Sven Rothaug, Stefan Böttinger and Heinz Dieter Kutzbach, Hohenheim

Combine Grain Cleaning Unit with Circular Oscillation

Steadily increasing throughputs in modern combine harvesters require new ideas for the developing combine cleaning units. One possibility for increasing the throughput of the cleaning unit is to use a vertical circularly oscillating sieve. Many tests were carried out to optimize its amplitude and frequency, airflow direction, sieve inclination, sieve opening and sieve type. This article shows some examples of the test results.

Dipl.-Ing.sc.agr. Sven Rothaug is a member of the scientific staff at the Institute of Agricultural Engineering of the University of Hohenheim, Department of Basics of Agricultural Engineering. As successor of Prof. Dr.-Ing. Heinz Dieter Kutzbach, Prof. Dr.-Ing. Stefan Böttinger is the director of this department, Garbenstr. 9, 70599 Stuttgart; e-mail: *boettinger@uni-hohenheim.de*.

Keywords

Combine, cleaning shoe, circularly oscillating sieve

The necessity of further developments of the combine cleaning unit has already been explained many times [1, 2]. The investigations on the test stand for the circularly oscillating sieve cleaning unit at the University of Hohenheim have been finished lately. The vertically circular sieve movement allows much higher throughputs compared with conventional linearly oscillating sieves, which have been tested and optimised on the same test stand in a previous project [3].

Theory of circularly oscillating sieves

The theory of the circularly oscillating grain cleaning unit concerning accelerations and points of detachment has already been explained by Yin [1]. Based on these calculations flight numbers of Fr_V = 0.9 to 1.6 were tested. As the flight numbers are calculated out of amplitude, frequency, gravity and sieve inclination, combinations out of frequency f_E and amplitude a between f_E = 3 to 5,5 Hz and a = 10 to 35 mm have been found and tested.

The diagonal air flow through the sieve is assembled out of two air flow components. The vertical air flow component (1) supports the disaggregation and thus the fluidisation of the grain-MOG-mixture. The horizontal air flow component (2) supports the material flow on the sieve. An increase of the air flow direction increases the vertical air flow component and thus the fluidisation. Accordingly the horizontal component is reduced [4].

$$w_{vi} = w_i \cdot \sin \psi_i \tag{1}$$

$$w_{hi} = w_i \cdot \cos \psi_i \tag{2}$$

The mechanical parameters affect the work of the cleaning unit significantly so there has to be found a special air flow under the sieve for every tested air flow direction.

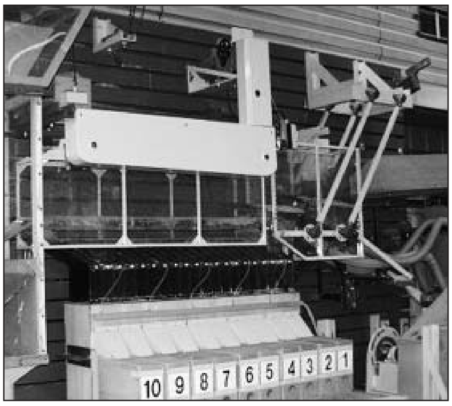

Fig. 1: Test rig with circularly oscillating sieve

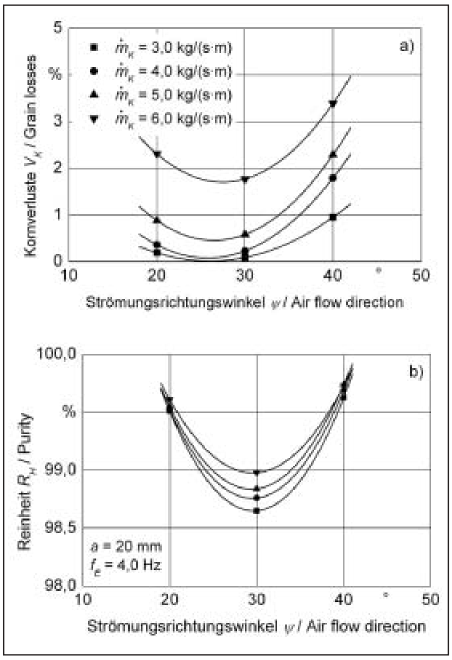

Fig. 2: Dependency of grain losses and purity on the air flow direction

Test equipment and methods

The test stand for basic research on combine cleaning units in Hohenheim has been changed to a circularly oscillating sieve box (*Fig. 1*). The movement of the sieve box is equivalent to the movement of a walker. The air flow towards the sieve is applied by five separately adjustable fans. Exchangeable cassettes allow an exact adjustment of the air flow direction. The transport of grain and MOG (material other than grain) to the sieve is accomplished by a 14 m conveyor belt. The MOG is manually laid onto the conveyor belt. The grain is then applied on top of the MOG layer by a sensor-controlled wheel grain feeder in a mass ratio of 70 : 30.

Separated grain is collected in ten collection boxes under the sieve to determine separation characteristics and the purity after a further cleaning process. The MOG which has been conveyed over the end of the sieve is also re-cleaned to collect the lost grain kernels. These grain kernels result in the percentage of grain losses referred to the whole mass of grain.

To allow a comparison between the circular oscillation and the linear oscillation tested by Zhao [3], the grain pans were still working in the linear motion and with two winnowing steps. The adjustments of the grain pans have been the following: Length: 900 mm, inclination: 3°, amplitude: 30 mm,

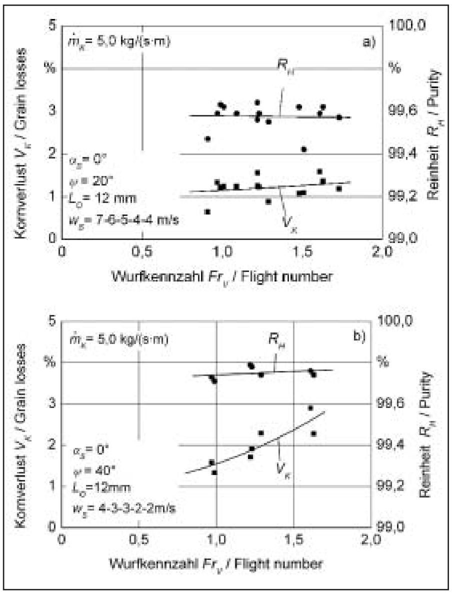

Fig. 3: Dependency of the flight number at a throughput of $\dot{m}_K$ = 5 kg/(s•m) on grain losses and purity at different air flow directions

frequency: 4 Hz, oscillation angle: 30°. The air velocity in the winnowing steps was 4 m/s in an angle of 20°.

The adjustments of the sieve box varied at different tests.

Results

This article shows some examples of the test results.

Air flow direction

The air flow direction for the linearly oscillating sieve of the test stand for basic research on grain cleaning units is ψ = 30° [5]. Additional to this air flow direction the angles of ψ = 20° and 40° have been tested with the circularly oscillating sieve. Empirical tests resulted in an air distribution of w_S = 7-6-5-4-4 m/s for the air flow direction of 20° while the air velocity at the beginning of the sieve was 7 m/s and was reduced to 4 m/s at the end of the sieve. The favourable air flow direction for ψ = 30° is w_S = 5-4-3-2-2 m/s and for ψ = 40° w_S = 4-3-3-2-2 m/s. ψ = 20° compared to ψ = 30° supports the conveyance of the material on the sieve, because the conveyance is mainly supported by the air flow on the circular oscillation due to a special throwing action. The improved material flow has been verified by a high speed camera. Though the adjustment of the air flow direction from the vertical to the horizontal component leads to higher grain losses, because the residence time of the grain-MOG-mixture on the sieve is too short for a complete grain separation. Compared to ψ = 30° the grain losses are slightly higher (*Fig. 2a*). A maximum of fluidisation is reached at ψ = 40°. At this air flow direction the support of the material flow is reduced and leads to a higher residence time of the material on the sieve, but also to a much thicker material layer. This thick layer does not allow the passage of all grain kernels to the end of the sieve, which results in very high grain losses. Thus the air flow direction of ψ = 30° is the optimum of the circular oscillation concerning the grain losses.

Higher grain losses have usually to be accepted for an increase of the purity. This is confirmed by the circular oscillation (*Fig. 2b*), too. The difference of the purities of the air flow directions of ψ = 20° and 40° dependent on the grain throughput are between 1 and 1,5% compared with ψ = 30°. Thus there has to be found a compromise between grain losses and purity to decide which air flow direction should be used. An air flow direction of ψ = 30° has been used for further tests on the circularly oscillating sieve.

Amplitude and frequency

The mechanical parameters amplitude *a* and frequency f_E significantly affect the process of the cleaning unit. Since the change of the air flow direction also changes both, material flow and fluidisation, the mechanical parameters have to be adjusted as well. Dependent on the calculation of the flight number the ideal combinations out of amplitude and frequency have been found. The results of these tests are shown in *Figure 3a and b* for two different air flow directions. The grain losses increase in an almost linear manner at increasing flight numbers. The lowest losses are reached at flight numbers around Fr_V = 1. A further reduction of the flight number is not possible, due to the risk of a blockage of MOG on the sieve, because of a too low mechanical incitation. Around Fr_V = 1.5 the mechanical incitation is too high and leads to high grain losses. Thus further tests on different sieve parameters were performed with flight numbers of slightly more than 1.

Comparison between circular oscillation and linear oscillation

The linearly oscillating sieve has been optimised by Zhao for throughputs of up to K = 6 kg/(s·m) [5]. Higher throughputs with lower grain losses and higher purities are possible only with the circularly oscillating sieve. The comparison in *Figure 4a* shows the optimised grain loss curve of the linear oscillation and the grain loss curve of the circular oscillation at an air flow direction of ψ = 30°. At higher throughputs than K = 6 kg/(s·m) the curve of the linear oscillation is very steep. The curve of the circular oscillation is very flat, which is its main advantage. The purity is approximately more than 1% better and increases with increasing throughputs, whereas the purity of the linear oscillation is decreasing.

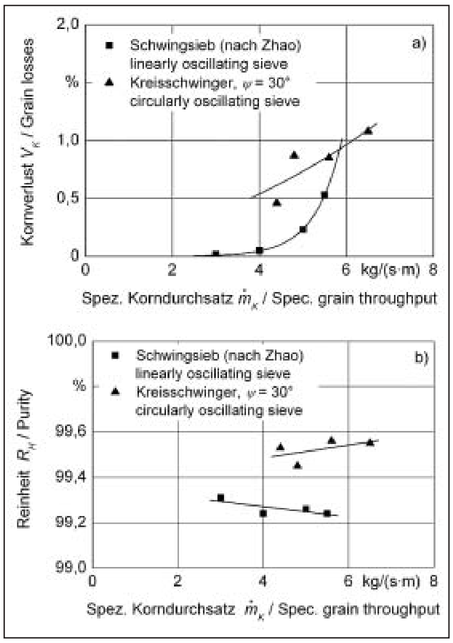

Fig. 4: Comparison between circularly and linearly oscillating sieve in dependency of the grain throughput

Conclusion

The circularly oscillating sieve is superior to the linearly oscillating sieve at higher throughputs of more than K = 6 kg/(s·m), concerning grain losses and purity. Further developments of cleaning units of modern combine harvesters with steadily increasing throughputs should take the circular movement of the sieve into account.

Literature

Books are marked by •

[1] *Yin, W., P. Wacker und H.D. Kutzbach*: Mähdrescher-Reinigungsanlage, Untersuchungen zur mechanischen Anregung durch Kreisschwingungen. Landtechnik 56 (2001), H. 4, S. 276-277

[2] • *Kutzbach, H.D., P. Wacker und S. Böttinger*: Mähdrescher. In: Jahrbuch Agrartechnik, Band 18, Münster, 2006

[3] • *Zhao, Y.*: Einfluss mechanischer und pneumatischer Parameter auf die Leistungsfähigkeit von Reinigungsanlagen im Mähdrescher. Forschungsbericht Agrartechnik VDI-MEG 387, Dissertation, Universität Hohenheim, 2002

[4] • *Dahany, A.*: Verbesserung der Leistungsfähigkeit luftdurchströmter Schwingsiebe bei der Korn-Spreu-Trennung im Mähdrescher durch Optimierung der Luftverteilung. Forschungsbericht Agrartechnik VDI-MEG 245, Dissertation, Universität Hohenheim, 1994

[5] *Zhao, Y., P. Wacker und H.D. Kutzbach*: Fallstufen – Einfluss der Luftströmung. Landtechnik 54 (1999), H. 4, S. 204-205