IOP Conf. Series: Journal of Physics: Conf. Series **803** (2017) 012090 doi:10.1088/1742-6596/803/1/012090

The control algorithm of the system 'frequency converter – asynchronous motor' of the batcher

S V Lyapushkin[1], N V Martyushev[1], S.Y. Shiryaev[1]

[1] Tomsk Polytechnic University, 30, Lenin ave., Tomsk, 634050, Russia

E-mail: lsv@tpu.ru

Abstract. The paper is devoted to the solution of the problem of optimum batching of bulk mixtures according to the criterion of accuracy and maximally possible performance. This problem is solved for applied utilization when running the system 'frequency converter – asynchronous motor' having pulse-width modulation of a screw batcher of agricultural equipment. The developed control algorithm allows batching small components of a bulk mixture with the prescribed accuracy due to the weight consideration of the falling column of the material being in the air after the screw stoppage. The paper also shows that in order to reduce the influence of the mass of the 'falling column' on the accuracy of batching, it is necessary to specify the sequence of batching of components inside of the recipe beginning from the largest component ending with the least one. To exclude the variable error of batching, which arises owing to the mass of the material column, falling into the batcher-bunker, the algorithm of dynamic correction of the task is used in the control system.

Introduction

The majority of mobile agricultural electrified machinery possesses batching systems that are controlled by electric drives. The specifity of electric drives in agricultural production is conditioned by the variety of load characteristics, modes and conditions of operation (environment, electric energy quality). Hence, special attention must be paid to the choice of systems of the electric drive, in order to provide the required modes of operation, namely substantiation of the necessity of adjusting the angle velocity of the electric drive and its ranges. Taking into account the requirements for the accuracy of batching of materials flows and mixture compositions, recently the systems 'frequency converter – asynchronous motor' (FC-AM) with pulse-width modulation (PWM) have been intensively introduced. They provide the necessary accuracy of batching and reliability of the system. In its turn, the adjustment of the speed of electric drives equipped with asynchronous drives is realised by means of changing the frequency and the magnitude of the supply voltage.

The solution of the task of optimal batching of bulk – according to the criterion of accuracy and maximal possible performance – multicomponent mixtures is connected first of all with formation of the control algorithm of the asynchronous motor of the electric drive of the screw batcher. The algorithm allows reaching the required accuracy and optimizing the time of batching.

In this paper, for the synthesis of the batching algorithm, we use the theory of digital governors [1, 2]. The choice of this method of synthesis of governors is conditioned by the dominant positions of the digital control systems in the field of automatic control systems of technological processes. The used algorithm and the model of the control system are discussed in detail in paper [3, 4].

IOP Conf. Series: Journal of Physics: Conf. Series **803** (2017) 012090 doi:10.1088/1742-6596/803/1/012090

The correction algorithm of the error caused by the mass of the 'falling column' of the material

When batching bulk cargoes, tension sensors record the weight of the material which is virtually in the storage bunker. If not to take into consideration the weight of the falling column of the material aloft after stoppage of the screw, there is a chance to make a significant final error in batching. In some systems of batching, the mass of the falling column can reach several tens of kilograms. It is necessary to compensate the mass of the falling column when setting the task for the control system. The mass, not measured by weight sensors, is already inside of the bunker in the state of falling. For its registration, it is necessary to add the magnitude of the calculated mass of the falling column to the feedback signal. The measured magnitude of the mass of the batched material, being in the bunker, enters the control system [5]. If the bulk weight of batched material γ is known and the bunker is implemented in the form of a parallelepiped, the mass of the falling column can be calculated. The geometrical sizes of the bunker and the density of the material are preset in the control algorithm as constant values; and the information from the weight sensors is necessary to control the mass of the falling column. Taking this into account, we obtain the expression for determining the mass of the falling column:

$$m_{col} = \left[\frac{\pi}{4}\cdot\left(D_0^2 - d_0^2\right)\right]\cdot\left[h_0 + \left(h_\text{b} - \frac{m}{\gamma\cdot a\cdot b}\right)\right]\cdot\gamma. \quad (1)$$

For the bunker realised in the form of a truncated pyramid with a parallelepiped in the base, the mass of the falling column is determined according to the following expression:

$$m_{col} = \left[\frac{\pi}{4}\cdot\left(D_0^2 - d_0^2\right)\right]\times\left[h_0 + \left(h_\text{b} - \frac{m\cdot 3}{\gamma\cdot(d\cdot e + \sqrt{d\cdot e\cdot a\cdot b} + a\cdot b)}\right)\right]\cdot\gamma, \quad (2)$$

where D_0 and d_0 – the outer and inner diameter of the screw; a, b, d, e – geometrical parameters of the batcher-bunker of a trapezoidal shape; h_0 – the distance from the screw to the upper boundary of the bunker; h_b – the height of the batcher-bunker, γ – the material density.

Then, we calculate the batching error taking into consideration the correction of the mass of the 'falling column' of the material, which enters the weight regulator input in the control algorithm:

$$\Delta m = m_{pres} - \left(m_\text{fs} + m_{col}\right), \quad (3)$$

where m_pres – the preset mass of the material; m_fs – the mass obtained at the feedback signal.

Let us build a block diagram for simulation modelling according to the formulae stated above (figure 2).

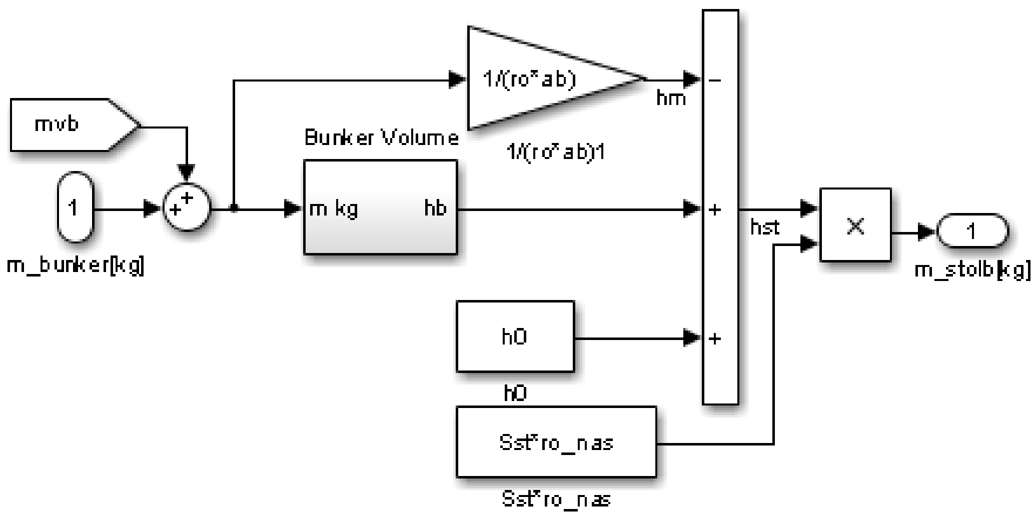

Figure 2. The simulation model of the computational algorithm of the mass of the falling column of the material

The block diagram of the record algorithm of the mass of the falling column of the material is shown in figure 3.

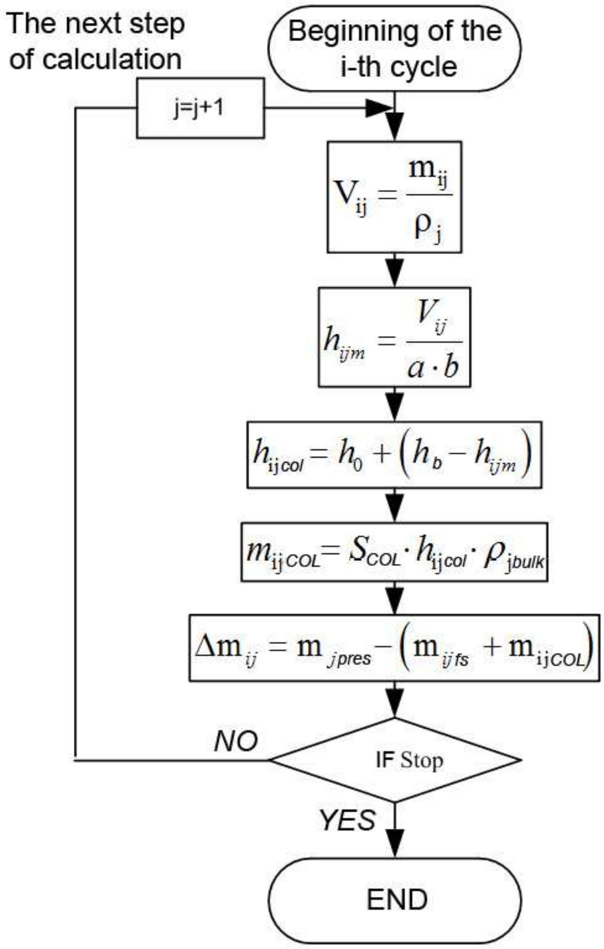

Figure 3. The algorithm of recording of the falling column mass

The results of simulation modelling of batching of 1 kilogram of the bulk material when using algorithms of error compensation are shown in figure 4 b. When starting without considering the correction algorithm, we can observe an absolute error of batching equal to 0.072 kg or a relative error – 7.2 % of the batched material. As figure 4 shows, the application of the algorithms of batching error compensation allows reducing the absolute error of batching. There is a 2.6 time reduction with regard to batching on the imitational model without the use of the algorithm of error correction. The resulting batching error amounts to 2.7%, which complies with the requirements of the technical regulation of batching of a bulk mixture – combination fodder (±3%).

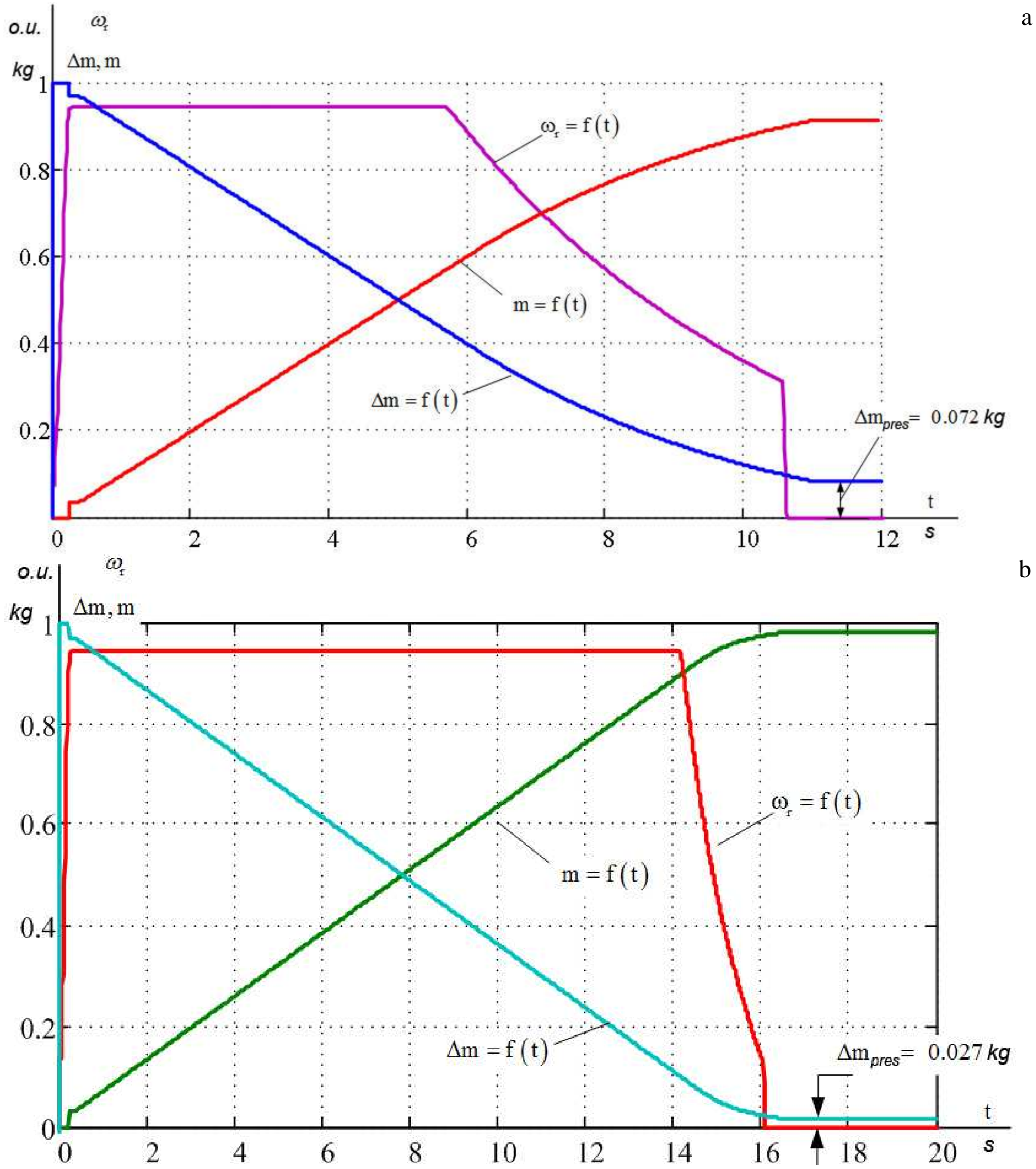

Figure 4. Batching a – without the use of the correction algorithm; b – when using the error correction algorithm

Conclusion

The control algorithm of the frequency-controlled asynchronous electric drive allowing batching small components of the bulk mixture with the prescribed accuracy was developed. It was revealed that for the reduction of the influence of the 'falling column' mass on the accuracy of batching, it is necessary to establish the sequence of batching of the components inside the recipe beginning from the largest component and ending with the least one.

It was discovered that in order to exclude the variable error of batching, arising due to the mass of the falling column of the material into the batcher-bunker, it is necessary to use the algorithm of the dynamic correction of the batching task, taking into account the compensation of the influence of the falling column mass in real time, in the control system of the frequency-controlled electric drive.

References

[1] Rotach V.Ya. 2004 Automatic control theory (Moscow: MEI Publisher) p 400
[2] Kuo B.S. 1986 Theory and design of numerical control systems (Moscow: Mechanical engineering) p 447
[3] Bukreev V. G., Lyapushkin S. V., Gusev N. V. 2014 Accuracy Enhancement of Electrotechnical System for Bulk Material Batching. *MATEC Web of Conferences* **19** 01017
[4] Bukreev V.G., Lyapushkin S.V., Edgulov M.M. 2015 Accuracy Enhancement of Automated System for Multicomponent Batching of Bulk Materials. *MATEC Web of Conferences* **37** 01012
[5] Lyapushkin S.V., Gusev N.V., Bukreev V.G., Nechaev M.A. 2013 Algorithms of accuracy enhancement in the batching system of bulk materials. *Electromechanical energy converters: proceedings of the IV International scientific and technical conference*. (Tomsk: TPU Publisher)