Korn, Christian; Fehrmann, Jens; Herlitzius, Thomas; Flanhardt, Michael and Acimas, Andreas

Development of a straw chopper for combines for increased working width

Increasing header widths lead conventional chopping systems with horizontal rotor and passive distribution elements to the performance limit. Only through extensive and power-intensive ancillary units, a sufficiently uniform cross distribution of the straw can be achieved. Using the principle of inertial cutting without counter blade, the development of a chopper test rig, characterized by two vertical rotors is realized in cooperation with the manufacturer Rasspe Systemtechnik. The results of extensive laboratory studies of power demand, material velocity, chopping quality and lateral distribution are presented in this article.

Keywords
straw chopper, combine, lateral distribution, chopping quality, spreading width

Abstract

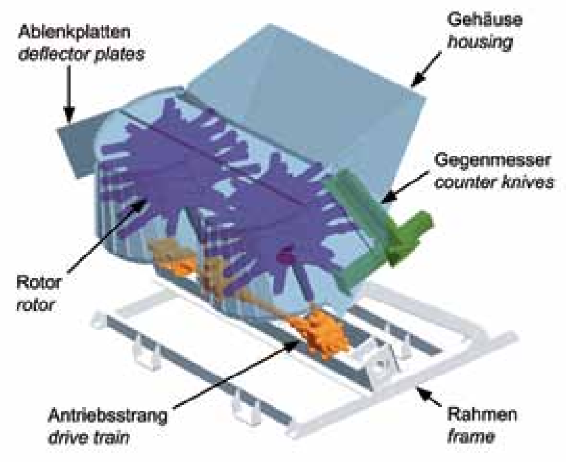
Landtechnik 67 (2012), no. 1, pp. 11–16, 7 figures, 1 table, 11 references

If the crop residues remain on the field after threshing, the chopping- and distribution quality play an important role for all following processes, including tillage, fertilization and crop protection [1 .. 3]. Based on an extensive analysis of the state of the art and science [4 .. 8], it was determined that current, conventional systems with a horizontal rotor, which is transversely aligned to the direction of travel and using passive distribution elements, the technical and physical performance limit is reached at about 9m working width. By subordinate active distribution elements (radial spreaders), the throwing width will be increased, which is associated with a higher power requirement and additional acquisition costs. Theoretical preliminaries, a list of requirements with technical and economic parameters and a comparison of variants have contributed to the development of a prototype of a straw chopper with two vertically aligned rotors. The main advantage over conventional systems with deflector distribution is, that the part of the chopped material, which is used to be transported in the most outer regions, suffers no energetically unfavorable deflection by guiding plates and can be discharged directly. It is therefore assumed that the chopped material exits the chopper with a higher speed and active distribution elements are dispensable.

Setup of the test rig

The test rig, developed at the chair of Agricultural Systems and Technology and shown in **Figure 1**, is designed for laboratory tests. It is driven by a variable speed three-phase asynchronous motor with a rated power of 75 kW, which is connected via cardan shaft and a torque measuring equipment with the test rig. The rotor speed can vary between n_R = 1 150...2 300 rpm, corresponding to a main circumferential speed (cutting speed) of v_u = 55...110 m/s. The non-intermeshing rotors are built up modular and consist of eight stacked rotor plates. Four pairs of flail knives are mounted on each rotor plate. The rotor plates can be removed if necessary and replaced by other rotational elements. To achieve the required chopping quality it is possible

Fig. 1



Setup of the chopper test rig

Fig. 2

Test rig with feeding equipment

to use controller bars with a variable side length in the effective range of the rotors. Furthermore counter knives are used, which are adjustable in terms of operation depth and angle.

Test performance

The feeding with long straw in the laboratory is realised by a threshing test rig (conventional threshing unit) with a channel width of b = 800 mm. Regarding the pre-damage of the starting material and the decompaction of the material layer, it can be assumed that the feeding is feasible. The experimental design involves the study of the impact parameter circumferential velocity v_u, straw throughput Q and the type of knife, whereas standard knives or paddle knives (Paddlemesser® by Rasspe) are used, and further design modifications with regard to their effect on power demand P_{An}, material velocity v_G, chopping quality and lateral distribution. The design of the feed duct is close to the straw hood of real combines, but made of perspex for observing the material flow and receiving behavior. At the top, the feed duct can either be closed, or as shown in **Figure 2**, be opened. Material flow studies on the maximum achievable throughput can be examined in addition to the above-mentioned feeding on a real combine harvester with a channel width of b = 1 600 mm. In this way, straw throughputs up to Q = 35 t/h can be realised.

Regardless of the experimental setup, the total experimental time is t_{ges} = 8 s, where t_{stat} = 5 ± 0,5 s stationary test period is available for evaluation. In each test, the drive torque and rotational velocity are measured. If necessary, the material velocity using a high speed camera and the lateral distribution using collection containers are captured. To assess the chopping quality, a straw sample is taken after each test. The configurations of the variants of the chopper, presented in this article, are shown in **Table 1**.

Test results

Power demand

The power demand P_{An} is specified in **Figure 3** for the test parameters circumferential speed v_u, straw throughput Q and straw chopper configuration. Defined is the total power consumption, which includes the idling power demand. With a constant straw feed rate a slight disproportionately high increase of the power demand with growing circumferential speed can be recognised,

Table 1

Configurations of the vertical chopper

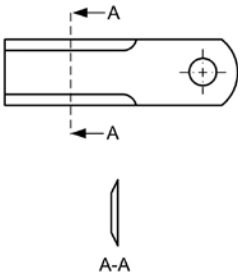
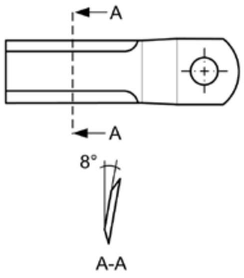
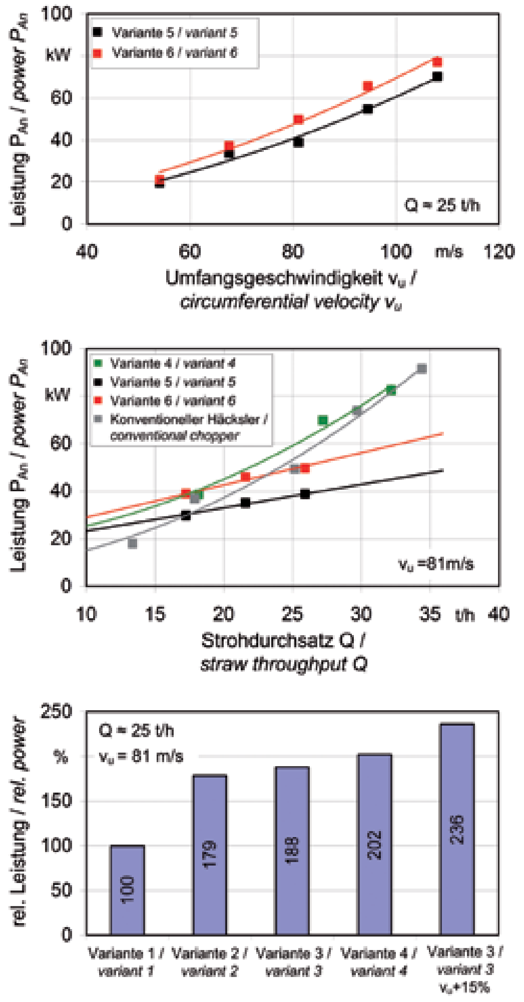
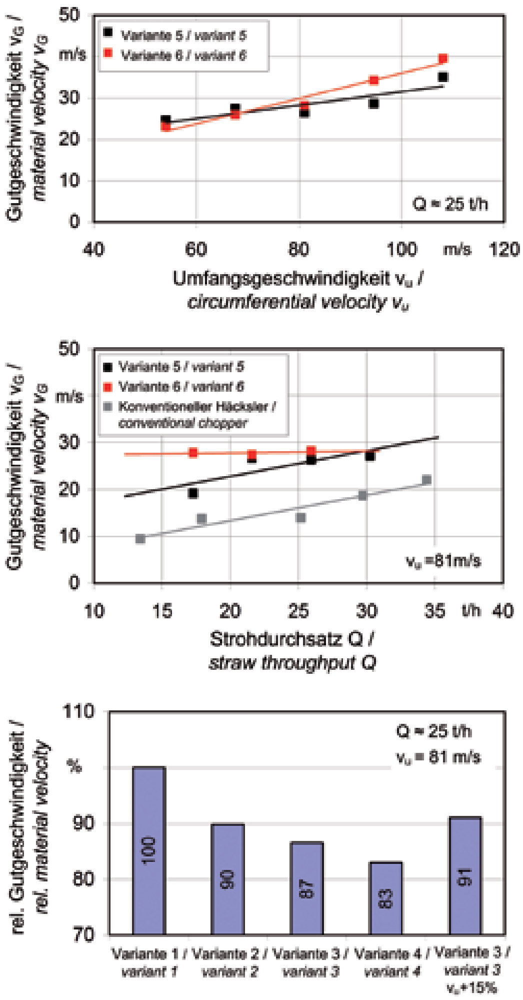
Variante ***Variant***	**Auststattung/Configuration**				**Standardmesser** ***Standard knife***	**Paddelmesser** ***Paddle knife***
	Messer/*Knives*		**Gegenmesser** ***Counter knives***	**Reibleisten** ***Controller bars***		
	Standardmesser ***Standard knives***	**Paddelmesser** ***Paddle knives***				
Variante 1 *Variant 1*	X	-	-	0		
Variante 2 *Variant 2*	X	-	X	0		
Variante 3 *Variant 3*	X	-	X	1		
Variante 4 *Variant 4*	X	-	X	2		
Variante 5 *Variant 5*	X	-	-	2		
Variante 6 *Variant 6*	-	X	-	2		

Fig. 3



Power demand

Fig. 4



Material velocity

which matches with specifications in the literature. The reason for that is not only the speed, but also the power demand is increasing, which can be explained by the input of idling power demand and by a higher number of material cuts. The result is expressed in **Figure 5** with a rising chopping quality.

Pictured over the straw feed rate, the different trajectories between the test variants with counter blades (variant 4 and conventional) resp. without counter blades (variant 5 and 6) stands out. The application of counter knifes into the scope of rotors causes a disproportionate high increase of the power demand.

If the trajectories of variant 5 (standard knives, plain) and variant 6 (paddle knives, twisted) are compared, variant 6 is characterised by a higher power demand. The torsion of the knife section compared to the bearing section with the paddle knives (see **Table 1**) causes a higher air flow rate and a higher material discharge speed, as described in the article later. For the comparison of total power consumption between the chopper with vertical rotors and the conventional chopper, variant 4 can be used, because of the similar configuration. Above a straw feed rate of 30 t/h the chopper with vertical rotors demonstrates lower power consumption. Below a straw feed rate of 30 t/h with the conventional chopping system a lower power demand appears, compared to the new system. This is because of lower idling power consumption.

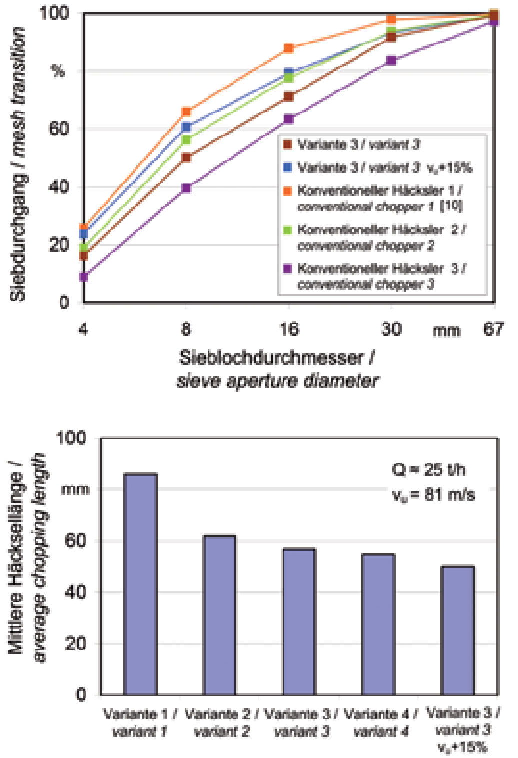
The new chopper system needs optimisation for lower power consumption in no-load operation. The influence of different straw chopper configurations (counter blades and controller bars) shown in **Figure 3**, behaves as expected.

Material velocity

For the determination of the material velocity v_G, a high speed camera is used, recording a representative area of the discharging material flow. At 2000 fps a test period of t = 4.1 s can be captured. By the tracking of 200 randomly selected particles per test, a mean material velocity can be calculated.

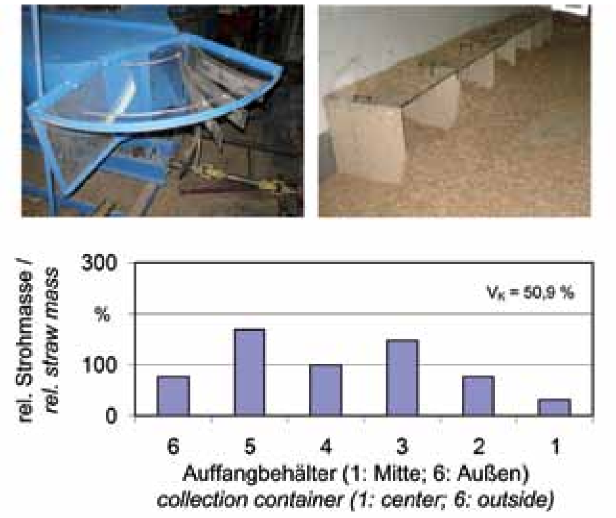
As shown in **Figure 4**, the use of paddle knives raises the material velocity, whereas the effect is more developed at high circumferential velocities. Both variants show the expected increase of material velocity with increasing circumferential

Fig. 5



Chopping quality

Fig. 6



Measurement of lateral distribution

velocity. The influence of straw throughput on the material velocity is at variant 5 (standard knives) and the conventional chopper characterised by a proportional increase, comparable with the data in the literature [3], whereas the vertical chopper shows of about v_G = 10 m/s higher material velocities across the entire range of throughput. The measurement of the conventional chopper is realised in the middle of the discharge area, so that the chopped material undergoes no deflection by deflector plates. A positive feature of the paddle knives (version 6) appears in the consistently high material velocities at low throughputs, due to the high volume of air flow rate, which, as it will be shown later in this article, is produced by the paddle knives. The influence of the chopper configuration is illustrated in **Figure 4** by indicating a material velocity related to variant 1. Elements to increase the chopping quality affect the material velocity negatively, but it will be shown below, that they are necessary for achieving the chopping quality, which is defined in the goals of this project.

Chopping quality

For the evaluation of the chopping quality, the respective straw sample is fractionated by a cascade screen. The screen sizes correspond to those used by the DLG, so that test results, for example [10], can be used as a benchmark for the vertical chopper. The presentation of mass distribution (rate of passage through a sieve) on screen diameter (length of straw fractions) in **Figure 5** demonstrates the comparability with a conventional chopper. By increasing the circumferential speed or the use of additional resistance equipment, the chopping quality can improved. This goes along with a higher power demand (see **Figure 3**). At this point, the goal conflict becomes clear, which exists between the requirements for low power demand, high material velocity and a reasonable chopping quality. The present optimization problem must be solved to find the best operating parameters.

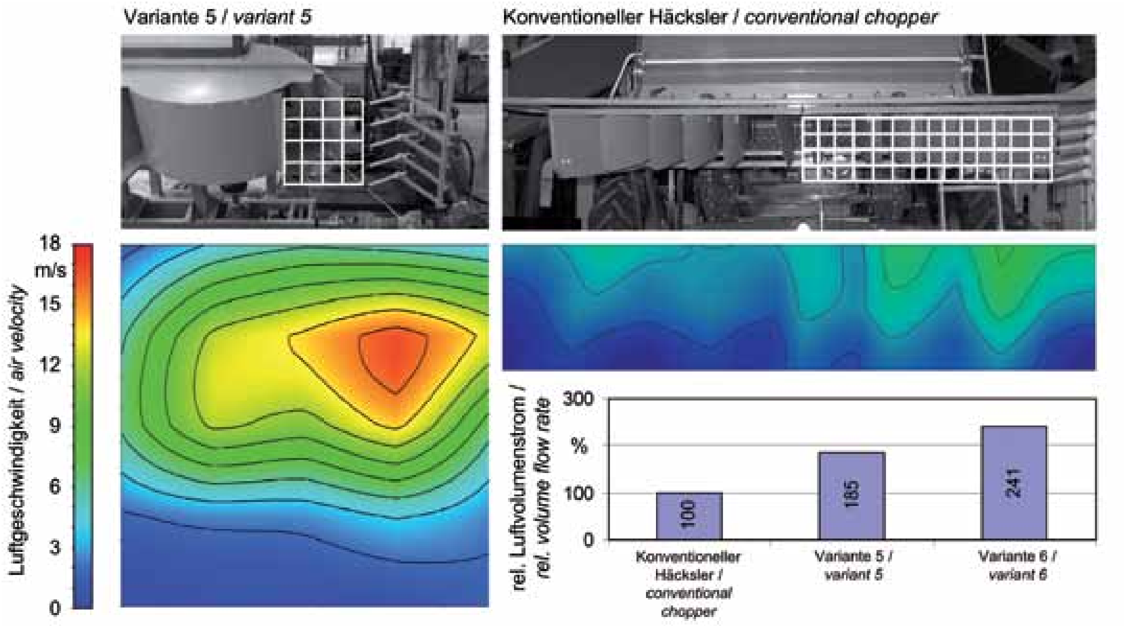
Lateral distribution

First test series to prove the uniform lateral distribution showed a coefficient of variation of V_K = 50,9 %. Compared to the goal of V_K < 25 %, this result is not acceptable. At this point, extensive research is required. The tests could confirm the requirement for a throw width of b = 12 m positively. The used collection containers shown in Figure 6 have a width of one meter.

Air velocity

The measurement of air velocity is pursuing the goal of finding a possibly existing correlation between the material velocity and the flow velocity in the range of discharge. It is simultaneously measured with five rotating cup anemometers over a period of t = 20 s, so that turbulent fluctuations of velocity have only a negligible influence on the averaging. The investigated measuring grid and the corresponding velocity profiles are comparative shown in **Figure 7**. The vertical chopper with flat knives (variant 5) shows a 85 % higher relative air flow rate over conventional chopper (also flat knives), which can be increased by the use of paddle knives (variant 6) again by about 60 %. Further measurements have shown that the flow profile of the vertical chopper can be evened out by the strategic use of left or right -twisted paddle knives. It can be shown, although initially

Fig. 7



Measurement of air velocity

only qualitatively, that there is a correlation between the flow velocity and the material velocity. At this point, further studies are planned, which are experimentally on the one hand and on the other hand are numerical, based on computational fluid dynamics (CFD). In [11] results have already been published on the use of CFD as a tool in the development of the presented project.

Conclusions

The executed laboratory studies on the vertical chopper have confirmed the potential for increasing throwing width up to 12 meters. At high throughputs and comparable chopping quality the power demand is equal to that of a conventional chopper. Because of the high material velocity at the discharge, it is expected that additional active distribution elements are dispensable and so a power saving is realised. The further experimental design includes the optimization of the idling power demand and the achievement of a uniform lateral distribution.

Literature

[1] Kiefer, J., (1988): Untersuchungen zur Sätechnik bei Getreide unter besonderer Berücksichtigung von Vorfruchtrückständen im Saatbett. Dissertation, Forschungsbericht Agrartechnik MEG, Kiel
[2] Hölzmann, H.J. (2002): Stroh häckseln oder bergen? GetreideMagazin 3/2002, S. 166–169
[3] Fehrmann, J.; Grosa, A.; Herlitzius, T.; Mohn, T.; Mohn, G. (2009): Introduction of a new tillage concept ROTAPULL. Tagung LAND.TECHNIK AgEng 2009, VDI-MEG, 06.–07.11.2009, Hannover, S. 251–258
[4] Kämmerer, D. (2002): Der Schneid- und Fördervorgang im Mähdrescherhäcksler. Dissertation, Braunschweig, Shaker Verlag
[5] Wieneke, F. (1991): Strohzerkleinerung. Landtechnik 46(6), S. 262–264
[6] Bognár, J.; Szendrö, P. (2004): Zerkleinerung von Halmgütern. Landtechnik 59(2), S. 82–83
[7] Lücke, W.; v. Hörsten, D.; Henning, H. (2004): Mähdrescherhäcksler. Landtechnik 59(1), S. 30 u. 35
[8] Wallmann, G. (2006): Gutzuführung für Mähdrescherhäcksler. Dissertation. Braunschweig, Shaker Verlag
[9] Wiedermann, A. (2011): Exaktschnitt im Mähdrescherhäcksler. Dissertation. Braunschweig, Shaker Verlag
[10] DLG Prüfbericht 5445F (2005): Häckselqualität John Deere 9880i STS. DLG Testzentrum, DLG Verlag
[11] Flanhardt, M.; Acimas, A.; Herlitzius, T.; Korn, Ch.; Fehrmann, J. (2011): Optimize the passive wide spreading of chopped straw on combine harvesters by using an alternative active principle. Tagung LAND.TECHNIK AgEng 2011, VDI-MEG, 11.–12.11.2011, Hannover, S. 39–45

Authors

Dipl.-Ing. Christian Korn and **Dipl-Ing. Jens Fehrmann** are members of the scientific staff at the Institute of Processing Machines and Mobile Machinery at the Technical University of Dresden, Chair of Agricultural Systems and Technology (Supervision: **Prof. Dr.-Ing. habil. Thomas Herlitzius**), Bergstr. 120, 01062 Dresden, e-mail: korn@ast.mw.tu-dresden.de

Dipl.-Ing. Flanhardt Michael is managing director and **Dipl.-Ing. Andreas Acimas** is director of product engineering at the company Rasspe Systemtechnik GmbH & Co. KG, 42929 Wermelskirchen.

Acknowledgment

The presented project was realised with support of the Allianz Industrie Forschung (AIF). We thank the manufacturer Rasspe Systemtechnik GmbH & Co. KG for the excellent collaboration.