

**AUTOMATED DISTRIBUTION SYSTEM OF FEED MIXTURE
BY USING FEEDING CARRIAGE**
/
**СИСТЕМА АВТОМАТИЧЕСКОГО РАСПРЕДЕЛЕНИЯ КОРМОСМЕСИ
КОРМОВЫМ ВАГОНОМ**

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ABSTRACT

Modernized design of automatic feeding carriage is suggested. The laboratory installation of the automated distribution system by using feeding carriage corresponding to the simplified scheme is developed. The description of the design and its operation principle is given. Frequency converter application in the control circuit of feeding carriage loader permitted stepless regulation of feed allowance. The test results proved that the suggested system provides allowance regulation depending on orts amount on the feed table with accuracy of ± 1.6 %.

РЕЗЮМЕ

Предложена модернизированная конструкция автоматического кормового вагона. Разработана лабораторная установка системы автоматического распределения кормосмеси кормовым вагоном, представляющая собой упрощенную схему кормового вагона. Приведено описание конструкции и принципа ее работы. Использование частотного преобразователя в схеме управления транспортером кормового вагона позволило бесступенчато регулировать норму выдачи корма. Результаты испытаний показали, что предлагаемая система обеспечивает регулирование нормы выдачи в зависимости от количества остатков корма на кормовом столе с точностью $\pm 1,6$ %.

INTRODUCTION

Presently in many countries, the automatization of cattle feeding process with the usage of automated feeding system (AFS) is implemented in a large scale (Da Borso F. et al, 2017). The system data differ in technical complexity, the advanced automatization level, etc. (Kupreenko A.I. et al, 2018; Losser C.H.L., 2016). According to estimates of various scientists in 2015 more than 1250 similar systems were exploited all over the world (Oberschätzl-Kopp R. et al, 2016). At that, the producers constantly make modifications; improve the design and technological feeding process as a whole. For instance, the system «Lely Vector» includes operation algorithm, which is based on animal feeding in accordance with their real needs, rather than in accordance with fixed allowance (Tangorra F.M. and Calcante A., 2018; Vtory V.F. et al, 2018).

In comparison with conventional feeding system, where mobile feed preparation shop is used, automated feeding system (AFS) allow to reduce labour and energy consumptions (Tangorra F.M. and Calcante A., 2018; Pezzuolo A. et al, 2016); to improve the utilization efficiency of livestock premises (Da Borso F. et al, 2017, Kupreenko A.I. et al, 2018); to increase feeding ratio considerably. It influences favourably on health, productivity and behaviour of cattle (Bisaglia C. et al, 2012; Mattachini G. et al, 2019; Oberschätzl-Kopp R. et al, 2016; Crossley R.E. et al, 2018).

However, while cattle feeding several times per day some disadvantages are displayed together with some advantages. In the course of research in the farming enterprise «Lopotov A.N.» of the Pskov region (Russia), where automatic feeding carriages «DeLaval RA135» are used, it was found that, feed consumption by cattle on all feeding fronts is irregular, which is not considered by automated feeding system (AFS) at consequent delivery in automatic mode (Kupreenko A.I. et al, 2018).

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Thus, for example, most often, feed is left uneaten near the equipment supports of the livestock premises. At the time of the next feeding the feed amount in this place increases. More intensive eating of feed in other areas of feed table at the prescribed allowance by cattle, results in its factual reduction as per capita. For preventing microbiological process germination and feed residues, hand cleaning is required in places of its sufficient accumulation. It makes difficult to use automated feeding system (AFS) in automatic mode, causes the necessity to switch them into manual mode. This complicates the personnel work at their operational use.

Thus, it should be stressed that, one of the directions of design development of feeding carriages is to provide the possibility to vary feed mixture allowance depending on actual presence of its residues on the feed table after the previous delivery.

MATERIALS AND METHODS

To solve the problem, we suggested the improved design of automatic feeding carriage; its scheme is presented in fig.1.

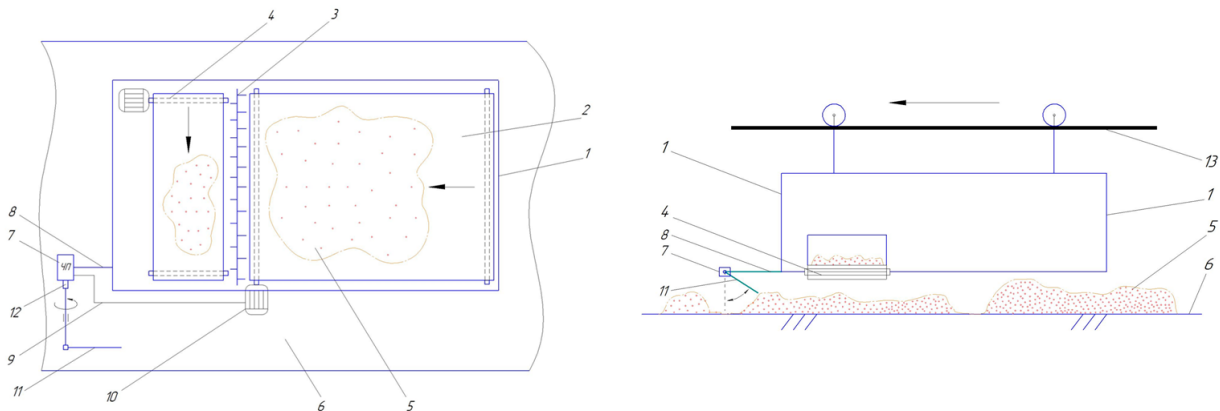


Fig. 1 - Automatic feeding carriage

1 - feeder; 2 - longitudinal loader; 3 - beater mechanism; 4 - cross loader; 5 - feed mixture; 6 - feed table; 7 - frequency converter (FC); 8 - telescopic rod; 9 - electric wiring; 10 - electric motor; 11 - adjustable pivoted guide plate; 12 - control knob FC; 13 - monorail

Automatic feeding carriage operates in the following way (fig.1). During its movement along the overhead monorail 13 above feed table 6 at the vertical position of adjustable pivoted guide plate 11 longitudinal loader 2 supplies feed mixture 5 to beater mechanism 3, which directs it to cross loader 4, unloading the specified feed mixture allowance on the feed table. At deviation of adjustable pivoted guide plate 11 from vertical position because of its contact with feed mixture residues on feed table 6 it rotates round its horizontal axis, effecting to control knob 12 of frequency converter 7. Herewith, the frequency of the current, which feeds the electric motor of the longitudinal loader, is reduced proportionally to the control knob rotation angle. It decreases its motion speed, and correspondingly, feed mixture allowance on the specified part of the feed table until complete stop of its delivery in the areas of the untouched feed mixture layer after the previous delivery. Thus, the excessive consumption of feed mixture is not permitted. To deliver complete feed mixture allowance to the unfilled areas of the feed table and to decrease it during the cross loader running above feed mixture residues, the coordination of control action of the adjustable pivoted guide plate with the movement speed of the automatic feeding carriage is provided by regulation of the length of the adjustable pivoted guide plate and the telescopic rod of its fastening.

To check working capacity of the suggested design we developed the laboratory installation of the automated distribution system by using feeding carriage (fig. 2) and the corresponding tests were carried out. The installation consists of a power drive station and a track carriage, which runs by the rails along the soil box.

The drive power station consists of an electric motor with the capacity of 5.5 kW and a parallel-shaft reducer, connected with chain gear. A flange with the mounted drive drum of the corresponding diameter is set up on the output shaft of the reducer. A cable rope is coiled on the drum; another end of it is fastened to the track carriage. The carriage movement is performed by means of the drive drum rotation. In conditions of the experiment running, its movement speed was 0.3 m/s, which approximately corresponds to the maximum speed of movement of feeding carriages «Mix & Carry» and «Free Stall Feeder» – 0.267 m/s, indicated in the technical specification in the official website «GEA Farm Technologies».

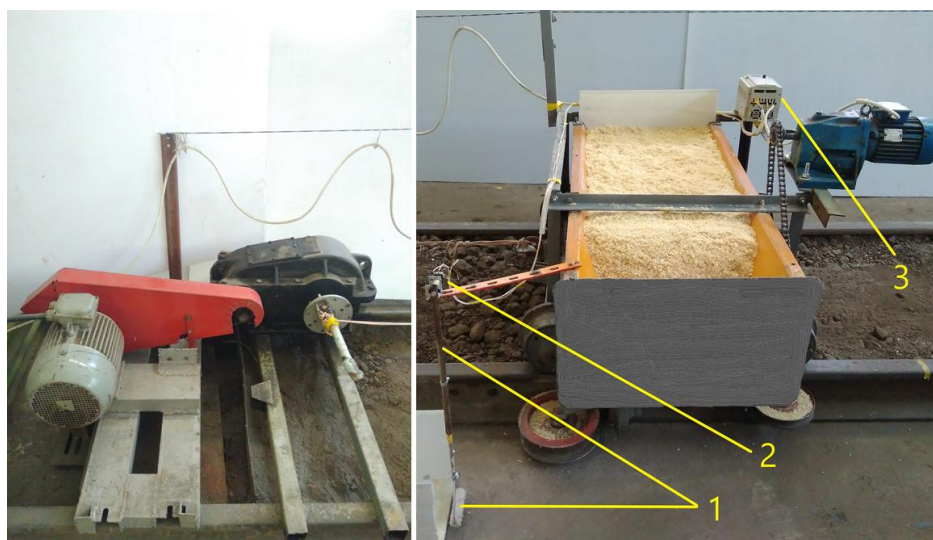


Fig. 2 - Laboratory installation: power drive station (left) and track carriage (right)

1 - guide plate; 2 - resistor; 3 - frequency converter

The track carriage frame carries a cross belt unloader from feeder «KCA-5Б» (Russia), its drive is carried out via chain gear with the help of a motor-reducer with the capacity of 1.55 kW and gear ratio, equal to 37, connected to the mains via frequency converter (FC) «Vesper E2-8300-005N» (application of frequency converter (FC) allows to obtain any allowance, this eliminates the shortcoming, connected with the limited number of this parameter adjustments in feeding carriages «DeLaval RA135» (Kupreenko A.I. et al, 2018). The output shaft of the reducer is connected with the drive carriage of the unloader by means of chain gear with gear ratio, equal to 1.4. In the experimental conditions the maximum movement speed of loader was 0.2 m/s. At that, complete discharge of the loader was done during 5.7 seconds at the length of wood dust layer 1.15 m and the height of 0.16 m. Unloading height was 0.54 m.

The feeder function was performed by a container made of plastic covers sized 2120x255x260 mm, proving complete discharge of the loader along the whole container length. We used wood dust instead of feed mixture as test material.

The key element in the laboratory installation design is the guide plate, pinned in the direction of the carriage travelling. Variable resistor connected into the circuit with the frequency converter is set opposite the axis of guide plate rotation. Torque transmission of guide plate rotation axis to the resistor axis is done because of the silicon tube mounted on their ends and performing the function of a jointing sleeve. Such a design compensates the deviation from coaxial position and protects the resistor from mechanical overloading, appearing because of the guide plate rotation. The stopper provides the protection of the resistor at the guide plate rotation from vertical position to the direction of the carriage travelling at its falling down. The roller rotating round its axis and located at the height of 25 mm from the container bottom was chosen as the guide element.

The operating principle of the laboratory installation consists in the following. During the movement of the feeding carriage (track carriage) along the feed table or feed crib (container), feed (in the experiment - wood dust) must be delivered according to the preset allowance. Unit control system is adjusted so that at the absence of feed in the feed crib the unloader moves with the maximum preset speed. At that, this speed can be controlled by setting the required parameter value of the frequency converter (FC) tuning. When feed is absent, the guide plate is located perpendicular to the floor; the resistor axis is turned to the position corresponding to the minimum resistance.

At the contact of the guide plate with feed residues it rejects to the angle, the value of which depends on the feed layer height. At that, rotation is transmitted to the resistor axis. The resistor is connected to the reference voltage source, and at its shaft rotation voltage is removed from it in the range of 0...5 V. This voltage is used in the unit control system to set the output frequency of the frequency converter (FC), feeding the motor-reducer of the unloader drive.

Thus, when the guide plate runs over feed residues it rotates and rotates the resistor axis, actuating voltage increases, and therefore, motion speed of the unloader and feed allowance decrease.

RESULTS

All test cycle of the laboratory installation consisted of the following steps:

- 1) selection of the optimal maximum speed of the unloader movement at delivery into the empty container (reference);
- 2) production in the container of reference profile out of wood dust performing the function of feed residues in the crib or on the feed table;
- 3) wood dust delivery to the container with reference profile at various height values of the carrier arm of its axis of rotation and the guide plate protrusion;
- 4) function check of the device for leveling the obtained wood dust layer.

At the initial stage «1» to select the optimal maximum speed of the unloader movement we carried out wood dust delivery into the empty container at current frequency values $v = 50, 55$ and 60 Hz (regulated in the parameter «3-00» of the selected frequency converter (FC)). At that, the height measurements of the obtained wood dust layers were performed in the following way: the container longwise every 100 mm; edge wise – in four measurements every 85 mm, the average value h_{cp} was obtained by their sum. Therefore, a plane crossbar with marks was mounted on the container top crosswise and the measurements of the distance from the crossbar to wood dust layer at the points are indicated in fig.3.

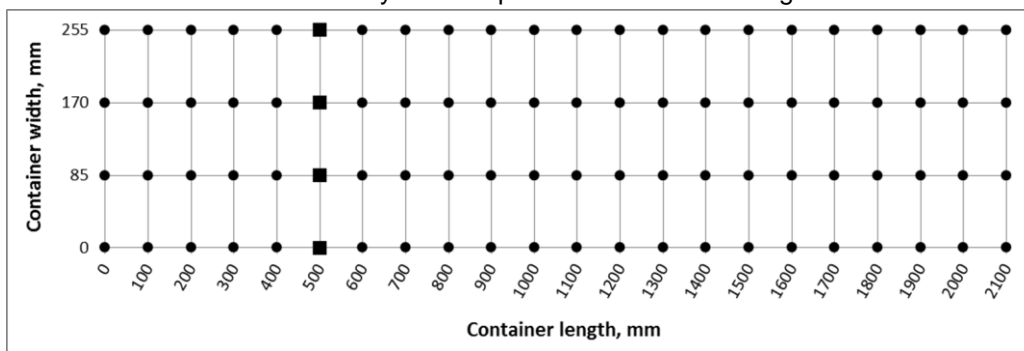


Fig. 3 - Network of the carried-out measurements (container view from above)

Then, the measurement results were processed in the MS Excel software, and the corresponding graphs were plotted. The formula to determine the average height value of wood dust layer for various values of the container has the following view:

$$h_{cp} = \frac{4 \times 260 - (h_1 + h_2 + h_3 + h_4)}{4}, mm \tag{1}$$

where: 260 – the distance from the crossbar to the container bottom, [mm];

h_1-h_4 – the distance from the crossbar to wood dust, measured at the points for the corresponding container length (for example, at the container length 500 mm (fig.3.) these points are marked with square marks).

According to the measurements results at the maintained mode of the unloader operation the wood dust layer height after the delivery into the empty container (reference) was in the limits:

- at $v = 60$ Hz – $210-239$ mm (on the average 225 mm);
- at $v = 55$ Hz – $204-221$ mm (on the average 212 mm);
- at $v = 50$ Hz – $188-209$ mm (on the average 198 mm) (fig.3).

The values, which were taken into consideration at that, are marked.

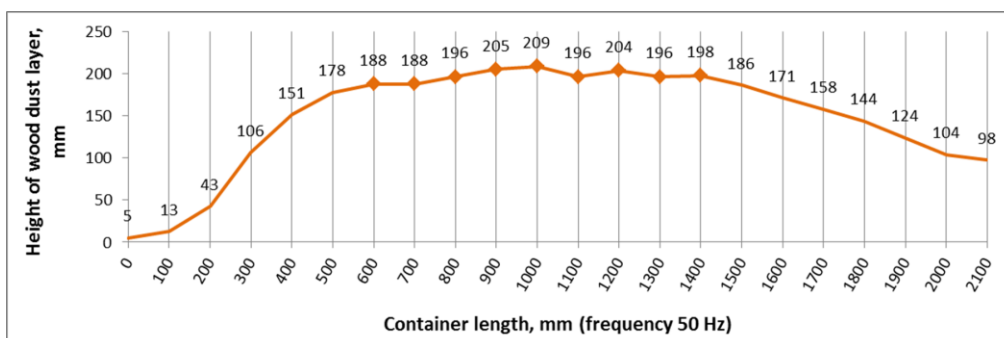


Fig. 4 - The obtained wood dust layer after delivery into the empty container

In as much as at high speed of the unloader during the delivery into the container with the reference profile wood dust poured over the container top, for further tests the frequency of $\nu = 50$ Hz was selected.

At the stage «2» to check working capacity of the installation, in the container the reference profile (fig.5 and 8) was produced from wood dust (the profile photograph was mirror like turned about horizontally by the «XnView» software). The maximum height of the reference profile corresponds to the average height of the wood dust layer, obtained at the delivery into the empty container at the frequency of $\nu = 50$ Hz (deviation is – 4 %).

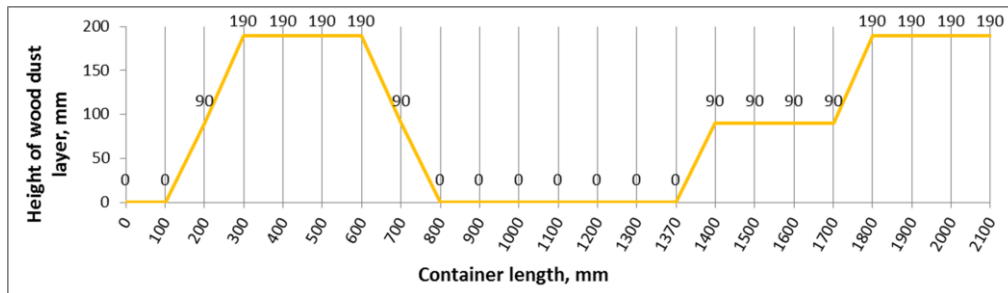


Fig. 5 - Reference profile dimensions

At the stage «3» we estimated the influence of the carrier arm height of the guide plate rotation h_k and its protrusion L_k on uniformity of wood dust delivery into the container with the reference profile. The guide plate control action was programmed in parameter «7-01» of the selected frequency converter (FC) in such a way that, while lifting the roller of the guide plate on height 195 ± 10 mm, the unloader stops.

The delivery was carried out in the following way: after the power-drive station start, when the guide plate reached the container top, the unloader start was done. The guide plate, regarding the height of wood dust layer in the container, regulated its motion speed during the carriage movement automatically.

The delivery results at $h_k = 740$ mm (average value) and $L_k = 230, 380$ and 495 mm (minimum, optimal and maximum protrusion correspondingly) are presented in figure 6 (top-down disposition). Herewith the value of parameter «7-01» was 95.

Layer unevenness at the top of the container is provided with the experiment peculiarities:

- the absence of a cross wall at the container top;
- the unloader start was done at the moment the guide plate reached the container top;
- wood dust layer on the loader from the unloading side had an angularity and was situated away from the unloader edge (≈ 50 mm);

The delivery results at $h_k = 550$ mm (average value) and $L_k = 245, 390$ and 505 mm are presented only for the optimal extrusion of $L_k = 390$ mm (fig.7). Herewith, the value of parameter «7-01» was 93.

The analysis of the data presented in figures 6 and 7 displays that for the minimum protrusion the automatics operation is delayed. It results in height increase of wood dust layer over the master profile and considerable decrease of the layer after it.

The maximum protrusion is characterized with the guide plate early actuation in this connection at reaching a pile, the cave is formed in front of it, and while passing it the pouring over takes place.

At the carrier arm height of the guide plate rotation axis $h_k = 735$ mm and optimal protrusion of the guide plate $L_k = 380$ mm the best results on the delivery uniformity (fig. 8): the height values of the obtained layer vary within the limits of 166-206 mm (on an average 188 mm) in comparison with the values within the limits of 155-220 mm (on an average 184 mm) at the parameters of $h_k = 545$ mm and $L_k = 390$ mm.

As compared with the reference delivery into the empty container at frequency $\nu = 50$ Hz (fig. 4) the deviation from lower and upper limits was 11.7% and -1.4% correspondingly, on an average deviation was 5%.

At the final stage «4» to increase the delivery uniformity we carried out the laboratory installation tests at optimally fitted values of parameters $h_k = 730$ mm and $L_k = 385$ mm with the device for leveling the obtained wood dust layer (fig. 9).

The delivery was carried out into the container with the profile produced from wood dust at two values of parameter «7-01»: 95 and 94. In the first case, the unloader stops at the guide plate roller lifting on height 195 ± 10 mm, in the second case, on height 225 ± 10 mm.

After delivery and performing the corresponding measurements the procedure of leveling was done. At that, the lower part of the leveling device was at height 200 mm from the container bottom.

At the value of parameter «7-01», equal to 95, the height of the obtained wood dust layer after the delivery varied in the limits of 150...219 mm (on an average 176 mm), after the leveling—in the limits of 158...201 mm (on an average 177 mm). In comparison with the reference delivery into the empty container at frequency $\gamma = 50$ Hz after the leveling, the deviation from lower and upper limits was -16 % and -3.8 % correspondingly, on an average the deviation was -10.6 %.

Test results at the value of parameter «7-01», equal to 94 are presented in figure 10. The line with marks designates the values obtained after the leveling procedure. Unevenness of the layer near the edge after the leveling is provided with the following: the working width of the leveling device was less than the container width.

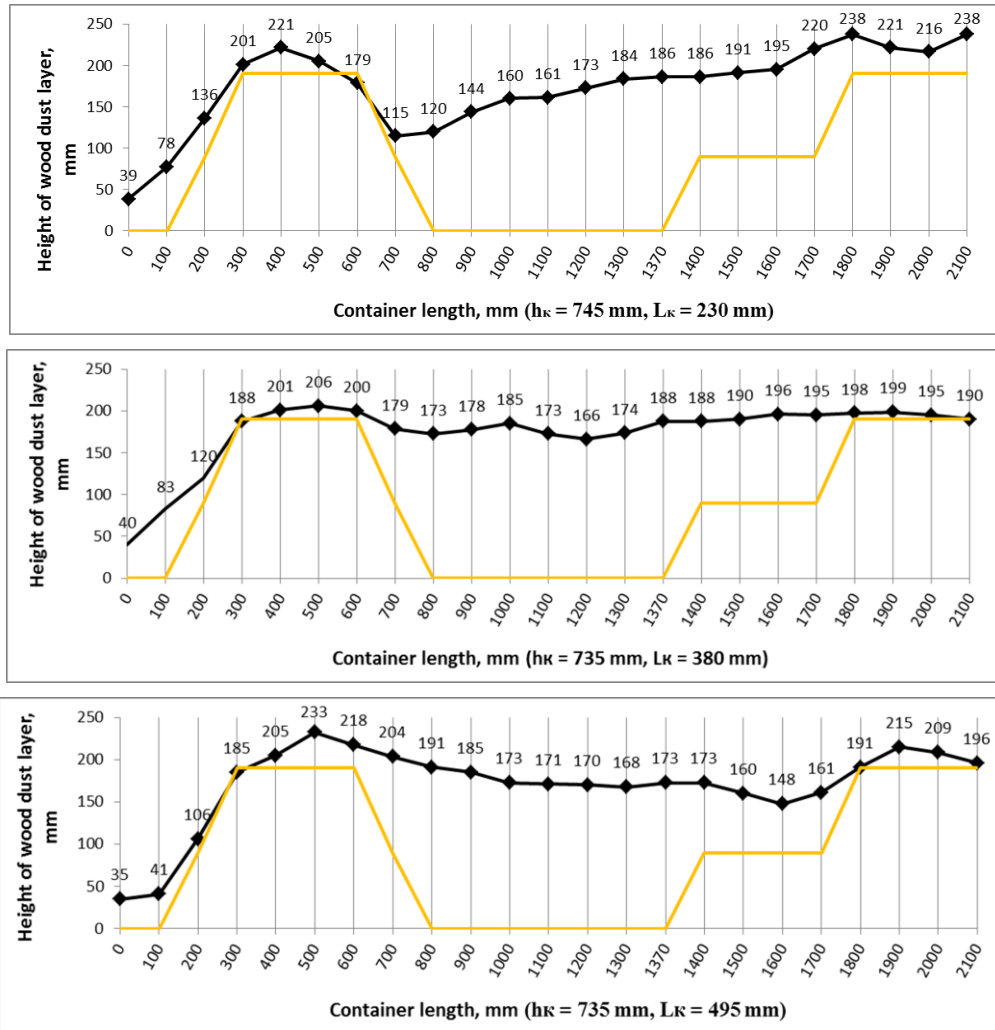


Fig. 6 - Results of height measurements of the obtained wood dust layers after delivery into the container with the reference profile at $h_k = 740$ mm

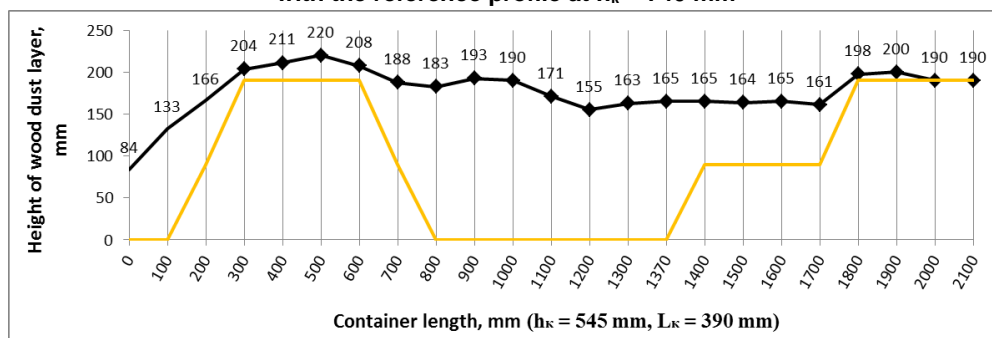


Fig. 7 - Results of height measurements of the obtained wood dust layers after delivery into the container with the reference profile at $h_k = 550$ mm and $L_k = 390$ mm

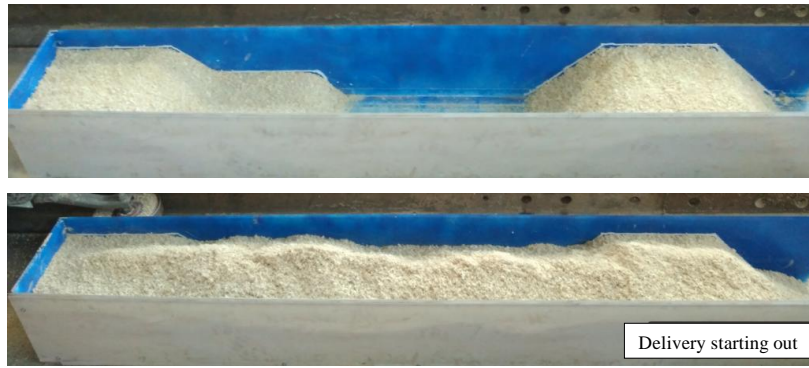


Fig. 8 - Reference profile (top) and delivery results (down)



Fig. 9 - Device for leveling the obtained wood dust layer

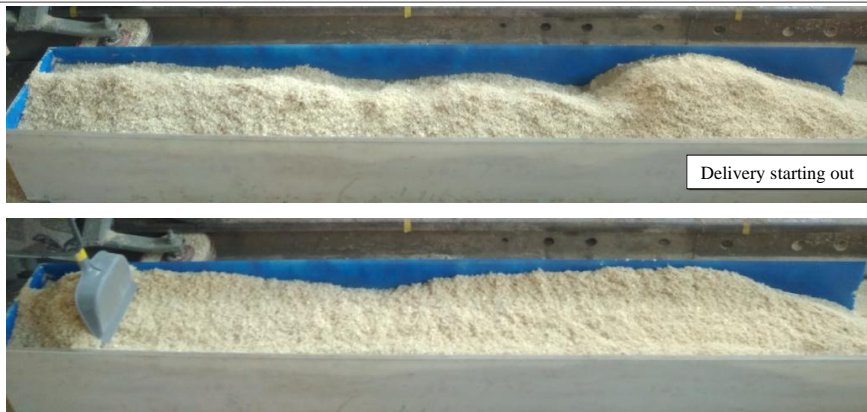
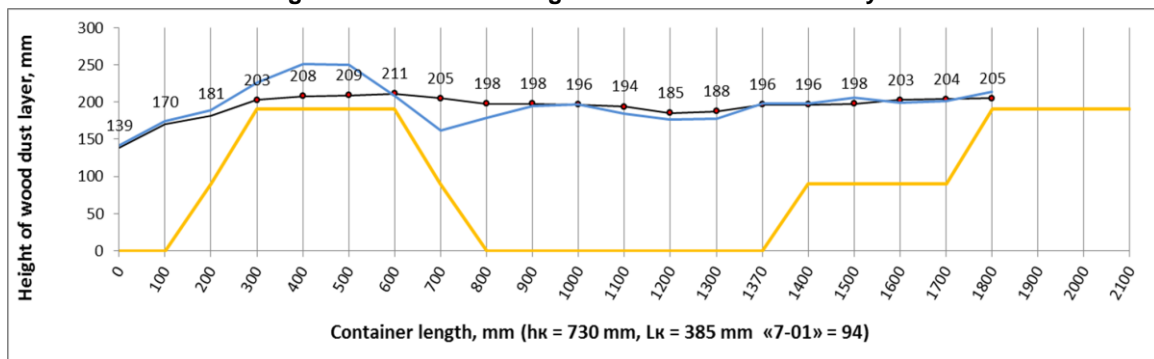


Fig. 10 - Results after the delivery with leveling («7-01» is equal to 94)

The height of the obtained wood dust layer after the delivery varied in the limits of 161-251 mm (on an average 201 mm), after leveling – in the limits of 185-211 (on an average 200 mm). In comparison with the reference delivery into the empty container at the frequency of $\gamma = 50$ Hz after leveling the deviation from lower and upper limits was -1.6% and +1% correspondingly, on an average the deviation was +1%.

CONCLUSIONS

The analysis of the obtained data proves that the suggested system of the automatic change of allowance of the feeding carriage provides its control depending on feed residues amount on the feed table with accuracy of $\pm 1.6\%$ at the selection of the optimal values of the guide plate protrusion, the carrier arm height of its axis of rotation, and at the utilization of the device for leveling and at the corresponding adjustment of the frequency converter. The suggested laboratory installation is a simplified scheme of the feeding carriage. In practice to change feed mixture allowance is necessary, at the account of changing speed of movement of the longitudinal loader, feeding feed mixture to the cross (unloading) loader. The substitution in the laboratory installation of the longitudinal loader control with the cross-loader control does not change the system operation procedure critically, because in the feeding carriage the cross loader feeds the allowance preset on the longitudinal loader. Only the response time to the actuating signal of the guide plate increases. The usage of the frequency converter in the design allows stepless control of allowance, which increases the feeding carriage operating efficiency.

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