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Automating the Side-overloading Process of Forage Harvesters

At the TU of Brunswick, an assistance system for parallel side-overloading is being developed. The assistance system makes it possible to partially automate the loading process, in order to relieve the burden on SP-forage harvester and transport unit drivers. The basis of the system is to ascertain the relative positions between the vehicles with GPS, as well as to automatically control the chute.

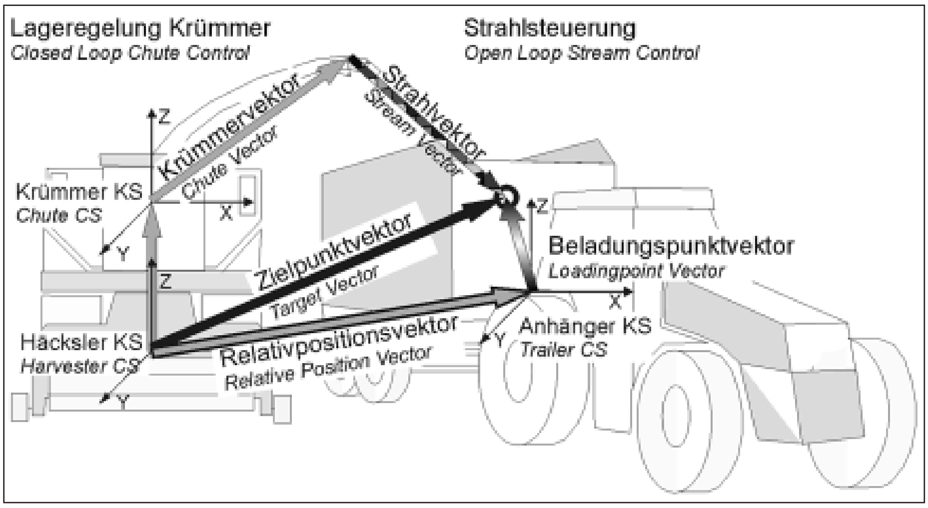

Fig. 1: Open loop stream control

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The project has been made possible by funding from the DFG (German Research Society). It is supported also by Messrs. Claas through the provision of a combine harvester. The development of the GPS System is carried out in a co-operation between IfR and Messrs. NAVSYS.

Keywords

Overloading, loading process control, GPS, relative positioning

Literature

[1] *Wallmann, G. und H.-H. Harms*: Assistenzsystem zur Überladung landwirtschaftlicher Güter. Landtechnik 57 (2002), H.6, S. 352-353

There is a trend in self-propelled forage harvesters not only to more powerful machines and a continual increase in crop throughput, but the loading capacity of the transport units also continues to rise.

Constant vigilance and high concentration are required by the drivers in order to avoid losses, overfilling or collisions between the vehicles. The higher the working speeds and the larger the trailers, the more these demands increase[1].

For this reason, the automation potential during the parallel overloading process is being investigated at the Technical University of Braunschweig. The Institute for Agricultural Machinery and Fluid Power (ILF) and the Institute for Control Engineering (IfR) are co-operating to develop an overloading assistance system for this purpose.

Assistance System for Parallel Overloading

Relative positioning

The relative position of the transport unit in relation to the forage harvester as well as the orientation are determined by a multi-receiver-GPS-system. The satellite navigation system supplies the relative position of the vehicles to each other with a precision within the centimetre range. The orientation of the harvester can be given with a precision of less than one degree. This GPS system is a prototype developed in co-operation between the company NAVSYS and the IfR. With the aid of mathematical models of the vehicle kinematics, the relative position between the base of the chute and a reference point on the trailer platform is computed.

Open Loop Stream Control

In order to steer for the platform of the trailer, the position of the chute and the deflector are controlled (closed loop control). The position of chute and deflector predetermine the distribution angle of the stream of forage material to be loaded. Due to the fact that the actual loading point (the impact point of the forage stream) cannot be detected, this can only be an open loop stream control.

The *loading point vector* describes the loading point within the trailer. The sum calculated between the relative position (chute to trailer) and the loading point vector results in the target vector. The set point value for the chute turning angle and the angle of the deflector is calculated from the target vector with the aid of a Simulink application of the chute kinematics (*Fig. 1*).

There is a dSpace platform installed on the harvester to house the stream control. This collects the data from the angle sensors determining the actual chute angles in three directions. It compares the actual and the set point values of the chute angles and calculates the according control signals which are send to the actuators.

By this means the forage stream can be aimed at a specific target point on the trailer. This target point can also be retained through varying relative positions by turning the chute and deflector.

The navigation aid for the tractor driver comprises of an LED indicator („traffic lights“) mounted on the harvester, which shows the tractor driver the optimal relative position according to the actual loading process. When driving in curves, the predetermined positioning prevents driving into areas, e.g., in which the chute cannot follow, due to the turning range being mechanically restricted towards the front.

Loading Strategies

For testing purposes it is possible to generate a set point manually. Therefor the loading point can be shifted across the trailer in 0,5 m steps by means of pushing a button.

The automated set point generation, i.e. the predetermination of the loading vector, is time related, at the actual stage of development. Whereby the loading point on the trailer is shifted in a sinusoidal motion or in a triangular motion either in the travelling direction or across it (*Fig. 2*).

In this way loading takes place in an even distribution over the whole loading area until terminated by the operator.

Two different strategies for regulating the loading were investigated. Loading is always carried out with the time related set point generation as described above. The height of the chute is manually set by the operator and kept constant. The distribution across the trailer is additionally supported by the movement of the deflector.

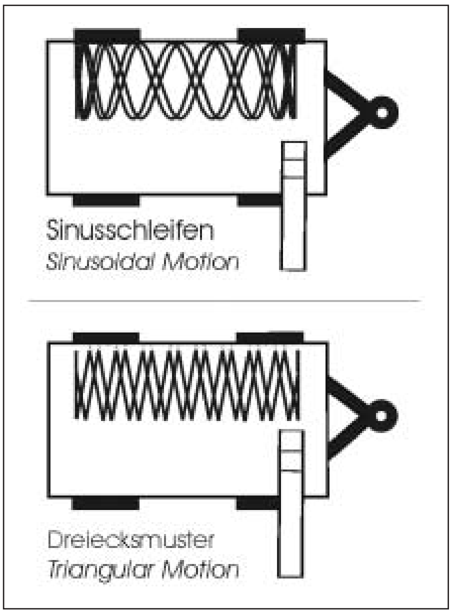

Fig. 2: Set point, loading point vector

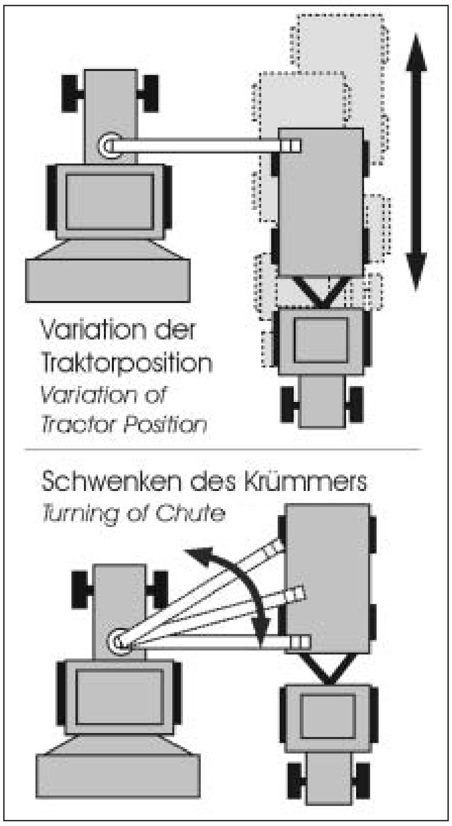

Fig. 3: Adjustment of incident point

Loading strategy 1 minimising chute turning:
The varying of the loading point on the trailer in the direction of travel is adjusted solely by the tractor driver. For this, the navigation aid indicates the optimal position to the tractor driver. Only if the trailer moves out of reach does the chute follow, in order to avoid eventual losses. (*Fig. 3 top*)

Loading strategy 2 minimising relative movement of the tractor:
The tractor driver keeps the relative position constant. By means of turning the chute, the loading point is varied across the loading area. (*Fig. 3 bottom*)

Results and discussion

The first tests during the grass harvest showed that the functionality of the system is guaranteed. The accuracy is 0,5 m when overloading with actual forage stream. A loss-free loading is possible if the safety distance of 0,5 m between the forage stream and the sideboard of the trailer is complied with. The safety distance does not restrict the complete loading of the trailer, as a heap is formed during loading, which also fills the peripheral areas.

The accuracy is reduced mainly by mechanical play in the sensor, chute and deflector adjustment. The resulting necessary tolerances in the position control further reduce the point accuracy.

Further the influence of exogenous disturbances such as wind or the material properties of the forage material have not yet been investigated.

With loading strategy 1 ñ minimising the turning of the chute ñ although this is possible, the tractor driver is subjected to more stress, as filling the trailer evenly can only be achieved by driving the tractor backwards and forwards. Advantage of loading strategy 1 is the short forage stream with a chute position at right-angles to the driving direction. Inexperienced drivers were usually relieved by the positioning aid, as opposed to more experienced drivers, who at first tried to control the loading process themselves and tended to come into conflict with the automation.

When using loading strategy 2 - minimising the tractor related movements - by turning the chute backwards, the forage stream length increased significantly. This results in an increased danger of losses caused by wind drifting. However strategy 2 did alleviate the stress on the tractor driver more than in loading strategy 1.

In both cases the evenly distributed loading of the trailer facilitated the control function of both drivers. The loading process must only be started and terminated as soon as the forage heap is higher than the sideboard of the trailer at one point. This means that the drivers can concentrate much better on the utilisation of the machines to full capacity. At the same time the duration of the non-ergonomic backward turn of the body can be considerably reduced for the tractor driver.

Summary and Outlook

The functionality of the assistance system could be confirmed during the first harvesting tests. The system considerably facilitates the task of overloading for inexperienced drivers. Experienced drivers are initially somewhat irritated by the self-will of the chute. Further solutions for the automated set point generation in order to improve the loading strategies are being developed at the moment. It is planned to develop a throughput related adjustment of the loading point with automatic supervision of the loading level and the loading process. To this end a loading level sensor is being developed in the IfR based on a picture processing tool.