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Strategies for Automated Front-end Loader Operation

Through electronic control of the front-end loader, work processes can be simplified by using automated functions. It is possible to position the loader arm and tool specifically by controlling the hydraulic cylinders valves electronically. Repetitive operational sequences can be carried out automatically. A control system with no position sensors on the loader makes this possible, as well as using various position, velocity or angle sensors. For the operator, the partially automated operation is only then beneficial, when the man-machine interfaces are optimised with regard to ergonomic, safety and control aspects.

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There are many possibilities for automatical activation of the front-end loaders operation sequences. The boom and tool can be driven at the touch of a button with the aid of electro-hydraulic valves and an intelligent control system. For typical recurring sequences during operation, such as restacking bulk material, the actuators can be controlled automatically facilitating the work of operators. This automation can be effected either by an open-loop system without position sensors at the cylinders, or by a closed-loop system with a sensor for position, velocity or acceleration to enhance the functioning.

Automation

The objective of an automatically activated front-end-loader is not only to improve productivity but also the working conditions for the operators.

A structural model of the working process is required in order to develop a suitable control system, whether with or without length sensors. For example [1] presented the front-end-loader working process in the form of a flow chart model. *Figure 1* show the classification of several functions of a typical working cycle, A to E. The line in the diagram depicts the normalised length of the cylinders during a bulk material reloading cycle. The motions of the cylinders, representing sequences with a high potential for automation are divided into the function blocks A to E, as follows: a) Moving the boom in relation to the bucket in front of the bulk material, b) Tilting the tool and lifting the boom, c) Lifting the boom to set up the front-end-loader for unloading, d) Jerky movements of the bucket to get rid of viscous materials, e) Repositioning the bucket in the horizontal for reloading.

An automation of these sequences would allow the tractor driver to concentrate on the necessary manoeuvring of the vehicle.

Open-loop Control

By developing suitable operating strategies it is possible to control the front-end-loader cylinder without using length sensors. The basic technical requirement is a load-sensing hydraulic system with electro-hydraulic proportional valves, pressure sensors in the working connections and a suitable controlling electronic system.

A repetition of the referencing of the cylinder lengths (function R in Fig.1) for these strategies is necessary. A further requirement is the knowledge of the through-flow characteristic of the valves as reference field. For this type of system the cylinder lengths are not registered by sensors, but the system information is fed back in accordance with a systematic, as described in [2], with the aid of load pressure signals from the cylinder chambers and thus indicating the various process stages. The valve control

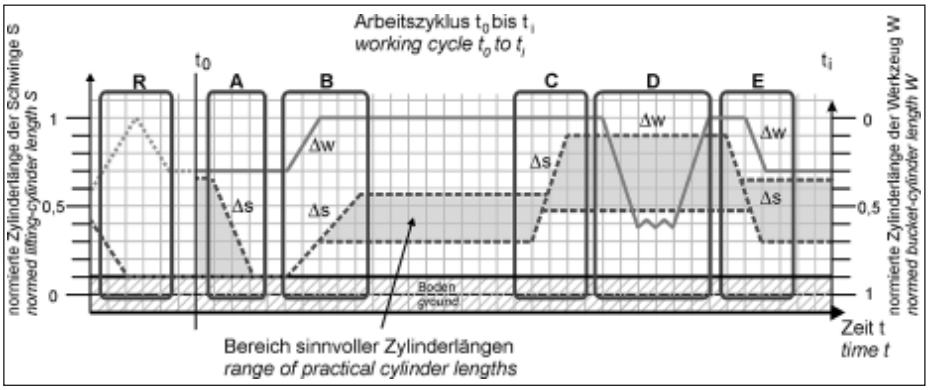

Bild 1: Automatisierbare Abläufe A bis E bei einem typischen Arbeitszyklus des Schüttgut-Ladens

Fig. 1: Classification of the functions A to E of a typical working cycle of bulk loading with a high potential for automation

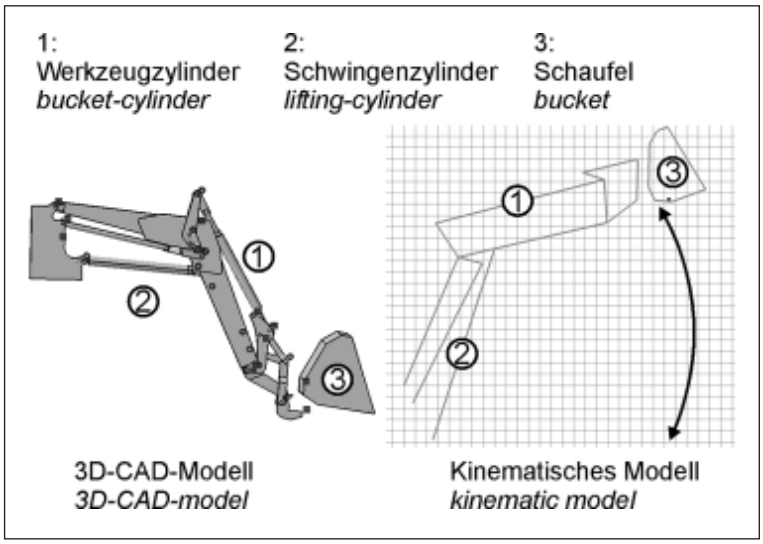

Fig. 2: Model of the kinematic interrelationships of a front-end-loader

enables the control of the duration of opening as well as the angle at which they are to be opened, which results in an adjustment in the cylinder length. This concept enables a precision adjustment of the cylinder length from which an automated process can be generated. The technical difficulties which can occur when several consumers are in operation concurrently, or due to drawing loads, can be combated with a suitable control strategy.

The model of a standard front-loader is shown in *Fig. 2* as a 3D construction diagram (left) and as a connection of single components (right). The manoeuvrability can be modified due to the length adjustments of the cylinder and the interdependency analysed by the control of the boom and tool cylinders.

When work commences with the front-end-loader the requirement situation is not known and single parameters are not yet optimally adjusted. During the first work cycle the operator must chose each function manually and set the parameters, such as tool angle or height adjustment. The first work cycle can be regarded as a sort of macro-programming, so that the subsequent processes have a predetermined programming for the relevant function.

The aim of a partial automation is that the work processes can be activated at the push of a button, alleviating the operator to a great extent. Although the operator is still required to react to non-preconceived disturbances and to operate the sensors accordingly. *Fig. 3* shows the structure of the man-machine-environment systems with the operator taking over the task of controller and sensor.

System Control

Automatic front-end-loader functions can be realised with high operator comfort and improved capacity by the utilisation of sensors on the cylinders. For example, the integrated speed sensors as described in [3] can be used, according to the control quality and required number of cylinders to be moved concurrently.

The work cycles with an extremely high automation potential can be realised in various concepts. Some examples of systems which have been realised in practice are the electro-hydraulic parallel guide [4], the automatic tool return [5] and an automatic angle adjustment of the tool [6]. The aim of all these functions was to facilitate the operation with the aid of electronic activation of the hydraulic valves. This type of automatic function is made possible by the utilisation of distance sensors, speed sensors, angle adjustment sensors or by means of contact switches. A complete system control, which included multiple sequential varying movements of the boom and tools, was introduced in [7]. However, at the moment, there is no completely automated concept for a front-end loader offer. Most probably the enormous input as well as the high costs have deterred a wide dissemination.

Due to the fact that there is far more electronic in modern tractors, the trend to the implementation of automated work processes for front-end-loaders will continue to increase, which means that the availability of suitable sensors and controlling elements will form the basis for many development projects.

Operating Strategies

The increased range of functions for the front-end-loaders resulting from the automated adjustability can only increase the productivity, if they are accepted and exploited by the operators. The possibilities and capabilities of the operator should neither be restricted nor overtaxed, which means that operator-friendly operating strategies are required, which will increase the comfort of the operator and enable even untrained personnel safe and effective handling of front-end-loaders. In the future it various control concepts are conceivable for the movement sequences by means of electronically activated valves, which will simplify the operation of front-end-loaders.

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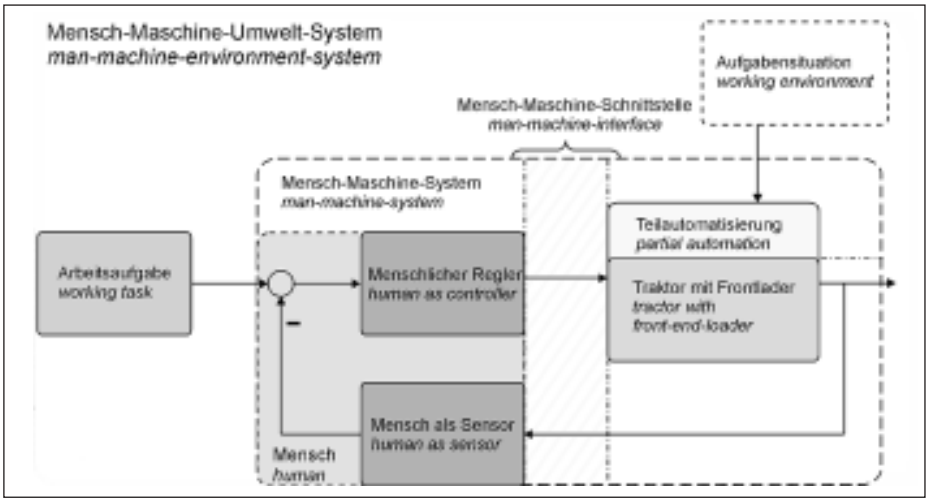

Fig. 3: Man as controller and as sensor in the man-machine environment-system