Study results of the on-board weight control system as exemplified by feed mixture preparation using a trailed feed mixer-and-distributor

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Abstract. The study purpose is to determine the operational efficiency of the on-board weight control system using the technological process of preparing the feed mixture as an example. The Daily TMR Manager, an on-board weight control system, consisting of communication components, digital indicators with information on the display installed in the operator's cab (of the mixer-and-distributor) and loader operator, and the "Feeding Management" software package were used as a means of controlling the technological process of preparing the feed mixture. The recorded data were transmitted via Internet resources to a cloud storage that provides round-the-clock access to information. The process of evaluating the performance of the weighing system involved loading stalky bulk and loose concentrated components of the feed mixture. Analyzing the evaluation results of the weight control protocols with the recorded data, the authors have determined the influence of human-machine interaction on accuracy, and revealed that the material dosing error increases inversely with the dosed material mass. To improve the operational characteristics of on-board weight control systems it is recommended to install weight sensors on the loader boom to reduce the error when dispensing materials and increase the operator's response speed.

1 Introduction

As the demand analysis for services in the global economy shows, logistics has been one of the most stably growing economic areas since 2008, increasing by an average of 1.1-3.7% per year. This is true for the rate of development of international and regional logistics: especially high dynamics is observed in the areas connecting the central regions of Russia, as well as in the areas connecting the regional centers of Russia with the logistics centers of China and European countries. The development of logistics is facilitated not only by Russia's accession to the WTO, but also by an increase in the international trade of consumer goods as a whole [1].

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Taking into account the above trends, the requirements for cargo transportation are being tightened, especially in recent years. This has affected the transportation of goods along federal roads by truck-type vehicles. The main criterion that tightens the transportation requirements is the amount of cargo weight acting on the trailer chassis and weight distribution along each axis. The considered limitations have made a significant impact on the ways of organizing the transportation of farm produce while performing various technological operations (sowing grain and root crops, forage production, transporting the feed mixture to livestock facilities) [2.11]. As most of the transport logistics stations, including the agricultural ones, are not able to organize weight control points, there is a kind of disagreement between the controlling services and the organizers of transportation. Because of this, many developers offer various technical solutions implemented in the form of automatic on-board weight control systems containing strain-gauge elements fixed between the chassis and the frame of the trailer's filled tank [3].

As such technologies for cargo batching are being developed, the principle of weighing transported materials on board a vehicle has become widely used in the construction industry for making sand and gravel mixtures of exact proportions, sand and cement mixtures, etc. In their turn, farm enterprises apply this method for preparing total mixed rations (typically abbreviated as TMR) using a mixer dispenser [4], where it is necessary to observe a clear ratio of components, the number of which varies from 3 to 7 [5], followed by mixing and controlling the dynamics of the material discharge.

It is worth noting that the introduction of automatic systems operating in an autonomous mode, including on-board weight control systems, requires taking into account the technological features of loading materials [6]. These features largely determine the probability of error in their filling. That is why on-board weight control systems must be equipped with systems for analyzing foreign metal bodies found when harvesting and preparing the feed base [7].

In the course of research, the authors evaluated the effectiveness of the Daily TMR Manager automatic weight control system, taking into account the above factors. The analysis performed made it possible to automatically control the loading of the feed mixture components with a bucket loader, taking into account the requirements of specialists who approve the feeding standards [8]. The research process of the weighing system included sequential supply of materials with remote monitoring of strain-gauge elements using wireless communications and software with neural network algorithms of process monitoring [9, 10, 12]. To ensure a reliable evaluation, the metered materials were evaluated by groups of components (concentrated and bulk ones) [13]. Taking into account the fact that the use of robotic platforms for the feed mixture distribution is gaining popularity every year [14], the dynamic monitoring of feed mixture distribution also increases the relevance of studies of the effectiveness of weight control systems (metering) [15, 16].

2 Purpose of the study

The presented study aims at determining the efficiency of the on-board weight control system using an example of the technological process of preparing the feed mixture.

3 Materials and Methods

To evaluate the effectiveness of the on-board weight control system, the authors analyzed the process of preparing feed mixture (Fig. 1). The mixer dispenser was equipped with the Daily TMR Manager system, consisting of communication components, digital indicators

with information displayed on the scoreboard installed in the tractor operator’s cabin (the control point of the coupled mixer-and-distributor) and the loader operator, as well as the "feeding management" software, operating in accordance with the concept (Fig. 2).

Fig. 1. Machines involved in the research process.

Fig. 2. Schematic diagram of the on-board weighing system operation.

The generated data control protocols based on the loading process results were processed using the MS Excel software package.

4 Results

The report on the results of loading the components into the mixer-dispenser is presented in Fig. 4. It was prepared by monitoring the technological process of preparing the feed mixture using the Daily TMR Manager on-board weight control system, which consists of communication components, digital indicators with information displayed on the board installed in the tractor cab (coupled with the mixer-distributor) and a loader operator.

Archive preparation

Inv. number of the component	Components	Total target weight	Target weight shown in the sensing element	% of correction	Target weight (in light of error)	Loaded	Inaccuracy (%)	Operator's error in weighing (%)
2	Haylage	44.220.00	44.220.00	0.00	44.220.00	45.385.00	2.63	2.66
3	Corn silage	14.580.00	14.580.00	0.00	14.580.00	14.955.00	2.57	2.57
15	Molasses	5.025.00	5.025.00	0.00	5.025.00	5.520.00	9.85	9.85
41	Carrots	4.785.00	4.785.00	0.00	4.785.00	4.335.00	-9.40	58.10
42	Haylage No.10	18.600.00	18.600.00	0.00	18.600.00	19.080.00	2.58	2.63
43	Corn silage No.5	39.380.00	39.380.00	0.00	39.380.00	40.855.00	3.75	5.09
50	Mixed fodder	15.215.00	15.215.00	0.00	15.215.00	17.880.00	17.52	17.65
51	Carnage	7.500.00	7.500.00	0.00	7.500.00	9.735.00	29.80	34.47
		149.305.00	149.305.00	0.00	149.305.00	157.745.00	5.65	8.43

The software is licensed: Russian Federation - Moscow region - Pushkinskiy district01/12/2019

Fig. 3. Data Protocol Form of the weight control system.

The Protocol (Fig. 3) is not editable (Russian-speaking license) - for agricultural JSC "Zelenogradskoe", Moscow region, Pushkin district, village of Eldigvino

Name of the lines: Inv. number of the component; Components; Total target weight; Target weight shown in the sensing element; % of correction (based on analysis results); Loaded; Inaccuracy (%); Operator's error in weighing (%)

The name of the column: Haylage 4; Corn silage 9; Molasses; Carrots; Haylage No.104; Corn silage No.5; Mixed fodder

Using MS Excel software and a data analysis package, the authors have found that when loading concentrated components of a lower mass relative to the bulk ones, the probability of error between the required rate of the loaded material and the mass of incoming material tended to increase.

Fig. 4. Protocol evaluation results of component dosing errors with the Daily. TMR Manager weight control system.

The analysis of the obtained relationship has shown that the wireless communication means transmitting data from the weight system of the mixer-distributor to the loader operator's scoreboard provide information with a delay, which slightly slows down the operator's response. Based on the results obtained, we decided to use the valves of the loader's hydraulic system with an analysis of the pressure exerted on the loader boom. The proposed concept was pre-modeled in the Matlab artificial environment with the Simulink visualization package using the Simscape Hydraulic libraries and the Sinks information processing components, Fig. 5.

Fig. 5. Model of the hydraulic system for measuring the load on the loader boom in the Matlab Simulink environment.

Fig. 6. Weight control components for bucket loaders.

The results assessing the error of filling the feed mixture components into the mixer-distributor are analytically processed and presented in Fig. 7.

Fig. 7. Protocol evaluation results of component dosing errors with the proposed weight control system.

5 Conclusions

1. Based on the study results, it was found that the error in the operation of weight control systems increases inversely with the mass of material being loaded in the loader bucket.
2. Installing calibrated valves that fix the load on the loader boom, which was converted into the mass indicator of the dosed material by means of a programmable controller, allowed reducing the metering error rate.

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