TRENDS IN THE DEVELOPMENT OF ROLL BALER AND BALER WRAPPER MACHINES FOR THE PRODUCTION OF HAYLAGE

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Abstract: *The paper presents an overview of the solutions used in modern machines for the production of haylage such as round balers and balers. Discussed elements of systems enabling monitoring the process of bales formation and influencing its course, to improve the quality of obtained silage and increase the efficiency and ergonomics of the machine's operation. Trends of development and reasons for increasing functional integration into single machines were determined. The paper was created as a result of cooperation between ŁUKASIEWICZ Research Network – Industrial Institute of Agricultural Engineering and METAL-FACH sp. z o.o. company located in Sokółka, Poland.*

Keywords: ROLL BALER, BALER WRAPPER, VISION SYSTEMS, CROP MEASUREMENTS, PRECISION FARMING

1. Introduction

In the production of roughage, the production of silage is more rational than previously spread hays drying. This is supported by lower dependence on weather conditions and lower losses in nutrients. In Western European countries, the production of dry hay began to go away already in the sixties. Currently, in these countries, the percentage of silage in the fodder balance of ruminants is 80 ÷ 90%, while hay, which is mainly produced for calves – 10 ÷ 20 %.

An increasingly popular form of the grassland fodder preservation is ensiling them in cylindrical bales wrapped in foil. The profits from such technology are so large that in most cases animals are given food in which haylage predominates through all of the year [1]. However, the preparation of a suitable product requires the use of specialized machines such as roll presses (fig. 1) and wrappers.

Fig. 1 *High-performance silage roll press by Metal-Fach company [7]*

Along with the development of automation and vision systems in agriculture [2], modern solutions are also applied to roll balers and bale wrappers. They are aimed primarily at increasing the efficiency and quality of the product obtained. This is achieved by intelligent control basis on yield and production monitoring, and by integrating all function in a single machine.

2. Constant swath monitoring

The optimal dose of silage additives depends on the parameters changing during operation. The dose is determined in relation to the weight of the swath, its moisture and temperature. By applying continuous crop monitoring and changing the applicator settings, reduction of consumption of additives and improvement of the final product quality can be achieved. Knowing the size and shape of the swath some automation for property mass flow of swath can be done. That can be useful to make it easier to obtain a proper bale structure for the machine operator.

In field conditions, the size of the harvested swath is variable. 3D sensors can be used for its measurement (fig. 2), the action of which is based on observation of infrared points emitted by the illuminator. Advanced camera types allow measuring the exact distance to the points from the camera in each direction. Additional software allows for processing of the information acquired. The advantage is the possibility of transmitting the image in the visible spectrum, using the camera as a monitoring camera.

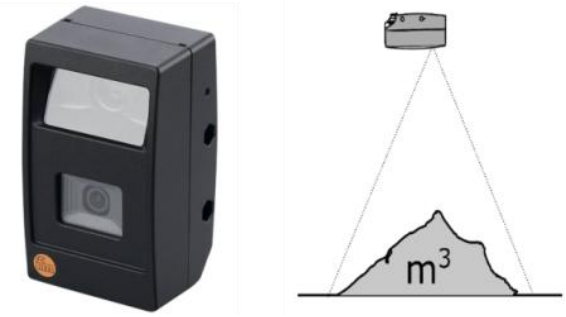

Fig. 2 *3D sensor O3M251 by IFM Electronic company [8]*

Measurements of the swath can also be made with the help of contact sensors, whose example solution developed in the Industrial Institute of Agricultural Engineering is shown in the fig. 3. Measurement according to the position of the kneading roller, where the cross-section of the swath under the embankment is approached to the trapezoid and its cross-sectional area is being calculated. The determination of the size of the swath takes place by reading the height of the shaft suspension points. This simple solution determines the application of fuzzy logic in determining the amount of swath (a lot, low, average).

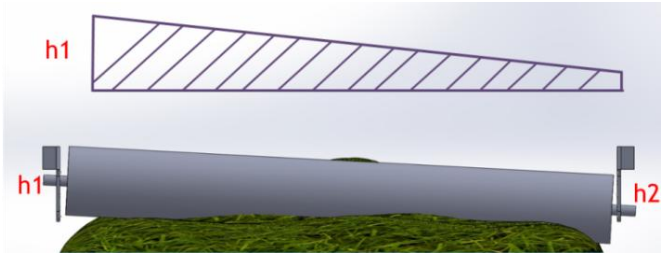

Fig. 3 *The concept of swath measurement based on the position of the kneading shaft / Source: own work*

The measurement of humidity in the mass flow of the swath can be carried out using several methods. One of them is the electric method, in which the humidity is determined on the basis of water tightness between the electrodes. The readings are accurate from 7 to 70% humidity. Conduction depends on the ions in the water that conduct electricity. These ions come mainly from mineral salts in hay or feed and may vary, so it is necessary to perform calibration. In the solution shown in fig. 4, the voltage between the electrodes placed at the ends of the feeder in the inlet zone of the

winding chamber is measured. The voltage drop indicates the degree of humidity given to the winding of the material.

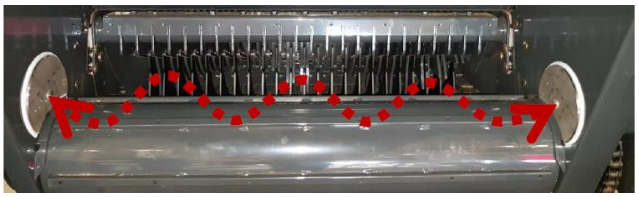

Fig. 4 *Device for measurement of the moisture of hay in a round baler [10]*

3. Haylage production monitoring

In modern machines, systems for measuring the degree of material crumbling and weight tracking are becoming more and more common. They make it easier to roll up bales of constant weight, regardless of the humidity of the collected mass. This prevents situations in which too much weight of the bale causes overloading of the structure. It is also important to adjust the weight of bales to the possibilities of machines used for harvesting them like for example front loaders [3].

The grade of swath pressing depending on the design of the press can be monitored by measuring the pressure on the damper cylinders (fixed chamber presses) or string tension (variable chamber balers). The momentary pressures from the left and right side of the chamber can be transmitted through visual and audible indicators as well as to the integrated control system enabling the conductive compensation of the driving method (example fig. 5).

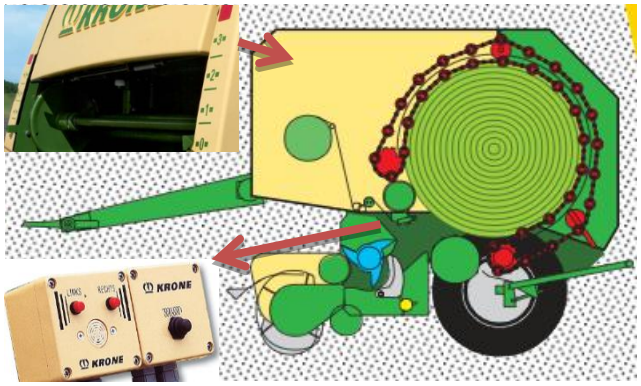

Fig. 5 *Grade of swath pressing monitoring used on Krone machine [9]*

Bale mass measurement can be carried out by tensometric force sensors between the press chamber and the axle of the chassis. However, this solution requires the proper filtering of disturbances caused by dynamic system changes. An exemplary signal waveform from the force sensors subjected to filtration as part of the studies carried out in the PIMR is shown in fig. 6.

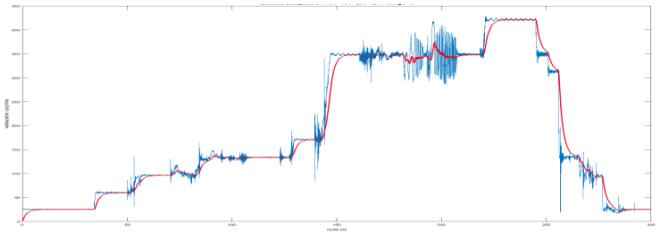

Fig. 6 *Filtration of disturbance signal waveform from a tensometric force sensor / Source: own work*

4. Marking of the final product

An important aspect in the production of haylage is the proper marking of ready-made bales, enabling product identification. It is also beneficial to code additional information obtained from the monitoring system. There are many applications for such information - from industrial labeling to the use of specialized bale printers.

Due to the limitations of classic bar codes, two-dimensional codes are becoming increasingly important. These codes allow recording a much larger amount of information. Improved error correction mechanisms applied in them ensure an effective reading of codes despite their damage. An example of coded information in QR codes is shown in fig. 7. On the left there is coded information about the bale identification number, for example 123456789, right-coded information with harvest date, humidity and material temperature, for example, date 21/04/2019, humidity 20%, temperature 15 °C.

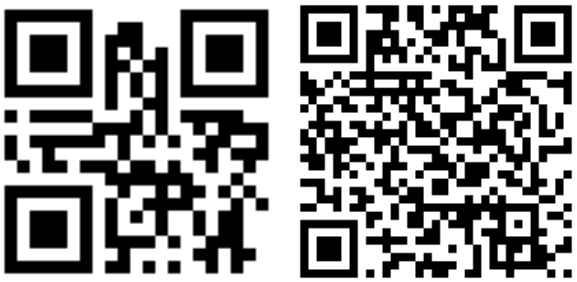

Fig. 7. *Examples of coded information in QR codes / Source: own work*

5. Integrated Baler Wrappers with the intelligent control system

Strong pressure to reduce costs and increase productivity is driving farmers and service providers around the world to use efficient multi-tasking machines. In response, the manufacturers of the machines began offering press-ironing machines that combine two traditionally separate functions - rolling and wrapping combined into one device. Modern balers and wrappers are equipped with an element of intelligent control, using previously described monitoring systems of harvested crop and processes carried out by the machine, with the support of indications with a precise GPS system positioning installed on the machine or tractor.

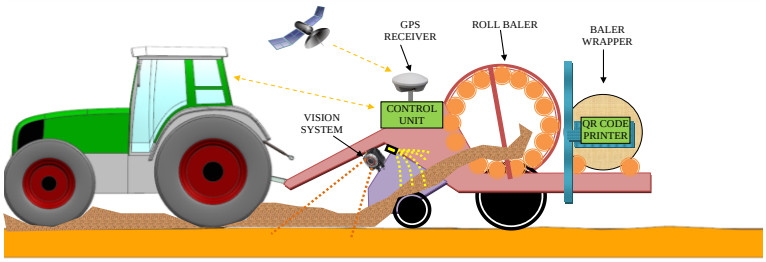

Fig. 8. *Roll baler and baler wrapper-combination for harvesting roughage in round bales with systems of monitoring and impact on the process of its production / Source: own work*

An example of such a solution is the innovative roll baler and baler wrapper-combination created as part of the project POIR.04.01.04-00-0067/18 for harvesting roughage in round bales with systems of monitoring and impact on the process of its production (fig. 8). When designing an integrated machine, advanced computer tools are used [4, 5], which guarantees its future strength and reliability. Thanks to the use of such solutions as the system facilitates the operator to obtain an even flow of harvested plant mass and a system of variable dosage of silage additives, depending on the properties of plants and machine working conditions, will not only improve the quality of produced feeds, reduce the number of field trips and fuel consumption. Thanks to the cooperation of monitoring systems with the GPS system, it will be possible to obtain data that can be used to create digital maps showing the condition of the field (example on fig. 9), which play an important role in the increasingly popular precision farming systems.

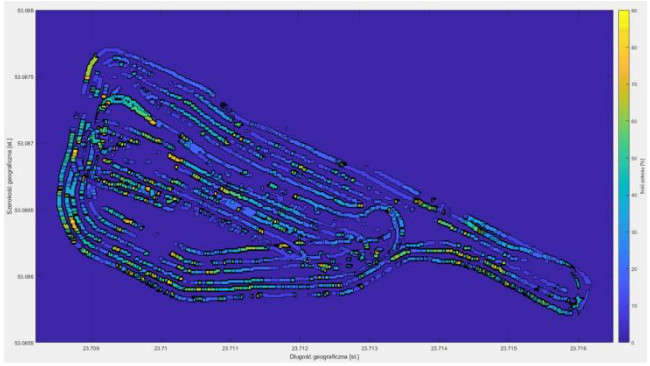

Fig. 9 *Example of forage yield map [6]*

6. Conclusion

Modern machines used for harvesting of the plant material for silage from the field are increasingly equipped with systems enabling monitoring of processes related to intelligent control systems. These solutions make it possible to improve the quality of obtained silage and increase the efficiency and ergonomics of these machines. The use of such solutions reduces the use of silage additives in the production of haylage, increases the harvesting efficiency and decreases fuel consumption. In addition, the information collected during work can be used to generate qualitative-quantitative precise yield maps.

7. References

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