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# A new functional element for conventional combines

Applying a model to investigate material transfer between threshing drum and straw walkers enabled development of a new functional element offering controlled conditions for grain separation and material flow at this point, even where working and crop conditions varied. The additional element comprises a multi-tine drum with fixed mantel. Theoretical observations of material transfer were verified through experimental investigations. With the optimised multi-tine drum, throughflow increases from 9 to 16% were achieved with 1% walker loss over the basis on the level but also in positions simulating uphill and downhill work.

***Keywords***
*Combine harvester, straw walker, slope*

***Abstract***
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Normally a rotating beater is used to transfer the grain-straw mix from threshing drum to straw walkers. Important for good grain separation is slowing the grain/straw mix as quickly as possible as it leaves the beater with its angle of direction changed and lands on the beginning of the straw walkers.

The danger here is that the beater carries the material further round its circumference instead of it being thrown onto the walkers. With current combine harvesters (used as basis) the flow is directed onto the walkers by a finger rake or basket with a baffle curtain additionally braking velocity (fig. 1). This transfer process is, however, sensitive to the influences of varying working parameters (e.g. rate of throughput, degree of slope) as well as differing crop parameters (e.g. moisture content, type of crop). This project's main aim was the establishment of a model for the material flow from threshing drum to straw walkers and its application in the development and testing of an additional functional element at this point to ensure controlled conditions for grain separation on the straw walkers under all conditions while maintaining efficient throughput.

## Theoretical observation of basis

As first, development of a movement model was established to act as basis. This was used to calculate material trajectory after leaving the beater and impact point on the surface of the straw walker where inclination angle was $\gamma$ (fig. 2).

Here main factor is the influence of the field slope in ascending and descending lines. The model assumes that, according to experience, the throw direction of material after leaving the beater agrees reasonably closely with the finger rake angle $\beta$. The coordinate origin (0.0) of the x-y coordinate system is in the finger rake endpoint and, with a combine longitudinal angle $\delta$, is not turned and therefore remains fixed. The impact point on the straw walker surface is the intersection of the trajectory equation (1) of the material $(x, y_G)$ and the linear equation (2) of the straw walker surface $(x, y_S)$.

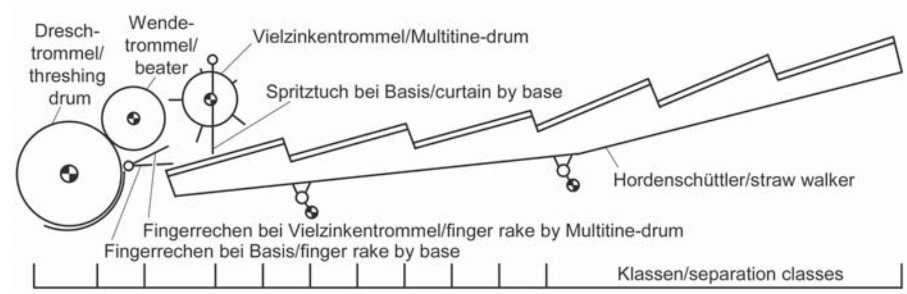
Unexpectedly, the calculations indicated that angle of slope had very little influence on impact point of material on the walker surface. Through the actual tangential velocity $v_0$ a very limited change of trajectory direction was caused by material gravitational acceleration g.

## Theoretical observation of additional functional element

Theoretical observation of material movement and grain separation continued, main focus being not influence of slope but instead improvement of grain separation on the level. Observations continued to assume that the throw direction of material leaving the beater could be controlled by finger rake angle. The thesis was advanced that, for improved grain separation, the material flow should impact against an active functional element with grain thus being deflected vertically downwards. The plasticity of the straw could therefore allow the deflected grain to penetrate the material layer and very rapidly reach the walker surface. The straw, on the other hand, must be braked by the additional functional element then actively transported further, being angled backwards/downwards, landing further back on the walker than grain deflected off the impact surfaces.

Additionally this action results in greater impact velocity on the walker of the straw mattress containing not-yet separated grain than with the basis and this also has a positive effect on grain separation performance. Such a functional element must therefore have an impact surface and effective element for straw transport. Meeting these requirements in principle would be the tine drums used by a number of combine harvester manufacturers. However, the rotating mantel featured with such tine drums means relatively few tines can be fitted and thus straw transport action is insufficient. For this reason, a multi-tine drum with fixed impact mantel was selected and tested. This version also replaced the baffle curtain with a conventional pick-up reel and its application helped by setting the finger rake angle steeper (fig. 1).

Fig. 1




*Test stand (base, Multitine-drum)*

With a model based on the above thesis (fig. 3) and the equations (3) to (6), the finger rake angle β can be determined to suit different positions (x, y) and construction parameters of the multi-tine drum. The imparity between impact angle $\alpha_1$ and throw angle $\alpha_2$ through the partly elastic impact behaviour of the grains on the impact mantel is taken into consideration through equation (3). The partly elastic impact is described by the impact factor k (k = 1:full elastic impact; k =0: plastic impact). Equation (4) results out of the requirement that the grains should be deflected vertically downwards. Furthermore, it is assumed that the thickness of the material mattress is determined by the distance d between beater and finger rake and therefore also influenced by finger rake angle. The material flow is reduced to a compact material stream. In that, however, the material flow is fanned out a little higher upwards rather than downwards by the positioning of the finger rakes after leaving the beater, the distance of the material stream parallel to the finger rakes is established not as ½ the material flow thickness but instead as ¾. The resulting equation (5) from equations (3) and (4) enable, together with equation (6), an iterative calculation of finger rake angle.

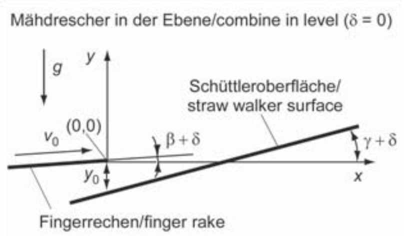
Fig. 4 shows the calculated finger rake angle β and the impact and throw angles $\alpha_1$ and $\alpha_2$ in association with the impact factor k (construction parameter as with experimental tests). For an impact factor calculated in [1] for wheat on steel with k = 0.5 the calculated finger rake angle is β = 30°. While impact and throw angles are clearly dependent on the impact factor, the reference line for finger rake angle is relatively flat. As a result it is estimated that it is not necessary to regulate finger rake angles for different types of material and material parameters.

## Experimental trials

To verify theoretical observations, a stand for laboratory tests was assembled [2]. The grains and non-grain-components (NGC) separated in the individual areas were recorded in classes. The trial material was unthreshed wheat. Trials were carried out with the basis (β = 4°, with baffle curtain) and with the multi-tine drum (β = 4 to 37.5°, no baffle curtain) (fig.1). The pick-up reel inserted as multi-tine drum with adjustable tines comprised 5 rows of tines with 56 mm tine interspacing and 105 mm active tine length. The engagement angle of the tines was adjusted to transport the straw effectively. Distance between the tine points and the beater was as small as possible so that, as with the basis, only a minimum material throw round the drum occurred.

Applying high-speed photography, the material trajectories and associated velocities were determined. The very small

Fig. 2

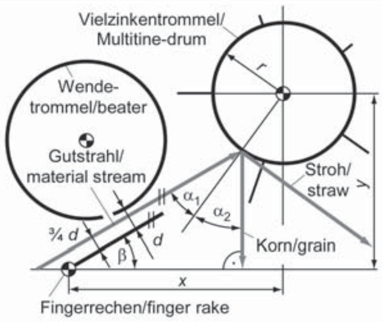



$$y_G = -\frac{g}{2}\cdot\left(\frac{x}{v_0\cdot\cos(\beta+\delta)}\right)^2 + \tan(\beta+\delta)\cdot x \qquad (1)$$

$$y_S = \tan(\beta+\delta)\cdot x - \left(\tan(\gamma+\delta)\cdot\cos\delta - \sin\delta\right)\cdot\frac{y_0}{\tan\gamma} \qquad (2)$$

*Model for impact point on straw walker surface*

Fig. 3




$$\tan\alpha_1 = k\cdot\tan\alpha_2 \quad (3) \qquad \beta = 90° - \alpha_2 - \alpha_1 \quad (4)$$

$$\beta = 90° - \alpha_2 - \arctan(k\cdot\tan\alpha_2) \qquad (5)$$

$$\tan\beta = \frac{y - \cos\alpha_2\cdot r}{x - \sin\alpha_2\cdot r + \frac{3\cdot d}{4\cdot\sin\beta}} \qquad (6)$$

*Model for finger rake angle*

changes in the impact point of the material on the walker surfaces through alteration of slope angle which were calculated as basis from theoretical observation were verified by the experimental trails. However, in order to enable slowing of the material velocity to normal walker transport speed right at point of impact, especially where throughflow of NGC $Q_{nkb}$ is low, effective baffle curtain positioning was necessary.

For verifying the observations on finger rake angle influence when using the multi-tine drum, walker losses in association with the finger rake angle were determined at a constant NGC throughput. The resultant optimum of $\beta \approx 30°$ (fig. 5) agreed very well with finger rake angle calculated from theoretical observation (fig. 4). With this optimised finger rake angle and further optimised parameters, NGC throughflow increases of 9 to 16% with 1% walker losses compared with the basis were achieved on the level as well as on ascending and descending slope lines [2] though application of the multi-tine drum. As expected, material flow in the beater to walker transfer area were not affected by angle of slope when the multi-tine drum was fitted.

## Literature


Books are identified by ●

[1] Thümer, W.: Beitrag zur Untersuchung der Kornabscheidung einer Leittrommel in Dreschwerken. Dissertation, Technische Universität Dresden, 1977

[2] ● Hübner, R.; Müller, H.: Steuerung der Gutgeschwindigkeit am Übergabebereich von der Wendetrommel zum Hordenschüttler. Tagungsband VDI-MEG-Tagung Landtechnik, Stuttgart-Hohenheim, 2008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## Notice:

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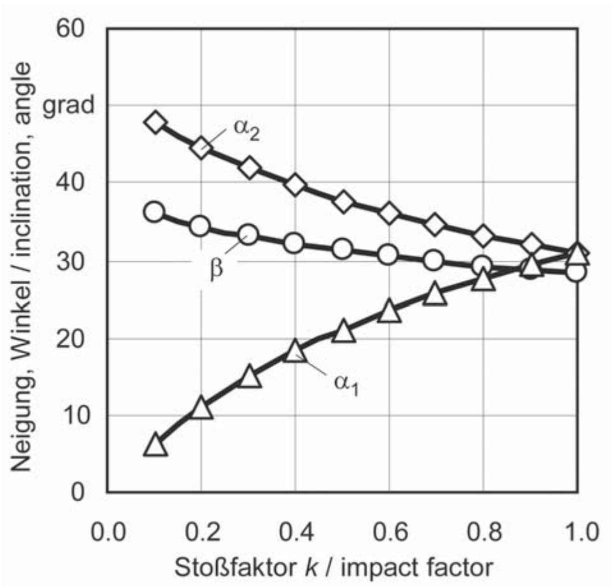
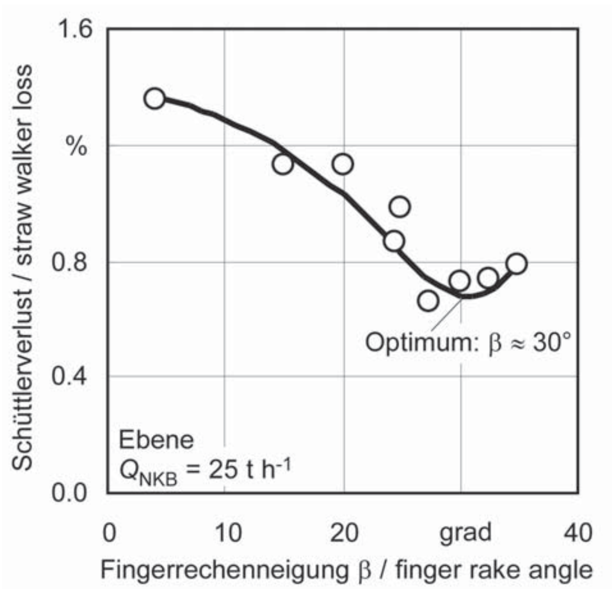
Fig. 4




*Finger rake angle and impact- and reflection angle vs. impact factor*

Fig. 5




*Straw walker loss vs. finger rake angle*