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# Combine grain-cleaning systems

## Investigation into mechanical action through circular oscillations

*Various alternatives have been investigated for the necessary further improvements in combine grain cleaning system performance. Alongside improvements in mechanical and pneumatic action, new construction forms are also being looked at. Modified flat sieve cleaning systems require hardly any alterations in the combine concept. For this reason a circularly-oscillating grain cleaning system has been investigated at Hohenheim whereby the flat sieve doesn't oscillate linearly but instead follows a crankshaft-driven circular motion something like straw walkers. First trial results indicate that, compared with the linearly-oscillating sieve, the circular oscillation action promises an increase in performance with slightly higher losses.*

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**Keywords**

Combine, cleaning shoe, circular vibrating sieve

The oscillating sieve with air throughflow within the grain cleaning system of combines has proved itself for grain-chaff separation over decades. Through increasing the mechanical action by enlarging the Froude number and increasing pneumatic action through transit onto a second winnowing step, substantial performance increases have been achieved in the last years [1]. Further increasing combine throughput and increasing use of multi-drum threshing systems as well as rotary corn-straw separation instead of straw walkers will also require further increases in grain cleaning performance. Alongside improvements in the mechanical and pneumatic action, new constructional design such as rotary cleaning systems comes into question [2]. According to [3] the pneumatic action can be improved through matching of air distribution on the sieve contents (falling air distribution) and the mechanical action, according to [4], through superimposition of lateral oscillations onto the sieve longitudinal oscillations. A flat sieve cleaning system was investigated at the Institute for Agricultural Engineering at Hohenheim which, like a straw walker, was mounted on crankshafts with resultant circular oscillations (circular cleaning). Circular oscillations have a good separation effect through their turn-over action, even with larger sieve loadings, and this enables high specific throughput [5, 7]. The movement direction is, however, relatively steep and thus the grain progression effect is limited. But with the combine cleaning system the transport effect is supported by the air movement.

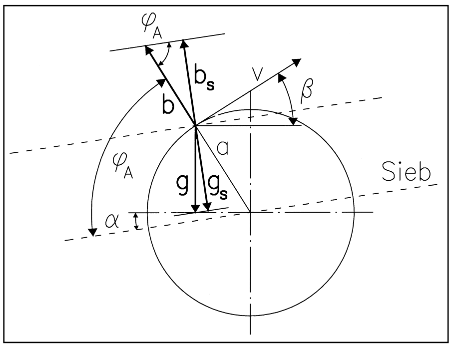


*Fig. 1: Accelerations and point of detachment by circular vibrating sieve*

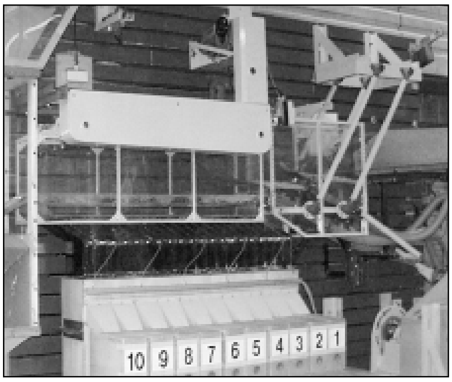


*Fig. 2: Test rig with circular vibrating sieve*

### Theory of circularly-oscillating sieve cleaning

Contrary to the linearly-oscillating sieve where grain is moved in direction of the sieve oscillations, grain movement with the circularly-oscillating sieve at point of detachment is tangential to the crankshaft circle *(figure 1)*. At the point of detachment the proportions of centrifugal and gravity forces acting on the grain vertically to the sieve are the same.

$$a\omega^2 \sin \varphi_A = g \cdot \cos \alpha \quad (1)$$

With the throw performance figure $Fr_v$ with circularly-oscillating sieves

Gleichung einsetzen (2)

there results detachment angle to

Gleichung einsetzen (3)

Above all with the higher throw figures (from $Fr_v \approx 3$), the throw takes place in a

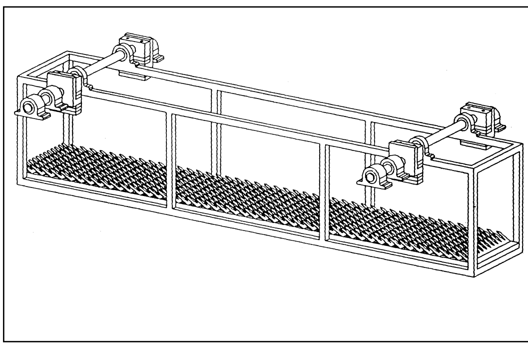

*Fig. 3: View of the sieve box*

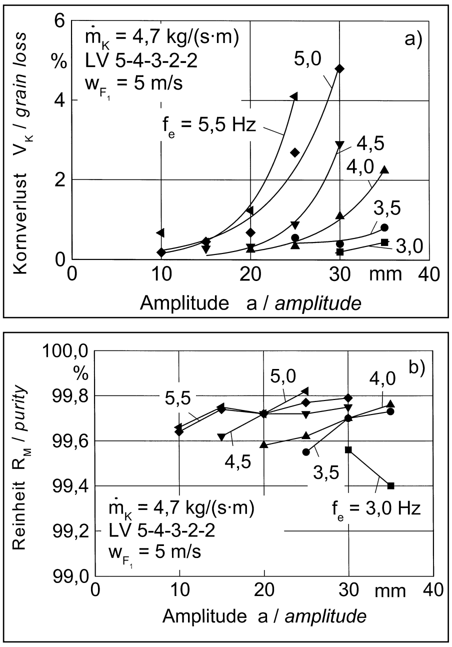


*Fig. 4: Effect of amplitude and frequency on grain loss (a) and purity (b)*

steep upward angle so that the grain velocity on the sieve is limited and must be supported by a more pronounced downward sloping sieve. In the cleaning system, grain movement is helped by the airflow through the sieve so that downward sloping sieves are not absolutely necessary.

### Trial design and method

For the investigation of circular cleaning, this type of sieve was fitted instead of the linear sieve to the grain cleaning test rig at the Institute for Agricultural Engineering *(fig. 2)*. The air throughflow via five adjustable fans and the cassettes for controlling airflow direction could be left unchanged. The grain transport via 14 m conveyor belt, the grain pan and the delivery to the sieve with one or two winnowing steps had only to be slightly adjusted. A comparison of the results with those from investigations carried out with the circular cleaning system [7] is therefore possible.

The sieve box was 1.56 m long by 0.27 m and driven by two overhead crankshafts *(fig. 3)*. Clearance between crankshafts and multi-sieve was 0.33 m. The crank radius a (amplitude) was adjustable in steps of 0 to 35 mm, the frequency $f_e$ from 3 to 5.5 Hz steplessly, by drive motor.

The trial was conducted with dry wheat ($U_K$=13.5%), and chopped straw ($U_{NKB}$=11.3%) from harvest 2000 in a ratio of around 73 : 27%. To keep the amount of trial material low, at first 1/3 fresh non-grain components (NGC) then 2/3 used NGC according to the desired throughput was laid on the conveyor belt. Grain amount was sensor controlled in the trial with a set amount laid on the NGC layer via metering system.

Grain and NGC was weighed in the receiving hoppers 1 to 10 and subsequently separated with a laboratory cleaner. Grain losses from the sieve transfer and thus cleaning losses were also determined through reference to the total grain amount.

For every trial the basic settings of the cleaning system were retained with one parameter in each trial being altered.

The following basic settings were chosen for the *sieve*:

Grain throughflow: 4 kg/(s•m), air distribution: 5-4-3-2-2 m/s, airflow direction: 30°, sieve slope: 0°, opening on multi-sieve: 12 mm.

The following basic settings were chosen for the *grain pan*: length: 900 mm, upward slope: 3°, amplitude: 30 mm, frequency: 4 Hz, oscillation direction: 30°.

An airflow velocity of 5 m/s with an airflow direction of 20° was chosen for the *winnowing step*.

### Results

In this paper first trial results with one or two winnowing steps are reported.

*Amplitude and frequency*

Oscillation amplitude and frequency are closely linked *(fig. 4a)*. High frequencies require small amplitudes, large amplitudes small frequencies, in order to remain in the low loss band, as is similar with straw walkers [8]. With increasing frequencies, especially with large amplitudes, losses increase sharply so that amplitudes from 20 to 20 mm as with the linearly-oscillating sieve appear optimal. These also lead to good purity which even increases a little with rising frequencies *(fig. 4b)*. Because of the high losses, however, these frequencies cannot be used.

For low losses in each case, optimum combinations of amplitude and frequency with throw figures of around $Fr_V < 1.8$ are reached. The purity reached with these throw figures is good at 99.6%.

*Throughflow*

Grain loss increases with throughflow (*fig. 6*). It lies above the loss from the linearly- oscillating sieve cleaning system. In the evaluation of throughflow it must be remembered that separation conditions during the Hohenheim investigation, despite the dry material, were relatively difficult in that the NGC consisted only of chopped straw, contained hardly any chaff and the grain had to penetrate the total NGC mass because it had been deposited on top of it. Also to be considered with this comparison is that the trial with the circular cleaning system could not be conducted with the same material as used with the linearly-oscillating sieve. Additionally, the parameters for the linear sieve cleaning have been intensively optimised in the research work by Zhao whereas this level of optimisation had not been reached yet by the circular cleaning system.

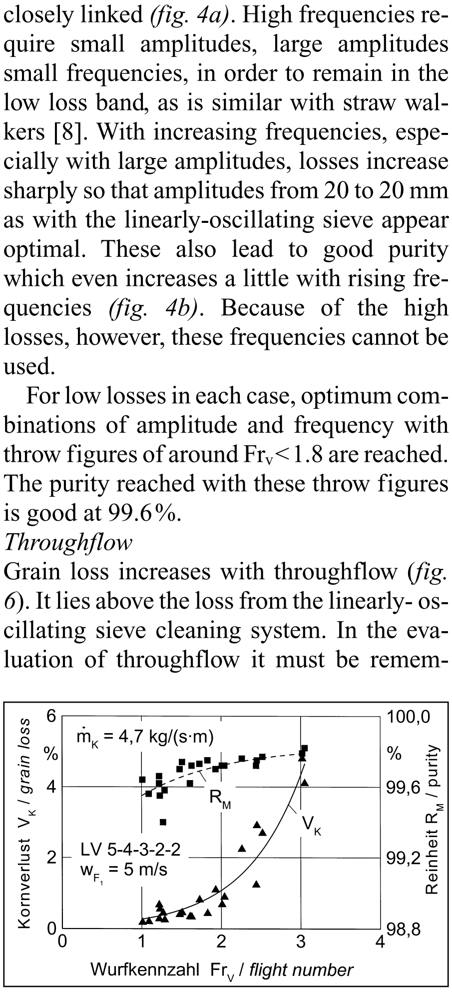


*Fig. 5: Grain loss and purity dependent from the flight parameter*

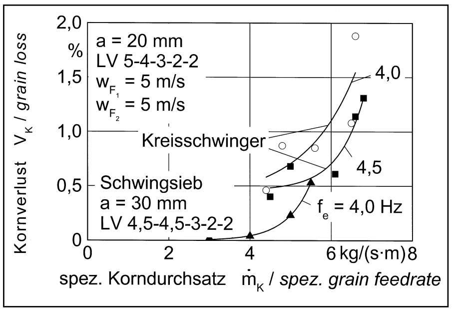


*Fig. 6: Grain loss dependent from specific grain feed rate*

### Summary

Present results with circularly-oscillating cleaning show higher throughput, but with higher losses than the linearly-oscillating sieve cleaning. Thus further investigations are required for optimising the circular cleaning system with regard to pneumatic action and grain progression.

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