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Cutting performance of the combine straw chopper

Fundamental investigations into the straw conveying and cutting procedure within a combine harvester straw chopper were carried out in a stationary trail station. An exact analysis of the effects of parameter variations was made possible through separation of drive performance into different individual components. An oscillating sieve was used for comparing chopped straw samples from the different trial settings. Through high-speed photography, the actions within the chopper could be visualised and analysed.

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A stationary trial station was built for investigation of the cutting and conveying procedures in a combine straw chopper. This comprised the building components supply belt, conveyor belt, the actual straw chopping equipment and a container for the chopped straw. A detailed description of the trial station, the trial procedure and additional results was publicised in [1].

For comparison of the effects of various parameter adjustments in individual trials, the quality of the straw chop must also be investigated. For this, the length of the straw pieces were measured.

Straw chop length

A straw sample was taken out of the chopped straw container for the sieve analysis. When taking samples, attention was always paid to the importance of taking them from the same area of the container where no chopped straw from the beginning and end of trials was deposited. In that the straw throughput also has an influence on the chop length, this aspect – as well as the rpm – was not varied during a trial. The chop samples with higher moisture content were dried. The oscillating sieve that was kindly loaned by the FAL Institute for Farm Technology – now the Institute for Farm Technology and Building Research – comprised six round-hole sieves with hole diameters 67, 30, 16, 8, 4 and 2 mm. The setting of the sieve is so arranged that the total sample is deposited over the 67 mm sieve. Long pieces of chopped straw which do not pass through the sieve are discarded to the side. The shorter chop lengths fall through the sieve onto the smaller-hole sieve underneath where the next fraction is separated. The shortest straw pieces are those that pass through all sieve layers. This results, therefore, in seven sizes of chopped material: in each case the lengths separated at each of the six lower sieves and the material that passes through the 2 mm sieve. No general straw chop length can be given to the individual straw fractions in that bent-over straw pieces can pass through sieves that straight ones of the same length cannot. But separation according to weight of the various fractions offers a relatively simple possibility of evaluating the effect of different parameters on straw chopping performance.

In *fig. 1* the alterations in sizes within the sieve fractions through variations of the rotor rpm are demonstrated. This is done through total curves which give individual sieve throughput as a weight percentage of total chopped straw sample. So, for example, 100% of all straw pieces produced at a rotor speed of 3000 rpm and higher pass through the 67 mm round hole sieve whilst with the sample from the rotor speed of 2400 rpm some straw pieces failed to go through the first sieve and only around 93% reached the 30 mm hole sieve. The two smallest fractions reaching the 2 mm sieve were combined and regarded as throughput of the 4 mm sieve. With a straw diameter of up to 5 mm, and with regard to the limited throughput force of these fractions, this simplification was the most practical. Fig. 1 clearly shows the increase in the fractions from the smaller diameter sieve holes with higher rpm which indicated a reduction of the average chopped straw length.

A manual analysis of the chopped straw lengths from the 4200 rpm sample gave the length graduations shown in *fig. 2*. Over half the straw mass here featured pieces smaller than 40 mm. Around 75% were smaller than

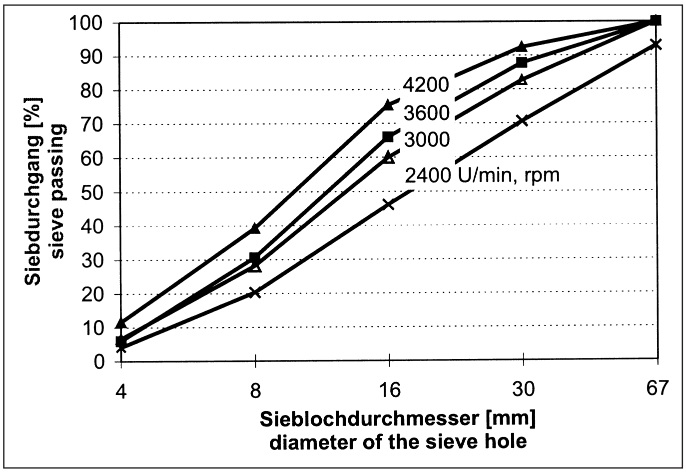

Fig. 1: Sieve analyses of chopped straw samples at various rpm (material moisture 32%, throughput 5 kg/s)

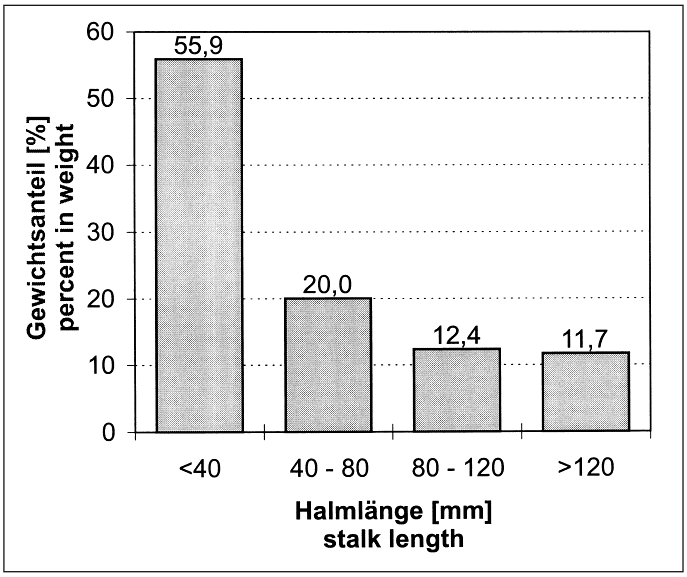

Fig. 2: Straw length distribution in a chopped straw sample (winter wheat, moisture content 32%, throughput 5 kg/s, 4200 rpm)

80 mm. This represented only a part of the demands made for the straw chopping operation by HERMANN [2]: that from the total straw mass 75% of the pieces must be shorter than 80 mm and only 3 % may be longer than 150 mm.

Another aspect was aimed at emphasising the quality of the straw chopping. If one starts off with a 5000 kg/ha mass of dry straw as straw chopper throughput this results, with a moisture content of U = 32 %, in a moisture mass of 735 g/m^2. With a share of 11.7% straw stems longer than 120 mm, a specific straw weight of 2.2 g/m and an estimated average straw length in this fraction of 200 mm meant 195 200 mm long straw stems per m^2.

Under the conditions shown with a straw moisture content of 32% and a very high throughput of 5 kg/s, it was only possible with 4200 rpm to reach an acceptable chopping result. In the process, there was a rise in power demand from 26.8 kW at 2400 rpm to 45.6 kW at 4200 rpm.

Through the increase in rpm the circumference speed of the chopper knives rose from 64.6 to 113 m/s. This had different results on the chopping performance. A first reduction in straw stem length took place at the bulk intake of straw through the chopper rotor from free fall. With this, uncontrolled cut, the straw stem is only cut-through when a sufficiently high opposite-force can be created. This opposite-force can comprise several parts. With every contact between knife and straw stem, the mass-resistance-force is activated through the acceleration of the straw by the knife. Depending on the length and the positioning of the straw stem and its rigidity, this can already be enough to break the straw though. Further forces attacking the straw can result from pressure against other straw stems or against the chopper housing, from the twisting of the straw with other stems, or from the air resistance.

The number of stems and straw pieces available for cutting is increased through the higher knife speed. Also increased through the higher rotor rpm is the number of knife contacts with the straw particles in their flight path through the chopper. This action depends on the speed of the particles in the chopper not being greatly altered. This assumption is supported in that the exit speed of the chopped straw decreased, despite an rpm and therefore knife speed increase of 75 %. In the trial arrangement shown, the straw exit speed reduced from 10 m/s at 2400 rpm to around 8 m/s at 4200 rpm.

The straw stems were increasingly further shortened on the way through the chopper. When the opposite-force required for the cutting action can no longer generate itself, the stem is only cut into, and is bent over at this point.

The stem settles against the blade of the knife and is carried with the blade and thrown by the centrifugal force off the blade outwards, or still further chopped through additional contact. The procedure during straw intake and propulsion was investigated with a digital high-speed camera. In *fig. 3*, a cutting from a high-speed video is presented which shows the area of the contra-blade. The fixed contra-blade can be seen to the left in the picture. The cutting blade looms into the picture from the right hand side and begins at this moment to disappear between the contra-blades. This exposure took place at 3300 rpm (circumference speed of knives 88.8 m/s). In the marked area several straw particles can be seen that have pressed themselves against the revolving blade. The preceding pictures show clearly that this is not a cutting procedure but that the particles are in fact moving along with the cutting blade.

Summary

The investigations showed a definite association between the rotor rpm and the reduction in size of the straw stem particles. Increasing the revolutions in order to achieve a better reduction in size with limited technical investment has been used in the past by combine manufacturers. This also means, however, a substantial increase in the power requirement. But the increase in revolutions does not lead to a rise in the exit speed of the straw particles and so is not a way to achieve a greater expulsion force and better lateral spreading performance over the field surface. The oscillating sieve that was used for the comparison of chopped straw samples out of different trial settings proved a good assessment tool. Through the use of a digital high speed camera the analysis of the cutting and propulsion procedures was greatly helped. The investigations are continuing.

Literature

[1] *Kämmerer, D.:* Untersuchungen am Mähdrescherhäcksler. Landtechnik 53 (1998), H. 6, S. 390 – 391

[2] *Hermann, K.:* Technologische Untersuchungen an Mechanisierungsmitteln zur Strohzerkleinerung für die Düngung. Deutsche Agrartechnik 22 (1972), H. 6, S. 271 – 273

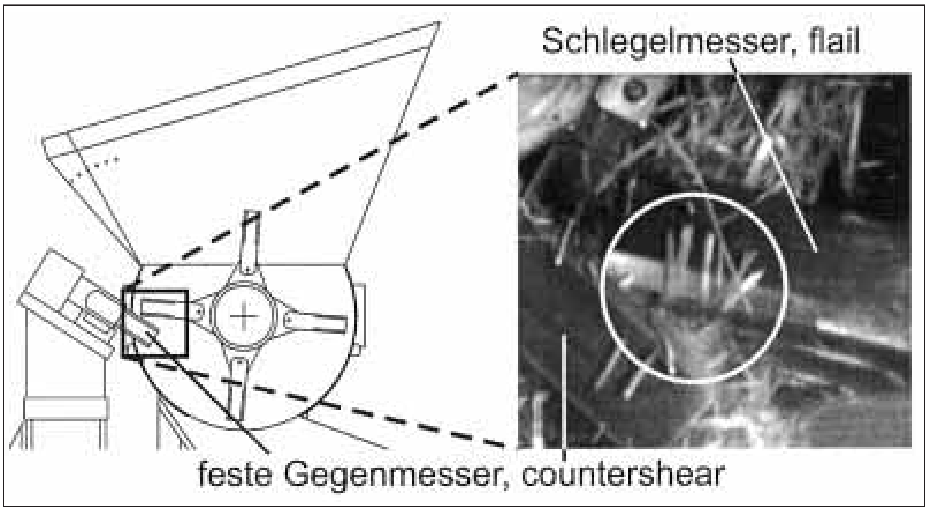

Fig. 3: High speed recording of the chopping procedure at 3200 rpm