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Investigation of an air ventilated preparation pan

With the steadily increasing installed engine output of the combine as well as the increasing market share of hybrid and axial threshing systems, further optimization of the functional assemblies in the combine cleaning unit is necessary. All the more a high rate of MOG (material other than grain) discharged from the residual grain separation is related to the hybrid and axial threshing system, which makes the cleaning more difficult. A crucial influence on a high cleaning performance is exerted by the pre-separation of the crop flow consisting in grain and MOG in the preparation pan (pp). To achieve this aim - a high cleaning performance – an investigation was realized in collaboration with the company CLAAS Selbstfahrende Erntemaschinen GmbH. A serial preparation pan was replaced by a partially ventilated step to create a fluidised bed.

Keywords

Cleaning unit, combine harvester, fluidized bed preparation pan (FBPP), angles of inclination, pneumatically aided

Abstract

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The influence of the mechanic and pneumatic parameters on the working quality of the combine cleaning unit, especially on the upper and lower sieve, has already been sufficiently examined. The movement patterns of several crop mixtures were observed on ventilated vibrating sieves identifying the kinematic parameters which influence the pre-separation process on the preparation pan [1, 2]. Rochell delivered the base of the theoretical analyse of the preparation pan in proving the interactions between feeding speed and time necessary for the crop layer to remain in the vibrating feeder to get pre-separated. This interaction decisively determines the separation effectiveness and the level of grain loss in the cleaning unit. He examined the inclination angels α_{VB}= -10, 0 and 10° of the preparation pan regarding the feeding speed, the optimal direction of amplitude, trajectory index and several geometric forms of the step. The feeding speed [3] increases with decreasing angle of the preparation pan. Manig and Haase, among others, point to the influence of the ideal layer structure of chaff on short straw on grain before entering the winnowing step of the cleaning unit. The trajectories of the particles do not cross in the winnowing step, which delivers the perfect condition for the following selection on the upper sieve [4, 5]. Furthermore, the preparation pan without ventilation was examined by Spittel, who noticed a higher feeding speed with a downward inclination, too. He explained the occurring decrease of grain loss with the lower thickness of the crop layer which improves the pre-separation. He confirmed the positive effect of a long pre-separation pan on the pre-separation but noted that the layer structure in conventional cleaning units still has optimization potential, because of the crop transfer from return pan to the pre-separation pan. Here the crop flow of the residual grain separation is put onto the separated crop of the threshing unit provoking a new sorting of the above lying grain [6]. Timofeev examined the pre-separation with higher crop throughputs on the preparation pan, where the mechanical excitation does not continue enough to reach the upper layers, which makes the pre-separation more difficult. A higher amplitude and a lower excitation frequency increases the effectiveness here [7, 8].

In order to improve the pre-separation and therefore to promote the following sift unit, an air supported separation process in the last third of the preparation pan is considered useful. The ventilation of this area fluidizes the crop layer, which improves, as is known, the pre-separation. With the aim of a better pre-separation, a test rig is run since 2009 at the University of Hohenheim to prove the influence of a ventilated preparation pan (**Figure 1**).

First results will be described below, showing the example of the setting parameters of the longitudinal inclination angle of the preparation pan.

Theoretical preliminaries

The retroactive effect of a modified geometrical position due to the longitudinal inclination to the step must first be checked to make the evaluation of the influence of the inclination angle on the fluidized bed preparation pan (FBPP) even possible. Here

Fig. 1

New test rig for cleaning units, University of Hohenheim

Fig. 2

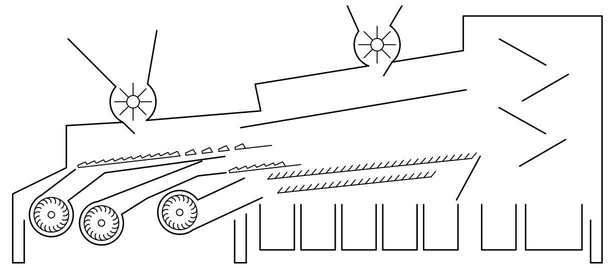


Illustration of the test rig

is the question to clarify, which parameter, winnowing step or fluidized bed, exerts higher influence on the cleaning performance. The first approach is the adaption of flow parameters as the air volume flow and the approach flow velocity in the winnowing step because of the longitudinal inclination of the preparation pan. Two cases are differentiated: the air volume flowing through the cleaning unit and the velocity of approach flow in the winnowing step are held at a constant level. The approach flow velocity follows the values of the serial cleaning unit. The approach flow velocity is calculated by using the continuity equation with a given height of the winnowing step and the flow section, respectively. To dimension the ventilation on the preparation pan, the calculation is based on the flow velocity of the crop mat expansion point of short straw-chaff-mixtures by Damm [1]. The calculation of the section of the openings being the perforation of the preparation pan as well as the consideration of the pressure loss coefficient was necessary to determine the fan speeds.

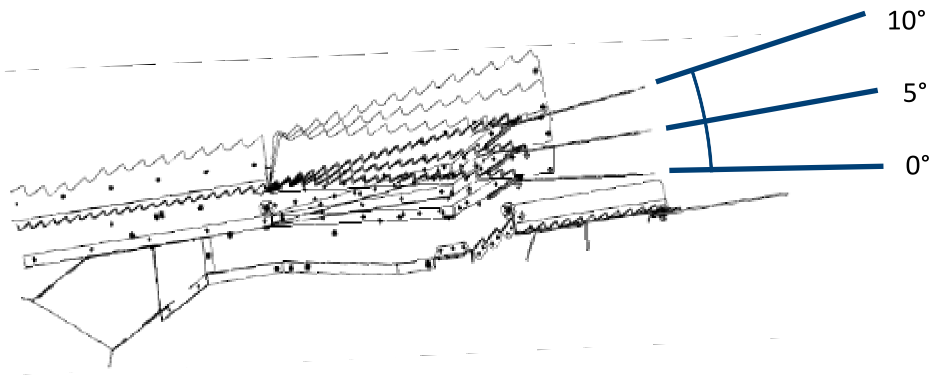
Design of the test rig

The tests are designed to picture the process of harvesting machines as close to reality as possible. Therefore separate crop mixture feedings for the preparation pan and for the return pan in the cleaning unit is realized. Base of the test rig is a CLAAS Jetstream-cleaning unit. Three radial fans to ventilate separately the so called functional elements are used to show the influence of the flow on the winnowing step, the preparation pan and the sieve pan. Preliminary tests without crop were necessary to adapt the designed cleaning unit (500 mm width, longitudinal section scale M 1 : 1) to the flow conditions of the serial cleaning unit and to verify the fan speeds (**Figure 2**).

The serial preparation pan had to be modified to show the influence of the longitudinal inclination angle of the air ventilated part of the preparation pan. This modification consists in replacing the part of the preparation pan facing the winnowing step with a length of lVB = 650 mm by an air ventilated, unilateral pivoted preparation pan. Following the examinations of Damm and the construction of the serial preparation pan, the adjustable longitudinal inclination angles are determined at αVB= 0, 5 and 10° (**Figure 3**).

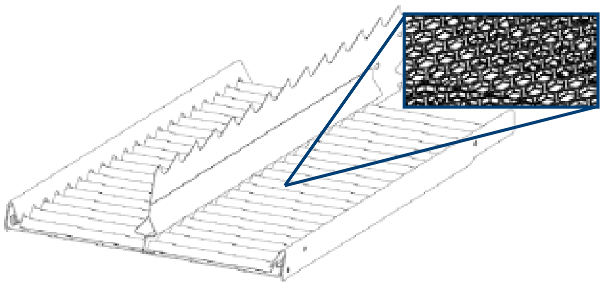
The perforation of the air ventilated preparation pan consists in hex holes with an opening width of SW = 2 mm (SW =

Fig. 3



Test variants of fluidized bed preparation pan

Fig. 4



Fluidized bed oscillating conveyor, similar to test setup

wrench size) and a web width of bs = 0,25 mm, resulting in a free sieve surface of 64 %. The examined variant is constructed similar to the plan shown in **Figure 4**.

Test procedure

The tests are based on an automated feeding of the cleaning unit [9]. The MOG throughput/grain loss characteristics are recorded. The cleaning unit test rig offers the possibility to hide the entering phase of the feeding with a controllable flap mechanism, which also allows a distinction between stationary and non-stationary measuring phase. The grain loss is determined by analysing the cleaning output. To evaluate the separation effectiveness and the separation length l80 (sieve length with 80 % of grain is separated), the separated grain is collected in 10 boxes fixed in driving direction under the lower sieve. The basic adjustment parameters for the test beside the longitudinal inclination angle are: overall test time tV = 30 s, overall test time stationary measuring phase t_M = 10 s, grain/MOG-ratio 3:1, preparation pan MOG-rate 50 %, preparation pan grain-rate 70 %. The kinematic parameters of the preparation pan like amplitude, driving speed, direction of amplitude and transmission angle remain unvaried. The analysed measurement series are defined with:

- Constant approach flow velocity in the winnowing step at α_{VB} = 0, 5 and 10° of the air ventilated part of the preparation pan,
- Constant air volume flow through the winnowing step at α_{VB} = 0, 5 and 10° of the air ventilated part of the preparation pan,
- Serial preparation pan without ventilation as reference value.

Results

The evaluation is based on the following target values: grain loss of the cleaning unit, grain-rate in the tailing and the separation length l80. The recorded cleanliness is not considered because no significant differences can be proved. Reference point for the evaluation of the measurement results is the grain loss of 0,3 %.

The tests regarding the influence of the longitudinal inclination at a constant approach flow velocity show that the air ventilated preparation pan working with α_{VB}= 5° achieves the highest MOG-throughput of 1,18 kg/(sm) with 0,3 % grain loss. This result is confirmed by the low grain-rate of 3,6 % in the tailing and the hereto related characteristic value l80 of 990 mm. The functional relation between the unvaried parameter direction of amplitude to the longitudinal inclination angle and the grain loss is confirmed by Spittel [6]. An increase in performance of about 5 % when using a ventilated preparation pan compared to a serial configuration has been proved. Another grain loss limit as the base for the test analyse makes the difference to the serial preparation pan more obvious. A sloping, ventilated preparation pan shows the highest performance loss with a constant flow rate and a constant air volume flow manifesting itself in a specific MOG-throughput 0,96 kg/(sm) (**Figure 5, Figure 6**). This result can be explained by the increasing feeding speed and the therefore decreasing thickness of the crop mat. The consequence is an overblowing effect just before the following step. Another approach can be the insufficient pre-separation effect due to a small time relation τ, which is calculated using the quotient of the remaining time of the crop on a certain feeding length at a time with 80 % separation.

Despite the adaption of the flow parameter, it is crucial for the evaluation of the influence of the inclination angle of the preparation pan to consider also the interactions described above because of the changing geometrical conditions of the step. A descending preparation pan and the therefore smaller height of the step reduces the performance of the following sift and sieve process. The sloping air ventilated preparation pan causes also a lower MOG-throughput of 0,78 kg/(sm) (const. v_{air}) and 0,85 kg/(sm) (const. Q_{air}). The reason is a lower feeding speed a local cop mat congestion on the air ventilated preparation pan causing negative effects on the pre-separation. Further notice should be taken of the unvaried kinematic parameters, because the movement of the crop mixture can be optimized by adapting the amplitude and the driving speed.

Summary

The longitudinal inclination of the air ventilated preparation pan influences the following cleaning process and therefore the grain losses in the combine harvester. The examinations show an optimal angle of the longitudinal inclination of α_{pp}= 5° if using a ventilated preparation pan (here the one of the CLAAS-Jet-Stream-cleaning unit). This equals the adjustment of the actual serial cleaning unit.

An increase of efficiency of the combine cleaning unit due to the here described ventilation of a part of the preparation can be set realistically at maximum 5 %, which is confirmed by further investigations.

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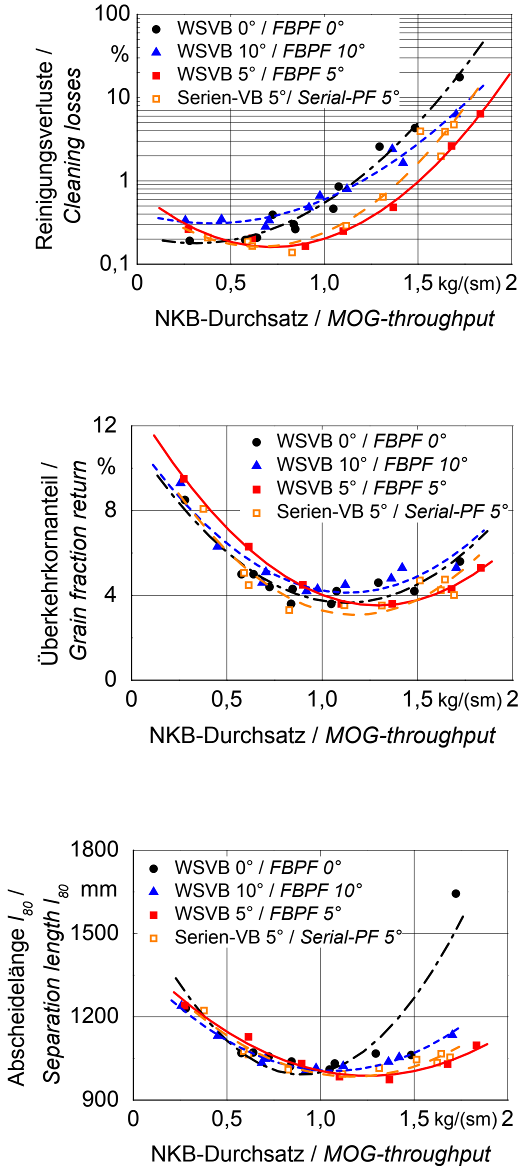
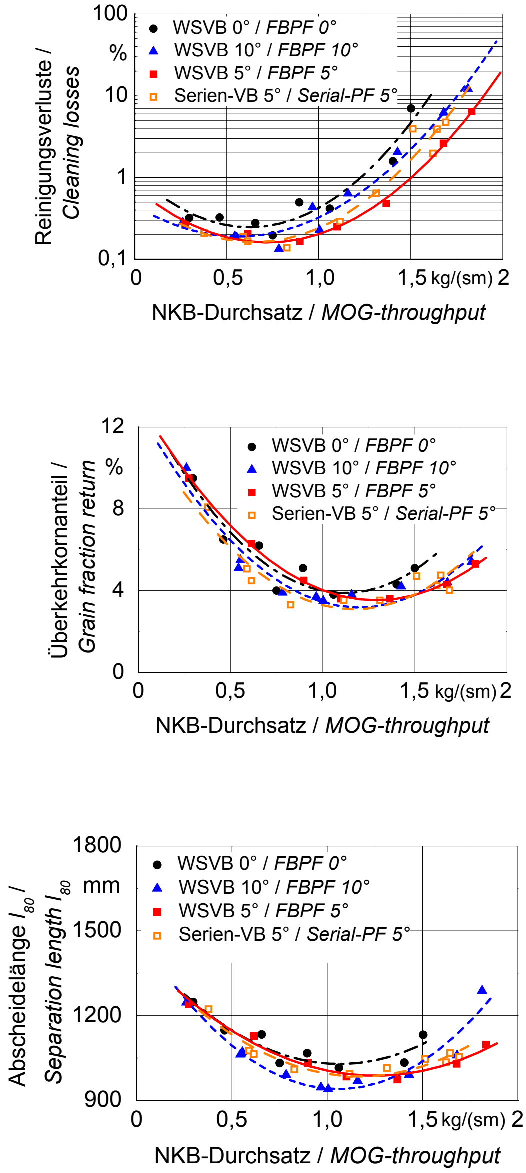
Fig. 5



Constant flow rate in the ventilated step

Fig. 6



Constant volume flow on the ventilated step

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