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Combine harvester cleaning systems

Basic requirements and development tendencies

In addition to agricultural machinery and oil hydraulics, pneumatic materials transport was a further working area for Prof. Dr.-Ing. Dr.-Ing. E.h. H.-J. Matthies. The author has fond memories of the lecture „Pneumatic transporting“ which he heard in 1964, little realising that the fluidisation covered in this lecture would become very important later on for his own research. Fluidisation and optimising the pneumatic parameters played an important role in the necessary performance increases of combine cleaning systems. The following paper includes the results of various research projects under the management of the author on this subject area and indicates the possibilities for further performance increases.

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Keywords

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Literature

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Grain cleaning systems in combines separate non-grain components (NGC) such as chaff, short straw and other adulterating matter from the grain. The winnowing oscillating screen has established itself for this task whereby separation takes place vibro-pneumatically (Segler), i.e. through a combination of sieves and sifting [1]. Extremely important for cleaning system performance is the interactive coordination of pneumatic and mechanical parameters as well as the adjustment of air velocity to match grain throughflow. Where winnowing velocity is too high, grain is blown away (flight phase), where this is too low, there is an insufficient loosening of the harvested material layers (layering phase). Both situations lead to high losses. Satisfactory matching of winnowing velocity and grain throughflow leads to fluidisation of harvested material on the sieve (condition of layers in flux). In this state, according to Matthies, the connection between individual component bodies within the harvested material mass is broken and a rapid separation achieved [2].

In comparison with other farm machinery and machine types the performance of cleaning systems has been continually increased in recent decades through intensive research and development [3].

Rotating cleaning systems working with larger accelerations, and thus lead to expected higher constructional space related performances, are [4, 5, 6] not yet on the market despite very promising beginnings. R & D work concentrates increasing performance of flat sieve cleaning systems through further optimising of mechanical and pneumatic parameters and walker steps. Also being investigated are circular oscillators [7].

Mechanical parameters

The mechanical parameters are above all oscillating amplitude a and oscillating frequency f. But the sieve elevation angle α and oscillating direction angle β also influence cleaning system efficiency. Typical values with current cleaning systems are: a = 20 – 25 mm; f = 4 – 5 Hz; $\alpha = 0 - 5°$; $\beta = 30 - 35°$. The throw dimension Fr_v completes these parameters for characterising mechanical

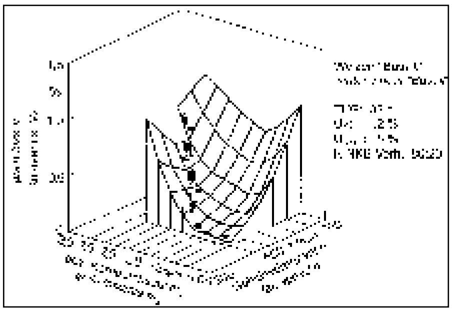

Fig. 1: Loss characteristic curve of a cleaning unit

stimulation [8, 9].

((Gleichung einsetzen))

Harvested material flows on sieves without winnowing gives throw dimensions of Fr_v = 3.3 preferably single throw. Every upward oscillation of the sieve tosses or throws the material which can separate-out during this action and hits the sieve surface once again within the sieve oscillation. Grain is separated in the following movement of harvested material over the sieve surface. In combine cleaning systems the harvested material is additionally lifted from the sieve by the airflow so that the cleaning system operates with throw values of $Fr_v \approx 1$. For satisfactory functioning of a sieve, mechanical and pneumatic parameters are exchangeable within limits, according to Freye [10]. The development tends towards a strengthening of the mechanical parameter in that the sieve is made more stable in its actions through changing material characteristics [11].

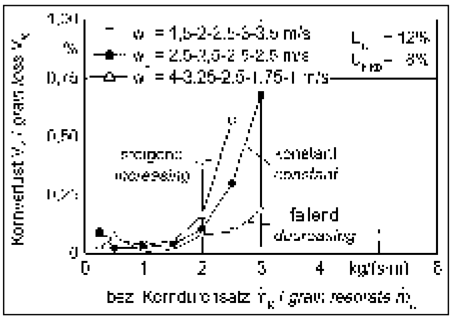

Fig. 2: Grain losses for different air distributions, according to [16]

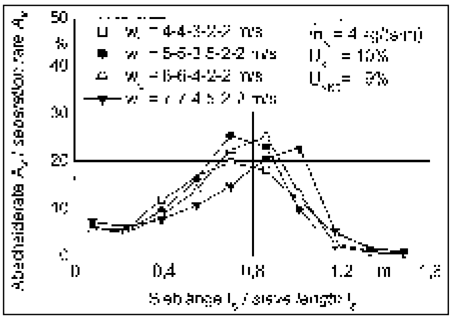

Fig. 3: Separation rate for different air distributions, according to [18]

Research at Hohenheim featuring the cleaning basics test stand already mentioned in this publication [12] have shown that size of amplitude is important along with the throw dimension. In relationship, recent developments in the last years have led to a slight increase in throw dimensions from 0.95 to 1.1 and to an increase in amplitudes from 20 to 25 (30) mm. The positive preliminary separation effect of the grain pan is, on the other hand, not always exploited nowadays. A good preliminary separation, grain under NGCs, leads to a substantial performance increase. If, on the other hand, the grain has to penetrate the whole layer of harvested material, grain on NGC, then losses are much higher [13]. This e.g. applies to the grain separated by the walker landing on the returns pan under the walkers and being deposited on top of the layer of harvested material on the upper sieve.

Pneumatic parameters

Contrary to many mechanical system flat sieve layouts which work without winnowing support, the air action is of special importance in cleaning systems for separating corn and NGC. The winnowing supports the fluidisation, helps prevent the separation of lighter NGC through the sieve openings, and thus increases sample purity. The winnowing velocity with loaded sieve w_L, the air distribution in sieve longitudinal direction and the material flow direction ψ are described as pneumatic parameters. In that these values can rarely be recorded with serially produced cleaning systems, the air volume flow in relation to the sieve area $\dot{V}'_L$ [$m^3/s \cdot m^2$] is often given, or only the fan rpm n_G.

Winnowing velocity must be adjusted to the grain throughflow to for optimum working load on the sieve. In field trials Böttinger [14, 15] investigated this relationship with a serially- produced cleaning system (*fig. 1*). The fan rpm can nowadays be adjusted electrically from the driving position and partly preset through the on-board computer to match grain types and harvesting conditions. A regulating of fan rpm, which must be done in relationship to throughflow and losses, is not yet introduced for serially produced combines.

The investigations by Dahany and Zhao have shown that air distributions falling over the sieve length with flow angles of 30 to 40° lead, compared with constant or even increasing air distributions, to a clear increase in performance (*fig. 2*). A decreasing air distribution in the front of the sieve had a winnowing velocity of 4 – 6 m/s, at the rear of (1) – 2 m/s [16, 17, 18]. In combines when sieves are well-loaded in the front, air is forced to the rear of the sieve area so that often there is increasing air distributions with high winnowing velocities there and lower winnowing velocities in the sieve front areas with flow directions of 10 – 20°. Too high winnowing velocities at the beginning of the sieve cause, however, a displacement of the separation toward the rear (*fig. 3*). The low winnowing velocity at sieve end favours separation and reduces grains being blown out.

The fluidisation velocity of wheat lies at around 0.8 – 1 m/s [2, 19], that of NGC around 0.5 m/s. For freshly-harvested material with a high grain proportion (up to 85%) Beck recorded fluidisation velocities up to around 0.95 m/s and showed that, with increasing fluidisation velocity, the performance of the cleaning system decreased because of the higher inner friction of the material [19]. This fluidisation velocity was substantially lower than the vertical component of the flow velocity at the beginning of the sieve which was around $w_{LS} \approx 2.5$ m/s ($w_{LS} = w_L \cdot \sin \psi$) and with that also still higher than the average NGC floating velocity. Through such high winnowing velocities a large proportion of NGC material is blown out at the beginning of the sieve.

Walker steps

Especially with the non-falling air distribution largely found in the combine harvester, steps between grain pan and upper sieve greatly increase cleaning performance. Because there's no sieve resistance and the airflow is targeted, the necessary high winnowing velocities at sieve beginning can be achieved and NGC blown out of the loosened harvest material layer. Steps also lead, where there's a high material throughflow and decreasing air distribution, to a further performance increase (*fig. 4*). It is apparent that for every air distribution there is an optimum step air velocity w_F with a flow direction of $\psi_F = 20 – 30°$. Basically flow directions of $\psi_F = 20 – 30°$ are to be aimed for in the steps too [16]. Through a second step within the grain pan the preliminary separation is further improved so that grain separation increases in the front sieve area and the performance of the cleaning system rises further (*fig. 5*). Under trial conditions with falling air distribution, optimum separation conditions were achieved with winnowing velocities in the steps of $w_{F1} = 5 – 6$ m/s and $w_{F2} = 6 – 7$ m/s.

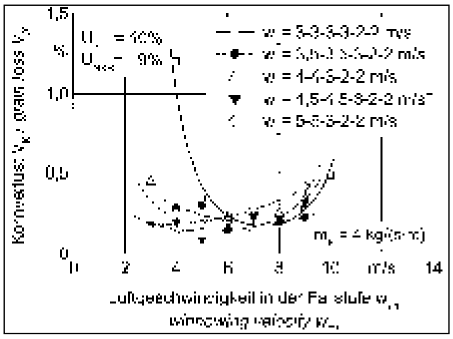

Fig. 4: Influence of winnowing velocity 1st step on grain losses, according to [17]

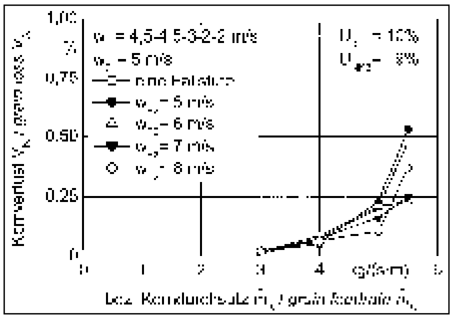

Fig. 5: Grain losses for different winnowing velocities of 2nd step, according to [17]

Summary

In addition to mechanical parameters, cleaning system performance is greatly influenced by winnowing velocities and flow directions on the sieve and in the steps. Through optimising these values, the increasing the oscillation amplitude and the automatic adjustment of winnowing velocities to match harvested material characteristics and throughflow, the necessary further increases in combine cleaning system performance appear possible.