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Model Based Control of Overloading Agricultural Goods

Besides maximum machine utilization, minimizing losses in overloading processes on large harvesters is in the foreground. Assistive systems for overloading can greatly ease the work, especially for untrained operators. Computer-aided visual monitoring of the loading status proves to be difficult, because of partially problematic agricultural conditions, for which a model based loading and overloading strategy can play a key role. In this paper the "Model Based Loading of Agricultural Trailers" project, sponsored by DFG (German Research Foundation), is presented.

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Fig.1: Limited visibility during parallel operation

In agricultural machinery, the trend is favouring more efficient harvesting machines with greater maximum throughput and growing working widths. The greater demands on the machines require increased investments for these machines. Large harvesting machines must be operated with the most efficient machine configuration and for the longest time possible during a campaign so that they can work in a sustainably profitable manner.

If the harvesting machine and the transport unit (generally tractors with trailers like in the case of a self-propelled forage harvester) are parallel operated, the quality of the overloading process is another significant value for the assessment of the efficiency of the entire process. Therefore, the attention of the operators must focus on the working process, as well as the overloading process. Moreover, machine collisions must absolutely be avoided. This division of attention is even more problematic because long operating times (which often include nighttime work) are necessary for optimal capacity exploitation, which wears the operator out even more. Given the ever larger measurements of both the machines and the transport units, a poor view into the units is another problem.

Assistance system for the overloading of agricultural materials (ASUL)

In order to solve the problems addressed in the introduction, an assistance system for the overloading of agricultural materials based on a self-propelled forage harvester and a tractor was developed at the Institute of Agricultural Machinery and Fluid Power, in cooperation with the Institute of Control Engineering of the Technische Universität Braunschweig, Germany. Thanks to the GPS-based determination of the relative position of the self-propelled forage harvester and the tractor, the prototype allows the position of the loading point to be controlled with the aid of the spout actuator. This system reaches a position accuracy of the loading point of 50 cm.

Model-based loading control for agricultural materials

During the development of ASUL, time-dependent loading strategies were developed in order to estimate the automation potential. These strategies enable the trailers to be filled continuously. However, two problems arise which are a fundamental hindrance to efficient automation [1, 2, 3].

- The continuous filling of the trailers is only possible until the material has reached the upper edge of the wall.
- The continuous, time-dependent change of the loading point results in an unacceptable additional physical load on the drivers of the forage harvester and the tractor.

In order to reduce the disadvantages of time-dependent loading strategies and to automate overloading or loading at the same time, the loading status of the agricultural trailer must be observed. Due to the agricultural environment, computer-based visual data acquisition with the aid of image analysis proves to be extremely difficult because the material flow itself as well as dust and changing light and colour conditions disturb

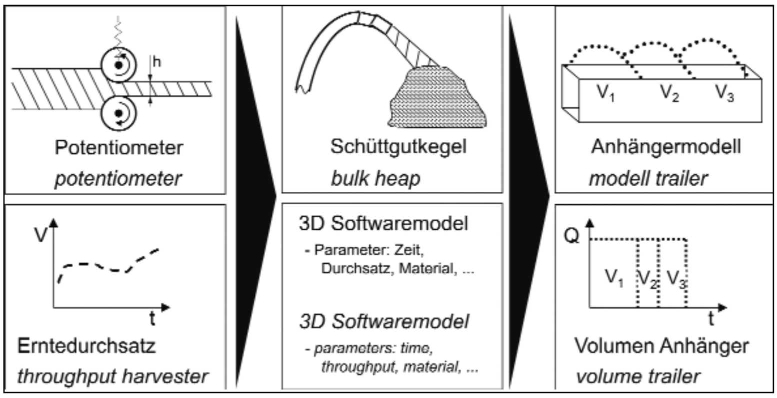

Fig. 2: Set up of model based loading of agricultural trailers

image acquisition. Thus, the development of model-based loading control systems is the next consecutive step in the development of automated overloading [3].

Structure of model-based loading control systems

The most important components of the model-based overloading system and, hence, model-based loading control, such as the determination of the relative position and the control of the loading point position, are parts of ASUL. These components are extended to include loading strategies which depend on the harvesting throughput. If the relative position of the vehicles (forage harvester and tractor) and the effective orientation of the spout are known, the current loading point can be calculated.

The functional principle of model-based loading control systems is shown schematically in *Figure 2*. Using a potentiometer, the deflection of the intake rollers is determined, and volume and mass flow are measured based on the geometry of the crop channel. With the aid of a software model to be developed, the loading condition of the trailer is simulated based on throughput and the loading point.

The trailer is divided into discrete partial volumes, which can be filled using a suitable, strategically efficient definition of loading points until the trailer has been entirely filled.

Development of bulk heap software models for agricultural materials

One of the most important tasks within the research project “Model-based loading of agricultural trailers“ is the development of fundamental software models for bulk heaps of agricultural materials. As reference for the software model, the measurement of bulk heaps of different silage crops in a real environment during the harvest is part of the project. The four most important parameters which can be determined and must be realized in the software model are:

- the angle of slope of different bulk materials in at least four spatial directions
- the geometric form of the bulk heaps
- the heaping-up process, i.e. the temporal behaviour of the heap during its formation
- interaction between the individual bulk heaps.

According to Schulze [4], one can assume that the inhomogeneity of internal friction increases significantly as the homogeneity of bulk materials decreases. According to his investigations, modelling or even the approximation of the loading condition of the agricultural trailer with the aid of DEM (discrete element method, a special numerical calculation method) would require enormous computing capacity, which generally cannot be provided on agricultural machines. Based on these investigations, physical effects, such as internal friction and the resulting equilibria of forces, are not considered in this project. In addition, the scope of this project does not include modelling with the aid of the DEM or CFD (Computational Fluid Dynamics, numerical flow simulation) methods used in process engineering.

Thus, two approaches can be formulated for the program-based modelling of bulk heaps, which, however, can only be outlined here. First, it is possible to model bulk heaps with the aid of elementary spatial-mathematical functions, such as ellipsoids, hyperboloids, or hyperbolical paraboloids. A big advantage of this approach is that elementary spatial functions can easily be implemented, altered, or varied in a program code. A negative aspect is that the relatively strict functional descriptions do not model the conditions and influences which act upon a real bulk heap. Theoretically, however, it is possible to supplement the elementary functions with weighted spatial descriptions (e.g. 2D or 3D matrices) in order to approximate both temporal development and the effective loading status to reality. In addition, the interactions between different bulk heaps must be modelled.

A second approximation approach for bulk heaps enables the loading process to be modelled spatially, e.g. by virtually filling modelled incremental volumes or by defining 3D matrices step by step depending on the loading status. Implementation can be carried out both iteratively and recursively. As compared with iterative structures, recursive structures have the advantage that they are more compact, relatively clearly structured for implementation and therefore also easier to change. Recursive structures are particularly suitable, if identical or similar processes occur in recurring sequences, where each step is based on the previous one. As compared with recursive structures of similar problems, iterative program structures are more complex because every decision or action must be defined iteratively even though similar decision and action trees consisting of a logical sequence of steps exist. As compared with recursive structures, iterative approaches are generally faster, because less computing capacity is required. In the development process, these three approaches are being pursued. Currently, it is not yet possible to give an evaluation.

Summary

With ASUL, an assistance system for overloading has been developed at the Institute of Agricultural Machinery and Fluid Power of the Technische Universität Braunschweig, Germany. For the more in-depth investigation of the automation potential of the continuous overloading process in agricultural machinery, model-based loading control systems are being developed and examined in a consecutive research project. Especially for the development of bulk heap software models for agricultural materials, approaches are available which will be investigated more in depth during this research project.

Literature

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