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Optimization possibilities for front-loader work

Due to their large functional range, tractors with front loaders are widely used in agriculture. In order to increase work comfort, technical solutions such as one-lever operation, parallel tool guidance and vibration damping have quickly established themselves. Further improvements in the way of better performance and work facilitation for the driver can be expected as a result of the introduction of partially automated work processes.

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As compared with the purchase of special loading machines, tractor front loaders result in only low additional expenses. Especially for this reason, they are the most widely used mobile handling machine in agriculture. The tractor- and loader functions are exclusively operated manually, which opens up large optimization- and automation potential.

Fig. 1: Tractor with front loader

State of the art

Today, most front loaders are designed as so-called „drive-in front loaders", i.e. the lifting arms can be removed from the tractor if required. In order to allow this process to be carried out without the driver having to leave his seat, some manufacturers have already presented initial automation solutions. Upon request, tool locking can also be remote-controlled.

For the facilitation of the actual loading work, the following solutions are known or have already established themselves:

- mechanical or hydraulic parallel guidance of the tools
- one-lever operation of the loader functions with mechanical, electric, or CAN-bus-based valve operation
- automatic return of the tool into the loading position
- quick emptying of the tool
- vibration damping

Alternative Operating Concepts

During front loader-based handling work, the driver must carry out several functions. Some of them require the simultaneous operation of different operating elements:

- operation of the front loader functions (one or several hand levers)
- driving speed alteration with the gearshift lever and/or the gas- or accelerator pedal
- changing of the driving direction using the reversing shift- or gearshift lever
- steering with the steering wheel

The efficient use of this technology requires the ergonomically favourable arrangement of the operating elements, which should be placed such that the driver does not have to switch between several levers. Currently, tractors with a continuously variable drive and reversing gearshift on the left side below the steering wheel as well as a multi-functional lever for the front loader arranged on the right side of the driver are probably the best technical solution for these requirements. The driver can use his left hand to steer and choose the driving direction while operating the front loader with his right hand. His right foot influences the driving speed.

On tractors with full or partial powershift, similar operating comfort could be achieved while keeping the requirements low if the gear steps could be changed using the front loader operating lever or if this process could be carried out automatically. Within certain limits, this would also allow switching between the gearshift- and the front loader lever to be dispensed with.

Some farmyard loaders are known to feature combined driving speed- and direction setting with an accelerator designed as a rocker. This operation is also conceivable on a tractor. In this case, the selection of the driving direction with the left hand becomes unnecessary. Once again, tractors with a continuously variable drive are predestined for this system.

Very large wheel loaders for use in open cast mining do not even have a steering wheel. In the so-called integrated steering- and control system from Caterpillar, one single lever for operation with the left hand is used for steering, the selection of the driving direction, and powershifting. This system is intended to provide shorter loading cycles and to ease the driver's workload while reducing the design requirements.

However, application in agricultural machinery is questionable because the necessary hydraulic steering (steer by wire) does not conform with the German Motor Vehicle Safety Standards.

It may be noted that different alternatives are available for the control of the movements of a tractor as the carrier vehicle of the front loader. However, the advantages and disadvantages of these alternatives can only manifest themselves in practical operation. For the actual control of the hydraulic front-loader functions, cross-shift- or multi-functional levers are state of the art.

In order to bring the front loader into a desired position, the required function (lifting/lowering or crowding/dumping) must be actuated using the operating lever until this position is reached according to visual estimation. During this process, the driver's attention for the simultaneous driving motion is restricted, which, given limited space, results in an increased risk of accidents or lower loading performance. Since, however, the movements and positions of the front loader from loading until unloading are always identical in many kinds of handling work, partially automated operation offers itself as a solution.

Automation of Operating Sequences

The pressing of one functional key each should be sufficient for the automatic setting of the loading-, unloading-, and transport position of the front loader with the tools. The technical requirements are position sensors for the determination of the positions of the loading arms and the tools as well as electrically operated hydraulic valves for the control of the lifting and tool cylinders. These actuator- and sensor signals can be processed by a program control system. The functional keys should be situated on the normal front loader operating lever. In order to be able to react to special situations, the driver must be able to interfere with the automatic movements. This can most easily be realized through manual overriding with the operating lever.

Operation with these automatic functions and further options will be illustrated below using the description of a loading cycle (*fig. 2*).

Loading
While approaching the material to be handled, the driver must only press the functional key for the loading position in addition to steering the vehicle. This position along with the other ever recurring front loader positions can be taught to the control system during the first loading cycle with the aid of a memory function. The material to be transported is now picked up by the front loader tools. Depending on the wheel slip, the front-axle drive should be activated automatically.

For bulk materials, the shear force acting upon the tool holding- or turning points can be a potential break-off criterion for the filling process. The shear force can either be determined directly using force-measuring bolts or indirectly as a result of increasing fuel consumption by the engine, for example. For part loads, distance sensors, such as ultrasound-, radar- or laser distance meters offer themselves.

Adopting the Transport Position
When the loading process is terminated automatically with the aid of sensors, the front loader and the tool with the load could fully automatically be moved into the preselected transport position after the changing of the driving direction.

If the expensive sensor systems are not installed, the driver must press the second functional key for the transport position.

Approaching the Transport Unit
After a renewed change of direction, the tractor travels to the unloading point, and the driver presses the third functional key. As a result, the front loader moves into the unloading position while still leaving the load in the tool. This function must be triggered as early as necessary and as late as possible so that the loader is able to complete the lifting process before the transport unit is reached while remaining in the transport position as long as possible, which is favourable for ride stability. Since this estimation is always difficult even for experienced drivers, this process could therefore also be carried out fully automatically by the program control system if sensors provide this system with the parameters driving speed, distance from the transport vehicle, and available hydraulic oil volume flow.

Unloading
For most agricultural goods, the front loader's ride to the unloading point should be controlled manually. On the one hand, this would allow an additional functional key to be avoided. On the other hand, the specific properties of the load could be considered. Some bulk materials, for example, require that the loading bucket or -fork be shaken at times in order to remove sticking rests. The sensor-based control of such functions results in increased requirements.

For bulk goods which are „uncomplicated" because they are homogeneous, such as grain, an automatically operated tool emptying system would also be conceivable which, for example, uses the signals of the above-mentioned sensor systems for distance measurement. When a preselectable distance from the transport vehicle is reached, the content of the bucket is dumped precisely at a predetermined point.

Moving Away From the Transport Unit
Immediately after unloading, the functional key „transport position" is pressed, and the loader returns to the store.

Summary

The described possibilities of optimization could allow several advantages to be achieved:
- physical facilitation of the driver's work through fewer operations
- mental facilitation of the driver's work through automated processes
- increase in performance due to reduced cycle times
- improved attention for vehicle control and observation of the environment

In total, the complex realization of these points allows higher performance and better comfort to be expected. If longer-range distance meters are dispensed with, the technical requirements stay within acceptable limits with regard to their costs or are already largely fulfilled in modern tractors.

Fig. 2: Partially automated load cycle