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Alignment of straw to optimise the cutting process in a combine's straw chopper

Cutting of straw and similar materials plays an important role in many agricultural processes. Especially shorter and less stable materials like grass and straw are often supplied to the cutting device in an unsorted mat. Thereby the orientation of the individual stalks to the effective direction of the cutting tools is stochastic. This stochastic orientation of stalks causes uneven cutting lengths in the cutting device. The Institute of Agricultural Machinery and Fluid Power at the Technische Universität Braunschweig researches the alignment accuracy of stalks and possibilities to align stalks in a systematic way using the example of a combine's straw chopper.

Keywords
Combine harvester, cutting, straw

Abstract

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Besides the harvesting process the cutting of threshed straw and its uniform distribution is of major importance during the grain harvest. Especially in conservation tillage systems an even and short cutting length of straw is desirable for undisturbed soil preparation and sowing. However, it should be noted that for any stalk cutting operation power is required. The shorter the straw is chopped the more cuts are needed and the greater is the power requirement of the chopper. To achieve the desired cutting length with a minimum of power, the cutting length of the straw has to be as uniform as possible in order to reduce the resulting cutting operations.

However, in practice the cutting length of a combine's straw chopper varies significantly [1, 2, 3] as the less stable and relatively short stalks are supplied to the blades in an unsorted mat. Within this mat the orientation of the individual stalks relative to the effective direction of the blades is stochastic. **Figure 1** displays that in a combine's straw chopper the theoretical cutting length L1 and the effective cutting length L2 differ significantly from each other according to the angle α. In the worst case with $\alpha = 90°$ the straw potentially will not be cut at all. For cutting these unfavourable oriented stalks into the desired lengths, the distance between the cutting zone 1 and 2 has to be chosen sufficiently small.

The distance between cutting zone 1 and 2 can be reduced by increasing the chopper speed or the number of blades. If these arrangements provide a sufficient short cutting of unfavourable oriented stalks, favourable oriented stalks are cut more often and consequently cut shorter than intended. This causes an unnecessarily high power consumption of the straw chopper. Therefore, in practice a medium speed is chosen for the straw chopper that leads to a reasonable cutting length distribution in combination with an acceptable power requirement.

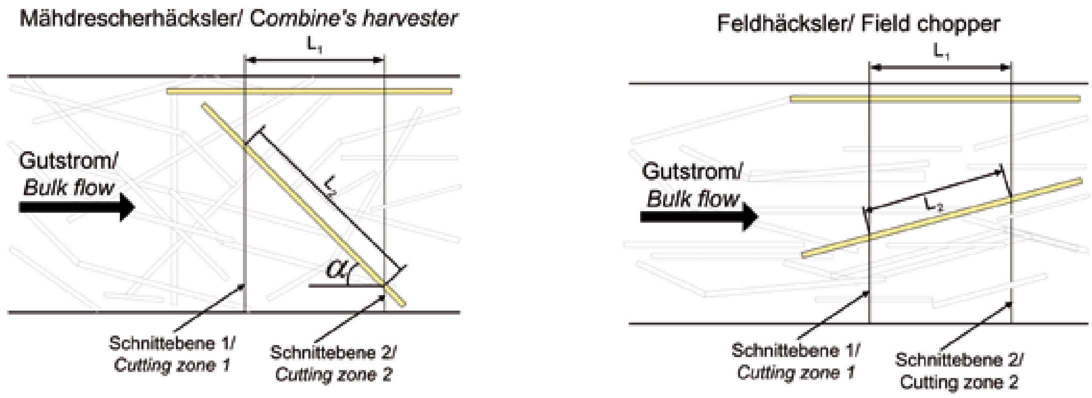
Compared to that in the cutting process of a forage harvester longer stalks like maize are aligned almost parallel and perpendicular to the blades (**Figure 1**). Accordingly the effective cutting length L2 is almost equal to the theoretical cutting length L1 and the power consumption is just on the required level.

Based on the previously described aspects possibilities to optimize the cutting process in a combine's straw chopper by systematic alignment of the stalks are researched at the Institute of Agricultural Machinery and Fluid Power (ILF) at the Technische Universität Braunschweig. This fundamental research project is funded by the Deutsche Forschungsgemeinschaft (DFG).

Pilot tests

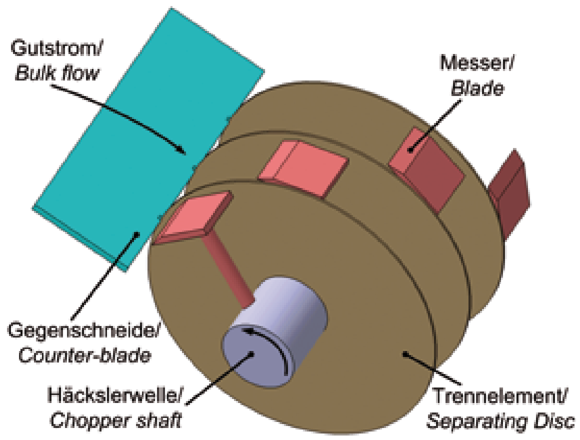
To assess the potential of systematic straw alignment in order to optimize the cutting quality various pilot tests were conducted at the ILF. Basis for the experiments was a chopper with an open design and segmented blades. This chopper has been modified in the way that unfavourable oriented stalks are blocked by separating elements. These elements are designed as discs which are located in each case between two blades on the chopper shaft. Their diameter is equal to the flight circle of the blades (**see Figure 2**). Thus unfavourable oriented stalks should be blocked by the separating discs and directed to the flight circle of the blades by the conveyed straw.

Fig. 1



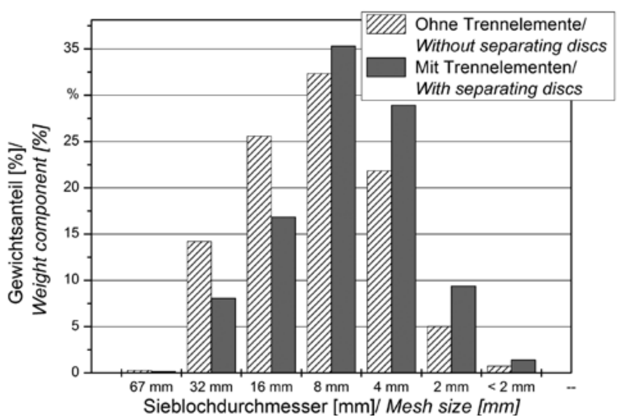
Theoretical and effective cutting length of straw in a combine's harvester and of maize in a field chopper

Fig. 2



Cutting device with integrated separating discs

Fig. 3



Cutting quality with and without additional alignment by a separating disc

The experiments were conducted with different throughputs and different number of separating discs (0, 3, 7). An exemplary result of cutting quality is shown in **Figure 3**. The figure displays the reduction of long chopped straw by using seven separating discs and furthermore constant experimental settings compared to a chopper without separating discs. The weight component of long chopped straw can be reduced significantly in favour of the medium cutting length. However, due to the friction between separating discs and straw the power consumption of the chopper is increased in the presented experiments.

The pilot tests display that in general the chopping quality could be improved through the use of alignment elements. But they also demonstrate that further analyses are necessary to align straw in a systematic way [4].

Examinations of the current state of straw alignment in a combine's straw chopper

As a basis for further research work, the current state of straw alignment in a combine's straw chopper was examined. In a first step wheat straw from a walker combine was collected on a plastic cover plate during the harvest 2010. The collected straw was manually cut out of the swath without changing the arrangement of stalks (**Figure 4**). Subsequently different straw samples were analysed in a computer tomograph (CT) of the Federal Institute for Materials Research and Testing (BAM) in Berlin.

The images from the CT were analysed by using a Matlab® based image evaluation routine. In this process the positions of stalks cutting a specific layer were identified in a three-dimensional coordinate system. By joining the individual layers it was possible to determine the position and orientation of the stalks without disturbing the structure of the straw swath.

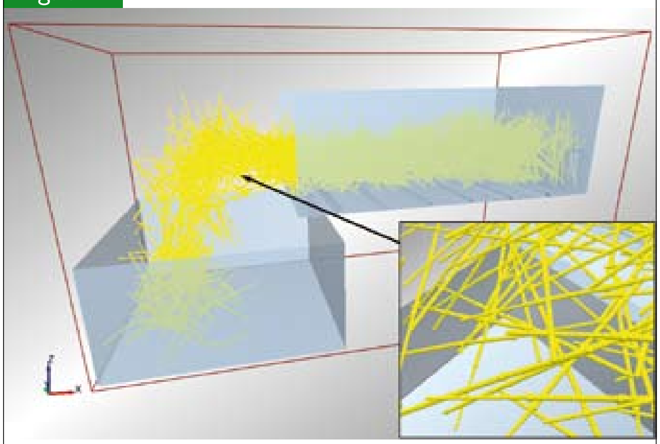
Simulating the behaviour of straw

To replicate the behaviour of straw in the feeding of a combine's straw chopper a simulation model is built up based on the analy-

Fig. 4

Separated straw sample and the belonging CT-picture of the sample

Fig. 5



The behaviour of straw in a DEM-simulation

sis of the straw samples. The "Discrete Element Method" (DEM) is used for this simulation as it is suitable for non-homogeneous and flexible materials like straw. The parameter setting is essentially based on literature, supplemented by additional experiments. **Figure 5** shows the current state of the simulation model. The stalks are modelled as chains of connected balls which are given on the right side on an oscillating conveyor. Through the oscillating movement of the conveyor the stalks are forwarded to the conveyor's end, where they are fed to the straw chopper in a free fall. Using the simulation, the interaction of stalks and their orientation can be analysed easily for different experimental setups.

In the further work the simulation model will be used to estimate the potential of systematic straw alignment for optimising the cutting quality. In a next step various mechanical devices will be examined in the simulation regarding their suitability to improve the straw alignment. The verification of the simulation model will be carried out on a stationary straw chopper test rig. For this purpose the feeding process of the chopper can be analyzed with a high speed camera and the cutting quality by using a vibrating screen.

Conclutions

Based on the theoretical considerations and practical experiments the presented project offers a great potential for optimizing the cutting process in a combine's straw chopper by improving its cutting quality and reducing its power consumption. The simulation of straw provides an important tool to support this research work. Currently, the development of a device to align the straw is a major challenge, as large material throughputs have to be processed in limited space. In the future the gathered knowledge could be transferred to other cutting processes such as in forage wagons or balers.

Literature

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