select the value of the current control range determined by the values of the minimum I_{min} and the maximum I_{max} of the permissible current. With a narrow range, the response of the control system to minor short-time load changes is possible with a wide range a long work in underloaded mode. At the same time, the value of the smallest permissible current I_{min} is limited by the decrease in the machine's productivity and the power parameters of the electric motor; the largest I_{max} is limited with the heating of the motor windings.

The energy efficiency of the motor is mainly determined by the dependence of the efficiency ç of the engine on its load factor $f_l = P_2/P_{2n}$, where P_2 and P_{2n} are the current and nominal power on the motor shaft, respectively. With a load factor $f_l = 0.875$, the efficiency of the asynchronous crusher motor reaches its highest value $\eta = 0.88$. It is reasonable that the value of I_{min} corresponds to this value of the load factor. The current I_{max} according

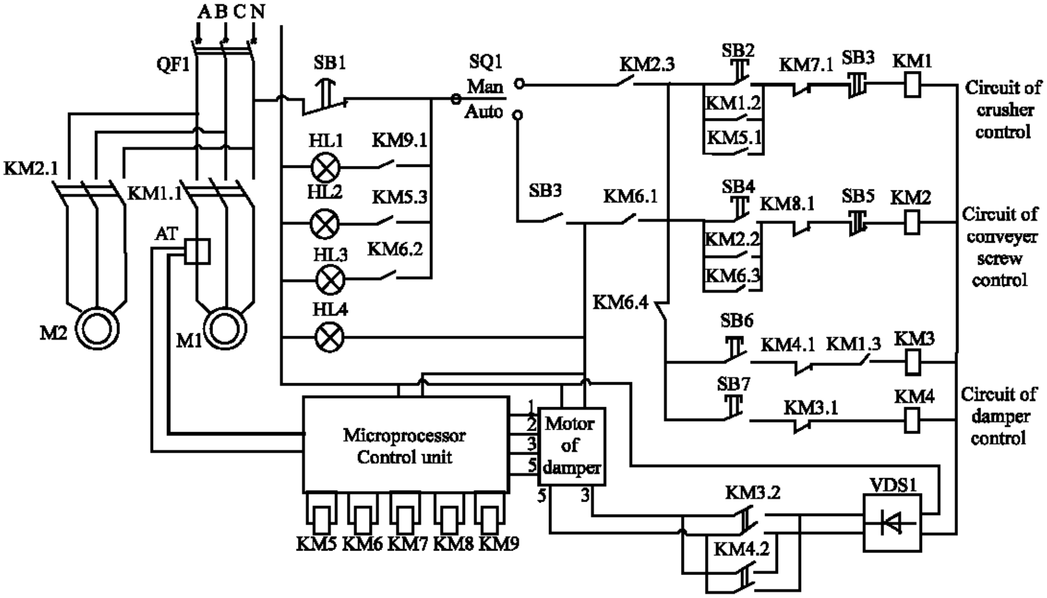

Fig. 4: Single line diagram of the crusher electric motor connections

to the heating conditions, cannot be greater than the nominal motor current I_n corresponding to $f_1 = 1$, hence, $I_{max} = I_n$. Thus, $I_{min} = 20.8$ A and $I_{max} = 23.65$ A. The average value of the detected currents is assumed to be equal to the value of the operating current $I_0 = 22.1$ A.

In order to exclude the response of the control system to rapid load surges, the program of the control system provides calculating the average value of the current amplitude in one second and uses this value in subsequent program steps.

An algorithm and control program, a prototype system, a laboratory bench and tests were developed to test the feasibility of implementing the proposed control method (Keshuov and Tananova, 1972). Single line diagram of laboratory bench is shown in Fig. 4.

In the automatic control system the following elements was used: microcontroller of Arduino Mega type built on the Atmega2560 microcontroller connected to a matching unit with a LCD-LCD12864 display an LC1 D4011 type relay, current sensor of transformer type up to 100A SCT013, damper actuator with an integrated damper angle sensor BELIMO SM 230 ASR.

The change in the crusher motor current is simulated with a three-phase Autotransformer AT to which the active load R1-R3 is connected. Phase current load and the angle of damper rotation were recorded using an oscilloscope DSO 3064. For laboratory tests, the program has the following effective values of currents-$I_{min} = 4$A, $I_{max} = 10$ A, $I_p = 7$A.

In the initial position, the damper is closed. As the current increases, the damper gradually opens and when the current reaches the operating value, $I_0 = 7$ A, it stops opening at 63°. Further on, when the current value varies from $I_{min} = 4$ A to $I_{max} = 10$ A, the damper remains stationary and maintains its position. With a current value greater than $I_{max} = 10$ A, the damper starts to close and when the current decreases to $I_0 = 7$ A, it stops closing at 44°. If current value less than $I_{min} = 4$ A, the damper starts to open and when the current is back up to $I_0 = 7$A it stops opening at 70°.

At a constant current value exceeding $I_{max} = 10$ A, the damper, regardless to the initial position is completely closed and at a constant current value below $I_{min} = 4$ A, the damper opens completely.

This experiment confirmed the working capacity of the prototype of the control system in accordance with the specified algorithm. Further on we conducted production tests of the experimental prototype of the plant with an automatic system for controlling the productivity.

A single line diagram of the machine electric motor connections is made taking into account the possibility of manual and automatic control of the crushing process (Fig. 4).

During the experiments, the load diagrams of the main crusher motor were taken from the value of the current I = f(t) and the power consumption of the same motor with manual and automatic productivity control under the same operating conditions. The PQA 824 Power Quality tool was used to take the characteristics.

RESULTS AND DISCUSSION

The results of the experiments are shown in Fig. 5 and 6. Fragments of the load diagrams shown in Fig. 5 contain

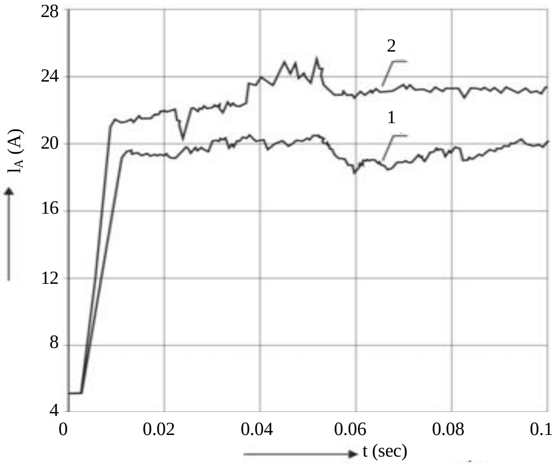

Fig. 5: Load diagram I = f(t), crusher motor with manual, automatic and productivity control

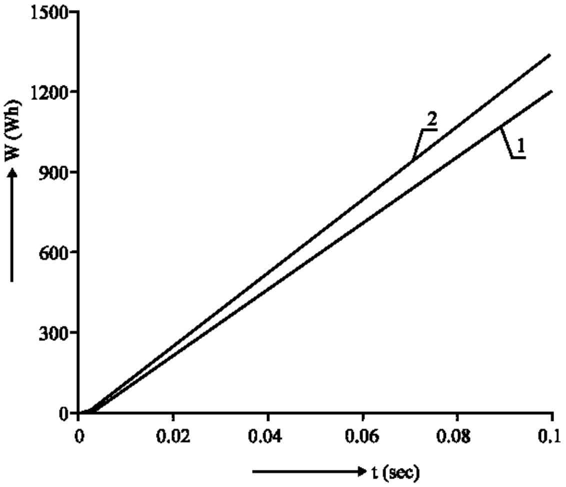

Fig. 6: The graph of electricity consumption by the crusher motor with manual and automatic productivity control

the process of opening the damper with the transition to the steady mode in the interval 0-0.06 h and then part of the steady mode period.

To evaluate the quality of the control, the expectation m_I, the Dispersion D_i and the mean square deviation σ_i of the engine load diagrams as random functions were determined by the following simplified equation:

$$m_I = \frac{\sum_{i=1}^{n} I_i}{n} \tag{1}$$

$$D_I = \frac{\sum_{i=1}^{n} (I_i - m_I)^2}{n-1} \tag{2}$$

$$\sigma_I = \sqrt{D_I} \tag{3}$$

Where:

I_i = Present value of current for time t_i

n = Number of values I_i

As a result of the calculations, the following data were obtained. To manually control the productivity of the crusher:

$$m_I = 19.22 \text{ A}, D_I = 0.012 \text{ A}^2, \sigma_I = 0.12 \text{ A}$$

And for the automatic control:

$$m_I = 23.17 \text{ A}, D_I = 0.002 \text{ A}^2, \sigma_I = 0.04 \text{ A}$$

The automatic control system significantly smoothes the load diagram of the crusher motor and helps to increase the value of the mathematical expectation of the current.

Also, Fig. 6 shows that within 0.1 h of the crusher's operation in accordance with the technological cycle of operation at a farm with automatic productivity control, the power consumption of the main engine of the crusher is increased by 200 Wh in comparison with manual control. Figure 5 and 6 indicate an increase in the crusher motor load under automatic control.

The productivity of the plant was determined by direct measurements of grain weight and the time of crushing. During the production tests, 8 tons of grain was processed. According to the test results with the crushing of grain (barley), the productivity of the plant was 4.1 t/h with manual control and with automatic control of 4.5 t/h. Thus, with automatic control the productivity increased by 0.4 t/h.

We evaluated the quality of grain crushing with manual and automatic productivity control by evaluating the finished product and the presence of fractions with various degree of fineness. For laboratory analysis, 10 kg of feed samples were obtained under different control systems of feed-processing plant. The analysis was carried out in accordance with GOST (1972). The results of quality analysis of the finished product are given in Table 1. It can be seen from the table that the quality of crushing is slightly increased in automatic control in comparison with manual control, so, the presence of fractions of average grinding is greater by 2.5%, fine (dust) fractions is reduced by 2% and the coarse fraction is also reduced by 0.5%. This promotes better absorption of nutrients by animals and increases their productivity.

Table 1: Results of quality analysis of the finished product

	Proportion of fractions with various degree of fineness (%)		
Type of control	Fine (Up to 1.8 mm)	Average (1.8-2.5 mm)	Coarse (>2.5mm)
Manual	8	90.0	2.0
Automatic	6	92.5	1.5

Improving the quality of the finished product with the automatic productivity control of the crusher is explained by the greater uniformity in the loading of the crusher which ensures an optimal grain crushing mode. Manual control does not ensure proper uniformity of loading. As the load decreases, grain crushing increases excessively and vice versa when overloading grain crushing is too low.

CONCLUSION

Comparison of the experiments results obtained with manual and automatic control of the crusher load shows that the automatic control system significantly influences the uniformity of the crusher load, improves the power parameters of the plant, increases the productivity for grain crushing by 0.4 ton/h and the quality of crushing.

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