Ralf Hübner, Dresden

Control of the Conveying Speed on the Straw Walker

Theoretical calculations of the influence of the conveying speed on the straw walker lead to the insight that an optimal conveying speed exists, which depends on the MOG feed rate. If the conveying speed is controlled depending on the MOG feed rate, the feedrate-loss curve of the straw walker is significantly flatter in particular at the upper loss level. For control, it is sufficient to measure the layer height on the walker and to keep it at a constant level. Both on level and sloped fields, slope compensation in the levelled combine can be taken into account in conveying speed control.

Dr.-Ing. Ralf Hübner is a scientist working at the Chair of Agricultural System Technology (director: Prof. Dr.-Ing. habil. Bernhardt) at the Institute of Processing Machines and Mobile Machines of the Technical University of Dresden, D-01062 Dresden; e-mail: *huebner@st.mw.tu-dresden.de*

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Farms which intend to utilize straw remain interested in conventional combines. However, the capacity of the straw walker has already been fully exploited. The greatest problem is the very steep feedrate-loss curve in the case of overloading. In order to reduce susceptibility to overloading, studies on conveying speed control on the straw walker are being carried out.

The Problem

The conveying speed has an influence on both the height of the straw layer and the retention time on the walker. Since both parameters have opposing effects on the walker loss, this results in an optimal conveying speed. Experimentally, however, this optimum is difficult to determine because the parameters which can be used to vary the conveying speed (rotational speed of the walker, crankshaft stroke, inclination angle of the walker unit) also change the other parameters of the separating process (the number of impulses, the vertical and horizontal speed of impact of the straw layer on the walker unit). In order to solve this problem, the optimal conveying speed is considered theoretically. These studies are based on tests on a length-independent de-mixing test rig in which a vertically oscillating sieve stimulates oscillations in a straw layer and a fed-on grain mass is de-mixed and separated.

The De-Mixing Test Rig

On the de-mixing test rig, grain separation σ is determined by forming the quotient of the separated and fed-on grain mass as a function of the separation time t_D. Reference [1] lists the grain separation values for several MOG mass loadings m_{MOG} (wheat straw) under the conditions of constant mechanical stimulation and grain mass loadings of $m_k = 2\ \text{kg m}^{-2}$ (*Fig. 1*). The regression equation

$$\sigma = 1 - e^{K1 \cdot tD + K2} \qquad (1)$$

with $K_1 = K_{11}$ $K_2 = K_{21}$ at $m_{MOG} = 2\ \text{kg m}^{-2}$
$K_1 = K_{12}$ $K_2 = K_{22}$ at $m_{MOG} = 3\ \text{kg m}^{-2}$
$K_1 = K_{13}$ $K_2 = K_{23}$ at $m_{MOG} = 4\ \text{kg m}^{-2}$
$K_1 = K_{14}$ $K_2 = K_{24}$ at $m_{MOG} = 6\ \text{kg m}^{-2}$
$K_1 = K_{15}$ $K_2 = K_{25}$ at $m_{MOG} = 7\ \text{kg m}^{-2}$

allows the measured grain separation values to be interpolated.

Transformation on the Straw Walker

In order to cover the entire range of variation of the MOG mass loading m_{MOG}, which is proportional to the layer height, another regression is carried out using the following equations with the values of the coefficients $K_{11} \ldots K_{15}$ and $K_{21} \ldots K_{25}$ as a function of m_{MOG}:

$$K_1 = K_{1a} \bullet m^2_{NKB} + K_{1b}\, m_{MOG} + K_{1c} \qquad (2)$$

$$K_2 = K_{2a} \bullet m^2_{NKB} + K_{2b}\, m_{MOG} + K_{2c} \qquad (3)$$

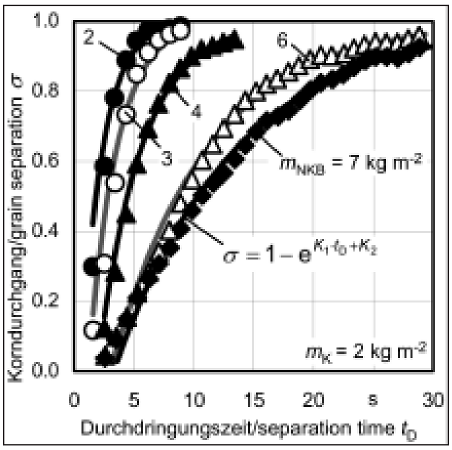

Fig. 1: Grain separation on a de-mixing test rig (according to [1])

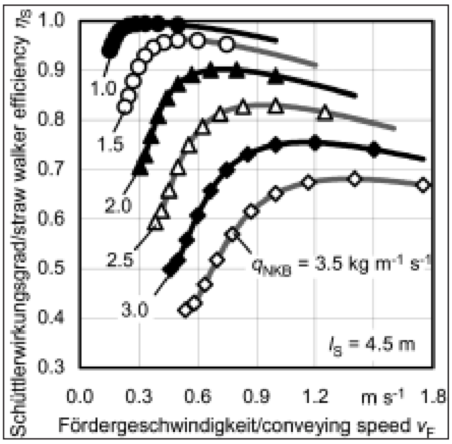

Fig. 2: Straw walker efficiency as a function of the conveying speed

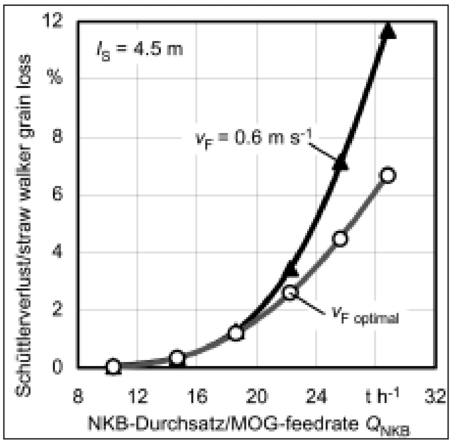

Fig. 3: Calculated feedrate loss curve

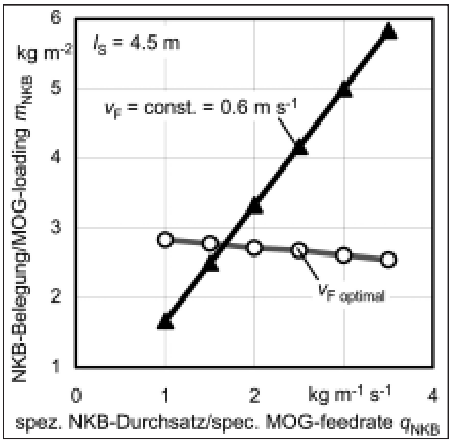

Fig. 4: MOG mass loading as a function of the specific MOG feed rate

If the results gained on the de-mixing test rig are intended to be applied in the continuous process on the walker, the separation time t_D and the MOG mass loading m_{MOG} must be expressed as a function of the conveying speed v_F. For this purpose, walker length l_s and the specific MOG feed rate measured directly on the walker are considered:

$$t_D = l_s / v_F \tag{4}$$

$$m_{NKB} = q_{NKB} / v_F \tag{5}$$

$$\sigma = \eta_s \tag{6}$$

On the walker, grain separation σ corresponds to walker efficiency η_s (eq.6). If equation 5 is put into equation 2 and 3 and the latter are put into equation 1 together with equations 4 and 6, walker efficiency can be derived:

$$\eta_S = 1 - e^{\left[K_{1a}\cdot\left(\frac{q_{NKB}}{v_F}\right)^2 + K_{1b}\cdot\frac{q_{NKB}}{v_F} + K_{1c}\right]\cdot\frac{l_S}{v_F} + K_{2a}\cdot\left(\frac{q_{NKB}}{v_F}\right)^2 + K_{2b}\cdot\frac{q_{NKB}}{v_F} + K_{2c}} \tag{7}$$

Calculated Optimal Conveying Speed

Equation 7 enables walker efficiency to be calculated for different conveying speeds, walker lengths, and specific MOG feed rates. *Figure 2* shows calculated walker efficiency for the common walker length l_s = 4.5 m as a function of v_F with q_{MOG} as a parameter. The markings on the curves cover the examined range m_{MOG} = 2 … 7 kg m^{-2}. For higher v_F values, K_1 and K_2 were extrapolated for m_{MOG} < 2 kg m^{-2}. As expected, walker efficiency drops with increasing specific MOG feed rates. However, it also becomes clear that walker efficiency reaches a maximum and thus an optimal conveying speed $v_{F\ optimal}$ exists. With growing q_{MOG}, the maximum shifts towards higher conveying speeds. Values exceeding the optimal conveying speed exert a smaller influence than values below the optimum.

Control of the Conveying Speed

The conveying speed of common current straw walkers is v_F = 0.5 … 0.7 m s^{-1}. *Figure 2* shows that this conveying speed range is the optimum for specific MOG feed rates q_{MOG} = 1.5 … 2.0 kg m^{-1} s^{-1}. For the conversion of the specific MOG feed rate q_{MOG}- measured directly on the walker into the MOG feed rate Q_{MOG} of a real combine, channel width and MOG separation in the threshing unit and on the walker of the combine must be taken into consideration. For this purpose, curves from laboratory and field tests were used. For a 6-walker combine, conversion leads to an MOG feed rate of Q_{MOG} = 15 … 19 t h^{-1}. Hence, the conveying speeds used today are only optimal for this MOG feed rate range in a 6-walker combine. At higher MOG feed rates, the conveying speed must be increased, whereas it must be reduced if the MOG feed rate is lower. However, the control of the conveying speed is most useful at higher MOG feed rates.

Capacity increase due to control based on the optimal conveying speed $v_{F\ optimal}$ as compared with the constant conveying speed v_F = 0.6 m s^{-1} at a walker length of l_s = 4.5 m is illustrated by the feedrate-loss curves shown in *Figure 3*. In order to determine these curves, the walker loss is calculated from walker efficiency (eq. 7) taking the thresher efficiency measured in the laboratory into account. Especially at the higher loss level, the feedrate-loss curve is considerably flatter and reduces the susceptibility of the walker to overloading.

Under practical conditions, the measurement of the conveying speed on the straw walker is relatively difficult. Therefore, a simpler possibility was sought.

At a constant conveying speed, MOG mass loading is proportional to the specific MOG feed rate. If, however, one calculates MOG mass loading on the walker at the optimal conveying speeds under the individual conditions (eq. 5), mass loading is virtually independent of the specific MOG feed rate (*Fig. 4*). If bulk density is constant, MOG mass loading is proportional to layer height. For this reason, constant layer height is suitable as a variable for the control of the conveying speed on the walker. Layer height is easier to measure than the conveying speed. Potential measuring methods are mechanical feelers and ultrasonic or laser distance measurement, for example.

The control of the conveying speed on the walker requires a solution to the problem that the other parameters of the separating process may not be changed. One possibility would be additional conveying elements on the walker. Moreover, the consideration of slope compensation in the control of the conveying speed in a levelled combine on both level and sloped fields is conceivable.

Literature

[1] • *Beck, Th.*: Messverfahren zur Beurteilung des Stoffeigenschaftseinflusses auf die Leistung der Trennprozesse im Mähdrescher. Fortschritt-Berichte VDI Reihe 14, Nr. 54, VDI-Verlag, Düsseldorf, 1992, Dissertation, Universität Hohenheim