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Grain loss detection in grain pre-cleaning devices

The piezoelectric grain loss detection has been established for mobile machinery, and is also suitable for process monitoring of grain pre-cleaning. For this purpose, an acceleration sensor measured vibrations of the grain impact of a baffle plate and converted it into an electronic signal which is proportional to the loss. A variety of pre-cleaners, that on the market today, are not electronically controlled or regulated, and a feedback from the loss to the control unit is not provided. The characterization of the sensor system was performed on the new test rig with a grain dose unit. Numerous measurements with different species of crop verify a deviation in the relevant range of less than 3 %.

Keywords

Grain loss, grain pre-cleaner, acceleration sensor, test rig, cleaning system, detection

Abstract

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Farms often use pre-cleaning for grain storage today, mainly devices like an air separator, **Figure 1**, which is a simple and inexpensive way and works at a fix fan speed with a constant air throughput. This enables the separation of material other than grain (MOG), whose floating state is achieved at a lower flow velocity than the one of crop [2].

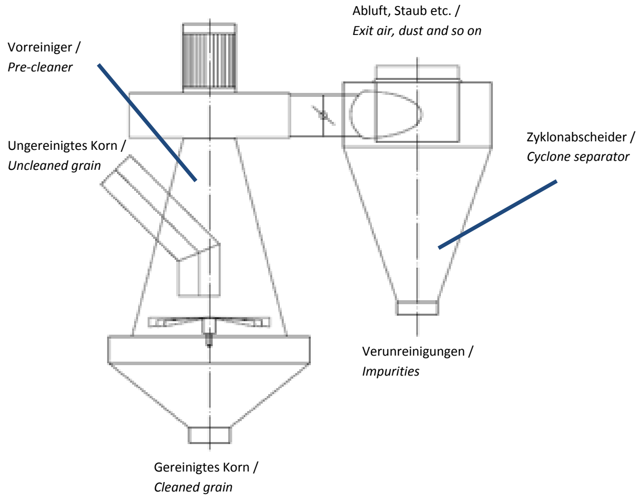
Today the pre-cleaners has only an adjustable throttle flap at the air output to regulate the air velocity in order to increase the cleaning/separation quality. But the reality shows that a regular control of the cleaning process and thus a grain loss control is rarely exerted. Changing crop and oil seed characteristics such as humidity, percentage of impurity and foreign matter as well as the thousand grain weight, require a flexible and independent adaption of the cleaning parameters to the actual circumstances. On this base a grain loss sensor will be integrated in the output air flow of the grain pre-cleaner to make the grain loss directly measureable as a process quantity and to return the information to the cleaning control. The Institute of Agricultural Engineering of the University of Hohenheim developed and mounted a special test rig [1] to examine suitable grain loss sensors.

The analysis of the given boundary conditions in the pre-cleaner like:

- Running in extreme dust
- Oscillations due to the fan
- Low cost of the pre-cleaner

helps to understand, that piezoelectric acceleration sensors suits well for grain loss detection in pre-cleaners, because they are solid, insensitive to dirt/dust and very reliable. A sensor was examined, which is a part of the CLAAS Lexion combine harvester for grain loss detection. In the combine the lost grains touching the sensor are registered absolutely and referred to a

Fig. 1



Grain pre-cleaner with additional cyclone separator (Photo: Fa. Schmelzer, Waldershof) neutral point fixed by the driver. This application will be used for the grain loss detection in pre-cleaners here.

Theoretical preliminaries

The physical characteristics of the material mixture in the output air flow of a grain pre-cleaner vary strongly. The main constituents are: grains of the crop, broken grains, shrivelled grains, and material other than grain (MOG), like for example chaff, short straw, insects, dust and seed of accompanying herbs and grasses. To specify the variable grain loss that is to be detected, a distinctive feature has to be found, which only characterizes the grain of the crop as a grain loss. For this purpose the corn mass is the right feature, because the oscillation amplitude of the baffle plate of the used grain loss sensor depends mainly on the impulse of a grain when striking the plate. The acceleration sensor converts the oscillations of the impulse detector into an amplitude proportional voltage and shows it as a measurement signal. If the constant speed of the striking constituents is guaranteed, the amplitude of the measurement signal can be interpreted. Thus an intact grain of the crop can be detected as a lost grain with high probability. First it is assumed that the lost grains are the constituents with the highest single mass in the output air flow of the pre-cleaner causing the strongest impulse. Therefore the first step is to define only a voltage limit which triggers the detection of a lost grain if exceeded. This procedure implies the use of a specific voltage limit for each crop, which must be determined by calibration. Further tests are planned to verify the functionality of this measuring system.

To compare the measurement results and to draw conclusions regarding sensor behaviour, special estimation variables must be introduced for this measuring system. The following estimation variables are defined: the signal strength σ is calculated with the signal value $|y|$ with a sliding arithmetic average over 1000 single measured values, with a sampling rate (scanning frequency) of 1 kHz and represents a non proportional variable linked to the oscillation amplitude, because the sensor signal vary within the range of measurement [3].

$$\sigma = \overline{|y|}$$

The signal strength depends, at a constant range of averaging and a constant sampling rate in a quasi stationary (steady-state) operating point, on the position of the sensor as well as on the physical characteristics of the material. Therefore the signal strength, as a relative variable for the crop flow guided over the sensor, allows extensive conclusions regarding the detectibility of single grains.

The grain detection efficiency η_D is introduced for the estimation of the single grain detection as a product of the identification efficiency η_E and the striking efficiency η_A. The identification efficiency indicates how many grains striking the sensor are really recognized by the software. The striking efficiency indicates how many of the grains that have to be detected strike the sensor.[3].

$$\eta_D = \eta_E \cdot \eta_A = \frac{K_D}{K_0 - K_V} \cdot \left(1 - \frac{K_V}{K_0}\right) = \frac{K_D}{K_0}$$

The quantities necessary for the definition are shown in **Figure 6**. With the test rig for grain loss detection, the number of grain that is to be detected K_0 can not yet be measured. Because a lot of time would be involved, the grain detection efficiency is set approximately with the thousand grain weight and the mass determined at the test rig.

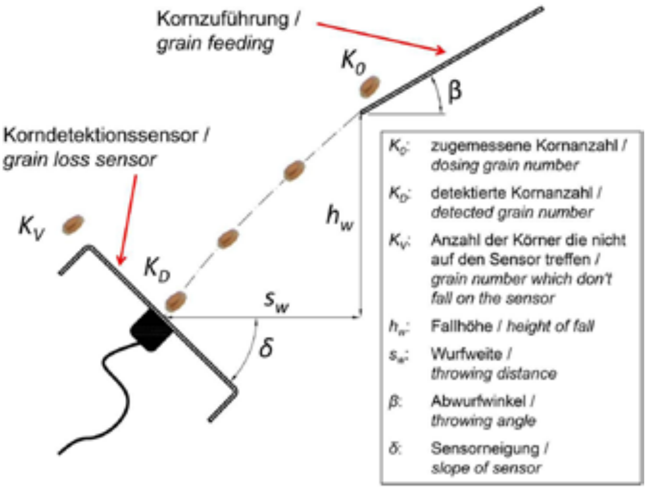
Design of the test rig

The following conditions must be satisfied to characterize the chosen grain loss sensor: reproducible boundary conditions, local independence and a variable but precisely known crop dosage. These requirements are impossible to meet regarding the mounting of a sensor in a grain pre-cleaner. Therefore it is necessary to run a test rig. **Figure 3** shows the design without the measuring technique. The values determined with the test rig are recorded under idealized conditions and allow only conclusions regarding the behaviour of the sensor in a grain pre-cleaner [3].

A rotary feeder, with adjustable speed, takes the crop out of the hopper above and transports it to the cascade below. The cascade effects two things: the distribution of the crop flow transversal to the rotary feeder extending beyond the width of the rotary feeder and it levels the crop flow peaks in the direction of the crop flow produced by the intermittent crop output of the rotary feeder. Below the cascade is mounted the grain loss sensor, which is adjustable vertically, horizontally and in inclination. A box on a precision scale is positioned under the sensor. By differentiating the signal with the scale, it is possible, considering the running time, to assign a momentary mass flow to each signal of the sensor. This enables to calculate the number of grains passing the sensor, considering here the thousand grain weight and the percentage of impurity and foreign matter. So it is possible to determine, at any time, the percentage deviation of the sensor measurement from the calculated value. The signals are processed with the software DayLab 11. The signals are read in and conditioned with the operators described above. **Figure 4** shows the signal processing.

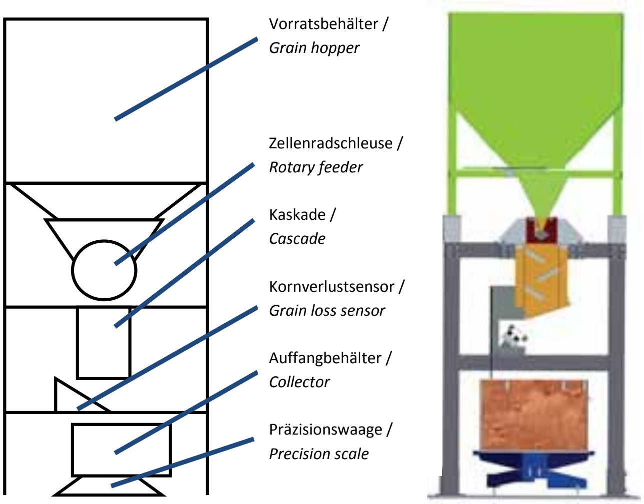
First the ideal position of the sensor must be found to guarantee the grain loss detection. It turns out that the height of free fall between cascade and sensor centre should be between 120 and 180 mm. Shorter free fall reduce the impulse of smaller grains and therefore they get even more difficult to be detected. Longer free fall makes the detection easier but the rate of grains hitting the sensor decreases due to the widening scattering cone. The vertical position of the sensor is directly related to the free fall height because of the law of inclined throw. The ideal inclination of the sensor can be found by maximizing the signal strength σ at a constant crop flow. At the moment of maximum amplitude, the grains hit the sensor exactly vertical to the sensor surface which creates the maximum impulse.

Fig. 2



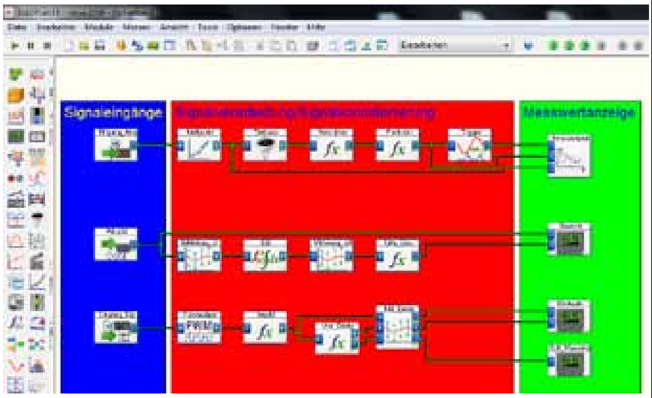
Evaluation parameters of the grain loss detection

Fig. 3



Test rig

Fig. 4



Signal processing of the grain loss detection

If there is a correlation between the sensor signal and the crop flow, then the sensor can be used as a quantitative measuring device. To find and prove this causal relation, quasi stationary measuring points are tried with constant rotary feeder speed. The grain quantity detected within a certain measuring time is then related to the sensor signal.

Another option for grain loss detection is the detection of single grains. Difficulty regarding this method is the precise distinction of shrivelled, broken and lost grain. This can be solved with a mathematical algorithm for the signal interpretation of the amplitude of the sensor signal. To verify the precision of measurements again quasi stationary measuring points are tried and related to a calculated value.

Results

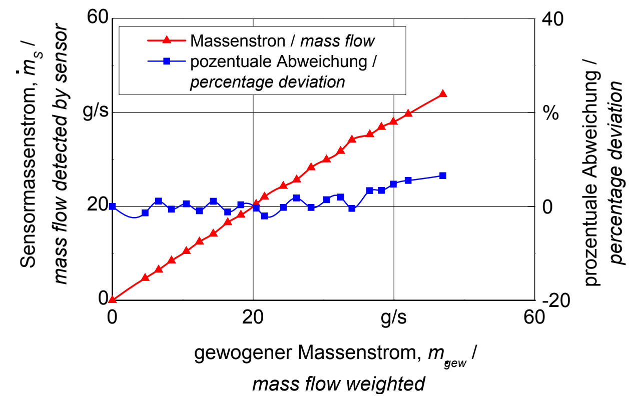
A nearly linear correlation exists between the crop flow measured by the grain loss sensor and the weighed crop flow (**Figure 5**). The deviation percentage for a mass flow under 35 g/s is ± 3 %. This is a precise result using the described measuring method, but presupposes the use of a crop specific proportional constant. For the use in the grain pre-cleaner it is possible to store these parameters in a performance data map of the control device to make them available according to the crop type and the conditions. Disadvantage of this signal interpretation method is the difficult distinction between shrivelled, broken and lost grain when working with high crop throughputs. All the parts of the crop flow are registered, except the light MOG. The subtraction of a correction value could be helpful but requires a well known and constant composition of the crop flow passing the sensor. To achieve this, another sensor to determine the composition of the crop flow would be necessary.

Here the question arises, if the MOG, shrivelled and broken grain even pass a grain loss sensor positioned after pre-cleaner and cyclone. With a high cleaning performance of the unit, the grain loss can be determined with the measuring method described above.

A third option for grain loss detection is the single grain detection, which is more suitable for the application in pre-cleaners because it is possible to distinct the grain components. The quality of this detection type depends mainly on a thousand grain weight specific calibration. Due to the amplitude depending on the impulse of the hitting grain, it must be exactly determined at what impulse the detection of a single corn will be triggered. **Figure 6** shows the sum of the detected number of grain as a function of the detected grain mass for the different throughputs. The references are the sums calculated with the grain mass and the thousand grain weight without considering the foreign matter.

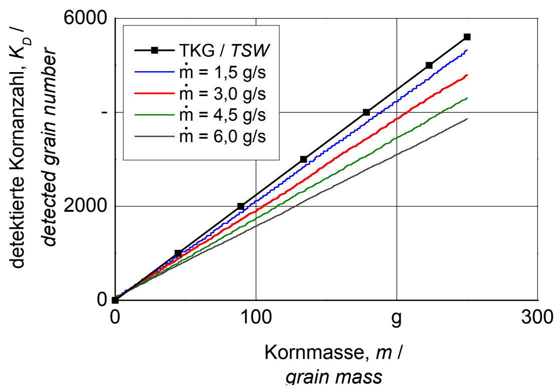
This explains the steep curve shape, because the existing but unknown quantity of foreign matter is also part of the calculation of the grain number. Clearly to see is that the detected grain number decreases with a higher grain mass flow at a constant grain mass. With an increasing grain mass throughput,

Fig. 5



Relation between the sensor mass flow and the weighted mass flow

Fig. 6



Correlation between detected grain number and grain mass

the number of grains hitting the sensor plate per time unit increases as well. This leads to the superimposition of the signal amplitudes triggered by the strike of each grain. If the oscillation amplitude cannot be free or is superimposed by others, it is not possible to detect singles grains following one after the other in a short time period. Especially with increasing grain mass flow, the sensor is not suitable to precisely detect single grains. But what kind of measuring accuracy is necessary to control the grain loss in a pre-cleaner? The inertia of the system is very high starting at the adjustable flap, then the adaption of the fan speed and finally the control of the grain loss in the outgoing air of the separation. Therefore it is sufficient if the sensor delivers only a tendency of grain loss. For this purpose, the measuring accuracy is satisfying and the drift of the measured values at increasing mass throughputs is not a problem.

Conclusion:

The measurements exerted at the test rig regarding the grain loss detection show two possible ways for grain loss detection: the analysis of the grain mass flow and the single grain loss detection. The latter allows to distinct between broken, shrivelled and lost grain and is hence more suitable for an application in the grain pre-cleaner. A proportional to loss value can be introduced ensuring a loss regulated pre-cleaning with absolute grain loss detection. Furthermore the detection of lost grain can be realised at the output of the unit due to the high performance of the pre-cleaner and the following cyclone.

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