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METHOD FOR RAPID DETERMINATION OF GRAIN LOSS DURING THE COMBINE HARVESTER OPERATION

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Grain loss is the key quality parameter for a combine harvester. Grain loss in a combine harvester depends on the weather, harvesting duration, biometric properties and ripeness of the grain crop, combine harvester parameters, threshing unit process parameters, straw and chaff separators etc. The operator monitors changes of light indications on the display of the trip computer which are related to the level of grain loss of the straw and chaff separator. Grain loss indication however is not read in kg ha^{-1} or %. Grain loss in a harvester is usually subjected to visual control. The existing methods for grain loss determination of the combine harvesters are time- and labour-intensive. The method for rapid determination of total grain loss of the combine harvester and separately of the header proposed in this paper helps the controller to control the combine harvester performance and verify the actual grain loss (in kg ha^{-1}) against the light indications on the combine harvester computer display.
Grain crops, combine harvester, harvesting, grain loss, method for determination of grain loss

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INTRODUCTION

Grain crop harvesting involves use of combine harvesters with either a straw walker or axial threshing separating unit. Performance of a combine harvester with a straw walker is restricted by the limit feed rate of grain crop mass and its composition, while a combine harvester with an axial threshing separating unit is limited in its performance by the moisture content of the threshed mass. Grain loss is one of the key quality parameters of a combine harvester. Grain loss is determined by weather conditions, harvesting duration, biometric indicators of the grain crop, thresher and straw separator process parameters (Fig. 1).

During harvesting with grain harvesters, grain loss of the straw walker and separation system is controlled. The permissible limit of grain loss in harvester according to agro-technical requirements is 0.5 %, while in case of unfavourable conditions – 1.0 % [Špokas, Žebrauskas, 2013].

During harvesting, combine harvester performance must be subject to regular control every 3…4 hours [Koval, 1991] as well as upon sudden variation of harvesting conditions. Control of grain loss of the straw walker or separation system is performed manually (Fig. 2).

The harvester throw down the straw on field in windrows the straw chopped by the chopper is thrown by two disk rotors along the header width. Where the straw is placed on the field in wide windrows, the long box (Fig. 2, *a*) rests on the stubble-field behind the rear wheels 5 times [Feiffer, 1975, Špokas, 1988]. Calculation of the quantity of free grains in the boxes is performed by determining the grain losses of the straw walker or separation system only where the drive of chaff spreader disks is disconnected. This method for grain loss determination is used in scientific research only. Grain calculation in boxes is time-consuming, and the boxes are fairly costly. Short boxes (Fig. 2, *b*) are placed under the combine harvester by the specialist next to the steerable wheel. The minimum of 5 boxes is required. This method is also time-consuming, and finding the box under the straw windrow is rather complicated. This method is applicable only for combine harvester performance control by specialists [Feiffer, 2002].

One box may be attached to the holder (Fig. 2, *c*), and the operator is able to release the box using the electric driving gear. After the combine harvester is brought to a stop, the quantity of free grains in the box is calculated and grain loss is determined in kg ha^{-1} according to table [Feiffer, 2005]. For reference, random data do not reflect actual combine harvester grain loss.

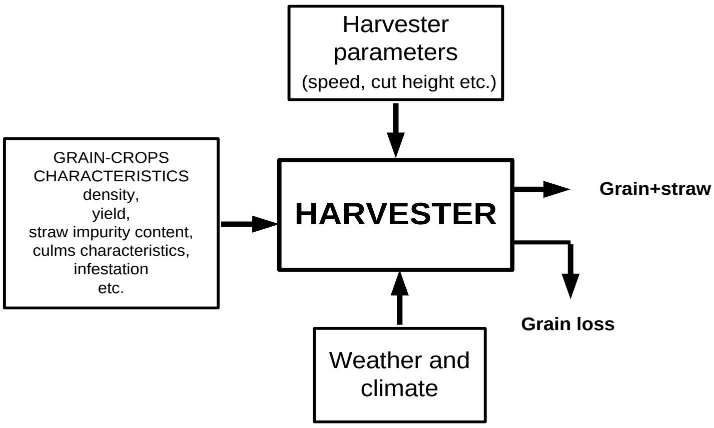
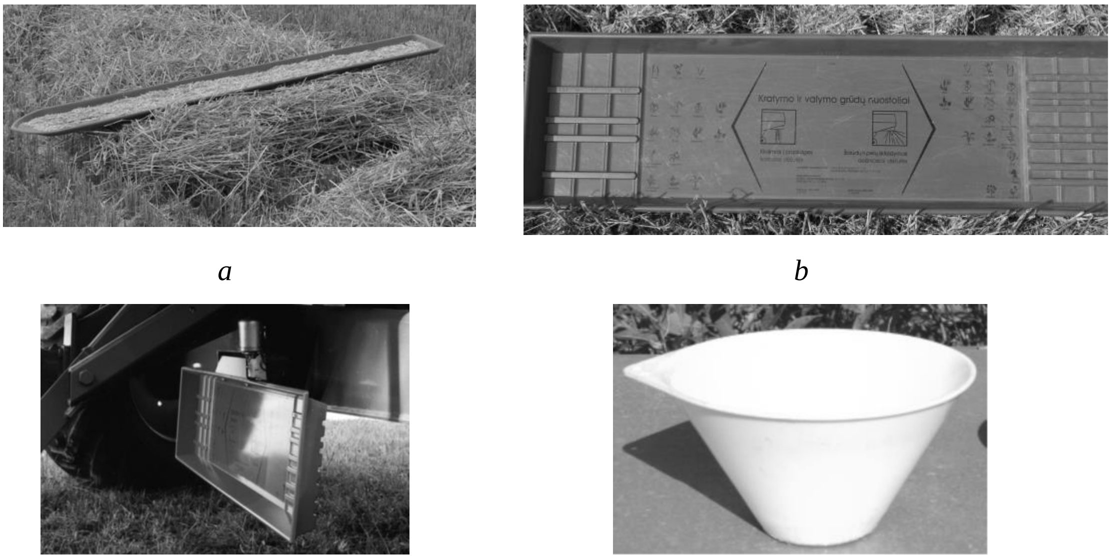


Figure 1. Factors influencing the cereals threshing process



a *b*

c *d*

Figure 2. Instruments for determination of grain loss of the combine harvester: *a* – box, 1.9 m long, *b* – box, 1.0 m long, *c* – suspended box, *d* – conical cup

Methodology and instruments developed at Aleksandras Stulginskis University are used in determination of grain loss of straw walker and separation system during straw shredding [Spokas et. al., 2013]. During movement of the combine harvester, two cut circular cone-shaped cups having the area of 0.0213 sq. m (Fig. 2, *d*) are placed under the combine harvester: one cup – next to the steered wheel, another – at one meter distance to the wheel, and subsequent cups – at one meter intervals between them. Grain quantity is determined for each cup, followed by determination of mean value, and then – calculation of grain loss in kg ha^{-1} of the straw walker and separation system under the formula. Grain loss of the straw walker and separation system of the combine harvester may be determined by an agronomist or another farm employee. This method, however, is not acceptable where straw is placed into windrows.

Grain loss dynamics of the straw walker is registered by the sensors located at the end of the two keys, while grain loss dynamics of the separation system is registered by the sensors located outside the top adjustable sieve [Drozhzhin, 1984, Myronenko, 2006, Dimitrov, 2011, Smolinskiy, 2012]. The operator is notified on increase or decrease of grain loss of the straw walker and separation system by two light indication columns on the trip computer screen. The column height changes along with the change in combine harvester movement speed and are not related to grain loss in kg ha^{-1} or %.

Aim of the research – to provide the rationale behind the method for rapid determination of grain loss during combine harvester operation.

RESULTS AND DISCUSSION

Simplified system of equations is proposed for analysis of grain loss dynamics of the combine harvester:

$$\begin{cases} \frac{dp_1}{dt} = \frac{dq_0}{dt} + q_0\lambda_1 - p_1\left(\lambda_1 - \mu_1\right), \\ p_2 = \frac{1}{\mu_2}\left[q_3\lambda_3 + q_4\lambda_4 - q_5\lambda_5 - q_6\lambda_6 - \frac{dq_5}{dt} \right], \\ p_3 = \frac{1}{\mu_3}\left[q_2\lambda_2 - q_4\lambda_4 - \frac{dq_4}{dt} \right], \end{cases} \qquad (1)$$

and the following equation is proposed for grain balance in the combine harvester:

$$q_0 = q_5 + p_1 + p_2 + p_3, \qquad (2)$$

where q_0 - feed rate of grain to harvester header, kg s^{-1}; $q_1, q_2, q_3, q_4, q_5, q_6$ – feed rate of grain from header to thresher unit (1), from thresher unit to straw walker as free grain (2), from thresher unit to separation system (3), from straw walker to separation system as free grain (4), from separation system (unit) to grain tank (5), from separation system to thresher unit as unthreshed ears (6), kg s^{-1}; p_1, p_2, p_3 – grain loss of the header (1), separation system (2) and straw walker (3) of harvester, kg s^{-1}; $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ – feed rate intensity; μ_1, μ_2, μ_3 – grain loss intensity, s^{-1}.

The analysis of grain loss dynamics has provided rationale behind the algorithm for grain circulation control in the combine harvester and its relation to the grain loss. To implement the algorithm, a series of various data on grain loss of the combine harvester is required.

Method for rapid determination of grain loss of the combine harvester has been developed and pilot tested. Occasionally, before or during barley crop harvesting certain share of ears result on the ground under the action of strong wind or heavy rain. Grail loss is determined using 5 mm wire frame 0.01 sq. m (10×10 cm). The frame is placed on the field 5 times. The expert picks up the grains and ears on the frame area. The ears are threshed and calculated, and real grain loss is calculated under formula (3). The real grain loss must be eliminated from the total grain loss of the combine harvester and header.

Grain Loss of the Header in the Case of Straw Windrows. Following passage of the combine harvester, the frame (0.01 sq. m) is placed chequerwise on stubble-field (between the side-frame of combine harvester and the band edge of header) five times. Free grain and grain containing years are then picked (grey ears are not picked) by the controller. Grain is extracted from ears manually, and the average quantity of grains per 0.01 sq. m is calculated. Grain loss (kg ha^{-1}) of the header is calculated according to the following formula:

$$N = a \ A \qquad (3)$$

where a – average grain quantity per 0.01 sq. m frame area; *A* – mass of 1000 grains, g.

Total Grain Loss of the Combine Harvester (chaff and straw fall onto the stubble-field from the top sieve). The controller removes the straw off the 0.5 m section of the straw windrow manually and casts it away. The frame (area 0.01 sq. m) is placed on the stubble-field without straw 3 times, and average quantity of grain per each area is calculated. Grain loss in kg ha^{-1} is calculated according to:

$$N_1 = \frac{a\ A\ b}{B} \qquad (4)$$

where b – straw windrow width, m; *B* – header width, m.

This method is used only for determination of grain loss of the header and straw walker, during operation of the drive of two disks for the chaff scattering. Grain loss (kg ha^{-1}) is calculated according to formula (4).

Grain Loss in the Case of Chopped Straw Spreading. Total grain loss (of the header, straw walker and separation system) is calculated. After passage of the combine harvester, the controller places the frame on the stubble-field five times: two times – on the axial line of harvester, one time – next to the rear wheel, at 1 m and 2 m distance to the steered wheel. Grains are collected from each frame area, and average number of grains per 0.01 sq. m is determined. Grain loss in kg ha^{-1} is then calculated according to the formula (3). For header width over 6 m, the frames next to the wheel are located at the distance of 1.5 m relative to previous frames.

Threshing Grain Loss. In case the straw is placed in windrows, 50 ears are picked three times at different locations of the straw windrow. The ears are then threshed manually, and average number of grains per 50 threshed ears is calculated. Afterwards, grain loss from unthreshed grain in kg ha^{-1} is calculated according to:

$$N_3=0.0002ka_1A \qquad (5)$$

where k – average number of culms with ears per 1 sq. m; a_1 – average number of grains in 50 threshed ears.

Experiments have demonstrated that application of the proposed methodology on grain loss determination of the combine harvester offers considerable time savings related to specimen sampling and processing, with the data accuracy higher by 25% compared to the existing methodology.

CONCLUSIONS

1. The existing methods for determination of grain loss of the combine harvesters are time- and labour-intensive. Combine harvester performance is assessed during scientific research only. In actual production conditions, their performance is subject to visual control.
2. The proposed method for rapid determination of total grain loss of the combine harvester and separately of the header proposed in this paper helps the controller to control the combine harvester performance and verify the actual grain loss against the light indications on the combine harvester computer display.

REFERENCES

[1] Dimitrov V. P., Kataev V. S., Markov I. A., Tishin A. S. About automation of quality control in combine harvester. State and prospects of development of agricultural engineer: materials of international scientific conference. Rostov n/D, 2-3 th of March. 2011. p. 226-229. (in Russian).

[2] Drozhzhin N. V. Technological and structural parameters of sensor for grain loss continuous control in combine harvester. Novosibirsk. 1984. - 21 p. (in Russian).

[3] Feiffer P. Accumulator of knowledge harvesting. VEB the German publishing house of agriculture of Berlin. 1975. – S. 383 (in Germany)

[4] Feiffer A. Grain harvesting by loss and harvesting problem. Nordhausen. 2002. – 36 S. (in Germany).

[5] Feiffer P., Feiffer A., Kutschenreiter W., Rademacher T. Grain harvesting – cleanly, reliably, quickly, 2005. – 44 S. (in Germany).

[6] Koval' S. N. Enhancement of assessment methods for agrotechnological efficiency and structural parameters of combine harvesters by testing. Glevakha. 1991. - 21 p. (in Russian).

[7] Mironenko V.G. Scientific and technical bases of development of facilities of mechanization with the guided quality of implementation of technological processes in a planting. 2006. – 398 s. (in Ukrainian).

[8] Rademacher T. Methodology to quality measuring and productivity-loss-function of combine harvester on the fields conditions. VDI-MEG Colloquium Agritechnik. Harvester. 2013. – 40. S. 83-94. (in Germany).

[9] Smolinskiy S. V. Grain loss control during the grain harvesting. Papers of the National University of Life and Environmental Sciences of Ukraine. - 2012. 170(2). - S. 207-213. (in Ukrainian).

[10] Spokas L. I. About grain harvesting . Grain-crops. 1988, - p. 28-31. (in Russian).

[11] Spokas L., Bulgakov V., Zhebrauskas G. Feature of winter rape harvesting in the combine harvesters. Collected papers Mechanization and electrification of agriculture. - 2013. - Issue 98. - p. 474-484. (in Russian).

[12] Spokas L., Zhebrauskas G., Smolinskyy S. Methodology for determination of grain loss in the harvester. Collected papers Mechanization and electrification of agriculture. - 2015. - Issue 2(101). - p. 295-302. (in Russian).

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