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Torque-controlled Forward Feed of Chain Slats in Solid Manure Spreaders

To improve the application accuracy of solid manure spreaders longitudinally, a driveline control (DLC) was developed, which keeps the mass flow at the beaters constant through a closed loop. The coefficient of variation of the lateral distribution (VK_Q) was between 11.7 and 16.5 %. With or without DLC the coefficient of variation of longitudinal distribution (VK_L) was between 15.6 and 35.7 % and hence significantly higher. DLC had no effect in the test procedure on VK_L.

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Keywords

Solid manure spreaders, distribution accuracy, longitudinal distribution, torque control

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When spreading solid manure and secondary raw material fertilisers, the nutrients must be spread over the area as evenly as possible in order to avoid over- or under-fertilising in certain locations. In addition, material cycles should be run while keeping nutrient losses into the atmosphere and the hydrosphere to a minimum. While the coefficients of variation for lateral distribution achieved by current spreading units meet these demands, using a combination of beaters and distributing plates, longitudinal distribution is still considered unsatisfactory [1]. Distribution in small areas [2, 3] and over the entire unloading distance [4, 5] exhibits high coefficients of variation for longitudinal distribution.

Material and Methods

DLC System

The principle of DLC (drive line control) is based on the linear relationship between torque at the spreading elements and actual mass flow [6]. With the aid of a control circuit, the forward feed of the chain slats is adapted to a given torque. For different materials and application rates, characteristic torque curves are stored in a job computer, which can be selected at the operating terminal of the driver's cab (*Fig. 1*). The set torque value is calculated according to equation 1 as a function of the driving speed, which is measured at a wheel with the aid of a rotational speed sensor (DW 20, Walterscheid company). The actual value of the torque at the beaters and distributing plates is determined at the drive shaft using a contactless inductive torque measuring hub (SF 250, Walterscheid company). The job computer compares the set value with the actual value and uses an electromagnetic proportional valve to control the speed of the oil-hydraulic bottom conveyor drive. An interface at the job computer allows the data of the control process to be read out on-line using a PC.

$$M_{set} = m \cdot v + M_{idle} \quad (1)$$

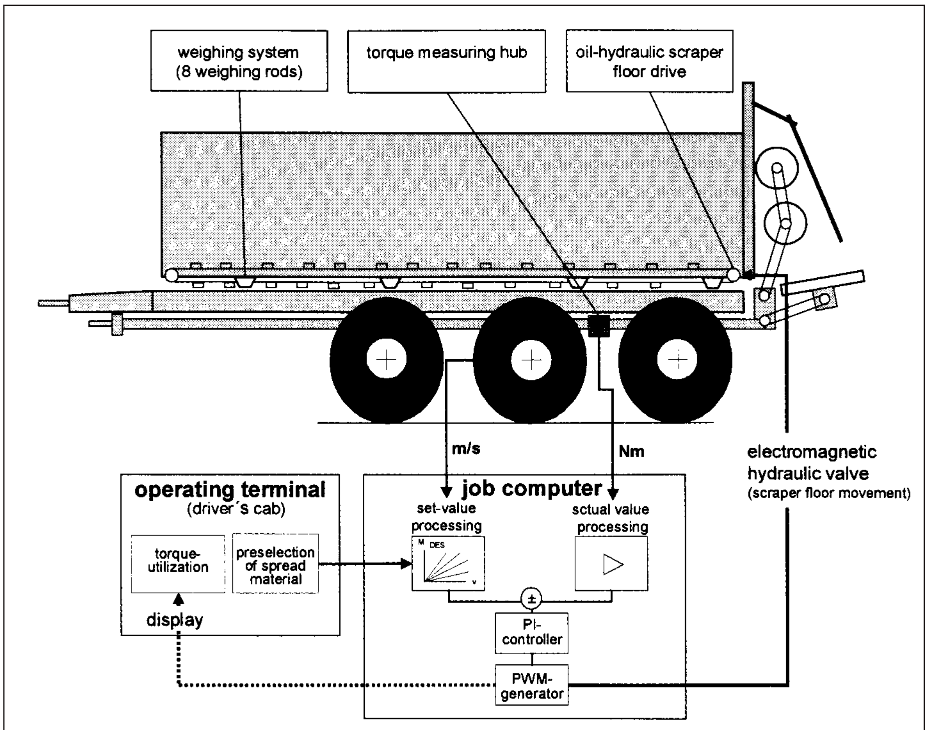

Fig. 1: Scheme of drive line control (DLC)

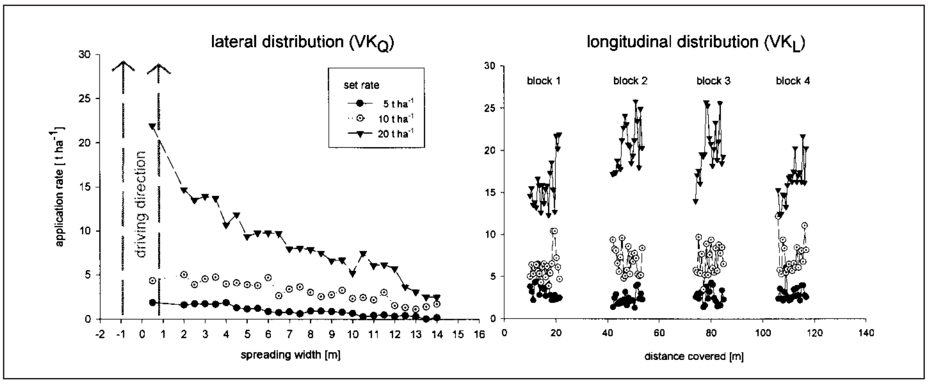

Fig. 2: One-sided spreading pattern of lateral distribution with different application rates (left). Manure distribution in longitudinal direction with drive line control, dependent on application rate (right)

M_{set} set torque value [Nm]
M_{idle} torque at idling speed [Nm]
m inclination corresponding to a characteristic curve for application rate and material
v driving speed [m/s]

Collection trays were used to determine the spread pattern during solid manure spreading in both a lateral and longitudinal direction. Three rates (10 t ha^{-1}, 20 t ha^{-1}, 30 t ha^{-1}) were applied and examined both with and without DLC system.

For the measurement of lateral distribution, the (unilateral) spread pattern was established using trays (50•50•5 cm) over a working width of 14 m in three blocks. Longitudinal distribution was measured over a total length of 120 m. At a distance of 4 m and 8 m from the tramline, four rows of trays (blocks) were set up, which comprised 20 trays each (58 • 34 • 11 cm) and were 12 m long.

Fresh, non-homogenised deep litter manure from a stall for suckler cows was used as material. The quantity of litter in the stall was 8 kg of non-chopped straw per day.

Results and Discussion

Depending on the application rate, the variation coefficients of lateral distribution (VK$_Q$) ranged between 11.7 % and 16.5 % (cf. *Table 1*). At values between 17.0 % and 35.7 %, the coefficients of variation for longitudinal distribution (VK$_L$) were significantly higher than those of lateral distribution. With a higher application rate, the coefficients of variation became smaller. They do not indicate that DLC system has resulted in improved longitudinal distribution (VK$_L$) (15.6% to 35.7%).

Figure 2 (left) shows the unilaterally recorded spread patterns of lateral distribution. At application rates of 5 t ha^{-1} and 10 t ha^{-1}, the spread flanks are rather flat, which enables overlapping errors to be kept small. *Figure 2 (right)* shows the spread patterns of longitudinal distribution for the test variants with DLC system over the trial distance of 120 m. It can be clearly seen that the variance within the test blocks is larger than between the test blocks. Only at the largest application rate (20 t DLC) a difference in the rates applied can be detected between the test blocks at an average of 16 t ha^{-1} in block 1 and block 4 and 20 t ha^{-1} in block 2 and block 3.

The evaluation of the torque courses has shown that in only one out of six trials did the torque deviate from the set value, which would be the prerequisite for the start of a torque-dependent control process. Obviously, the design of the spreader guarantees sufficiently even material supply and thus virtually constant torque even if the materials are less homogeneous. Since longitudinal distribution is subject to large fluctuations, in particular on a small scale, it is sensible to use collection trays when measuring the accuracy of distribution in both a longitudinal and a lateral direction.

Even though no improvement of longitudinal distribution was proven in the present trial, DLC system allows process reliability during solid manure spreading to be upgraded significantly.

- Material preselection and set value calculation allow for very easy and reproducible determination of the application rate.
- DLC system enables application rates to be kept constant even under different load conditions. *Figure 3* shows this using the aid of data recorded at the end of the unloading process outside the trial series. As bulk density decreases, torque is stabilised at distances between 620 m and 660 m.
- Driving speed-dependent torque measurement allows differences in driving speed to be evened out with the aid of DLC system.

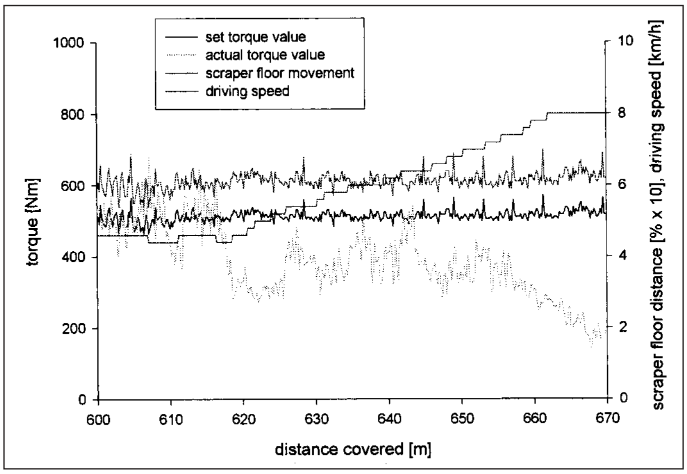

Fig. 3: Process data of DL control at the end of the spreading process and decreasing bulk density

Volume [t ha^{-1}]	VK$_Q$* -	VK$_L$ without DLC -system	VK$_L$ with DLC -system
5 t	16,5 %	35,7 %	31,6 %
10 t	11,7 %	21,6 %	25,1 %
20t	14,4 %	17,0 %	15,6 %

*calculation based on a tramline distance of 12 m

Table 1: Coefficient of variation of lateral distribution (VK$_Q$) and of longitudinal distribution (VL$_K$) with different application rates

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