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Self-propelled machinery: simulation of implement alignment with ground profile

Self-propelled machines are being applied increasingly in farming as in civil engineering with the associated requirement that mounted implements have to align themselves suitably to the ground surfaces. A simulation model has been developed to represent the ground profile so that machine movement can be thus visualised and information produced to help optimise kinematics or design of regulating systems.

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Keywords

Ground tracking, sef-propelled machine, mower unit, simulation

Self-propelled machines are being applied in cultivations and forage harvesting which have no rigid vehicle-implement attachment. The actual working implements are applied as decentral equipment acting as independently as possible and linked to the driving vehicle via attachment points with mechanical freedom of movement in different planes plus the possibility of control and regulation. With such a flexible design, the steering role of the vehicle becomes secondary. More important for accuracy of alignment with the soil surface is optimum design of attachment points. And in fact the usual tractors with detachable mounted implements used so far are increasingly being replaced by specially developed self-propelled machines with still higher standards of driving speed and work quality demanded of them.

Requirements

A typical and simultaneously intricate example of the above development is the multi-unit large-capacity self-propelled mower. *Figure 1* shows a virtual example with a three-point mounted front mower and two lateral units attached between the axles. The most important quality characteristic of such a machine is the ability to maintain a working alignment with the field surface over uneven land at high speeds. With minimum possible load pressure the lifting of the mowers should be avoided in all cases. Too high load pressure leads to premature wear of mowers, increased requirements for tractor power and fuel and unwanted ground compaction. Simultaneously, cutting angle has to be kept as constant as possible to avoid ground contact or crop skipping. The mowers have a certain ability to adjust for application on uneven ground with load pressure limited via mechanical or hydropneumatic spring absorption elements. At the same time a constant application angle is aimed at through pendulum attachment kinematics.

Understanding the ground tracking process is made more difficult because the system involves a number of free movement planes allowing three-dimensional action. Ideally, every mower should have freedom of movement in three areas (lift height, nod angle and roll angle) with each capable of free movement independent from one another and of the tractor movements. In reality, however, there are mostly only two independent planes of movement available and these are superimposed by vehicle movement and controlled through mechanical limiters. Simultaneously, the available load force is dependant on the oscillations of the mowers. The forces and movements during mowing are difficult to record, so an estimation of the actual ground tracking capacities is often only subjectively possible in trials.

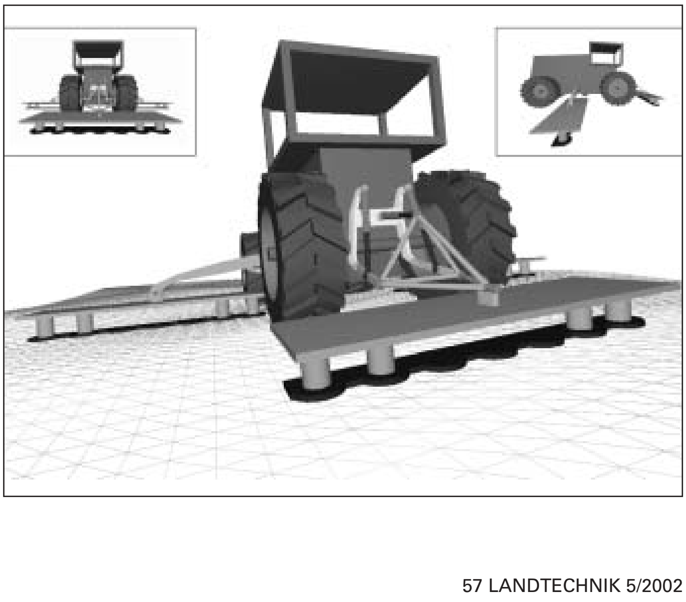

Fig. 1: Simulation of a virtual self-propelled high-capacity mower

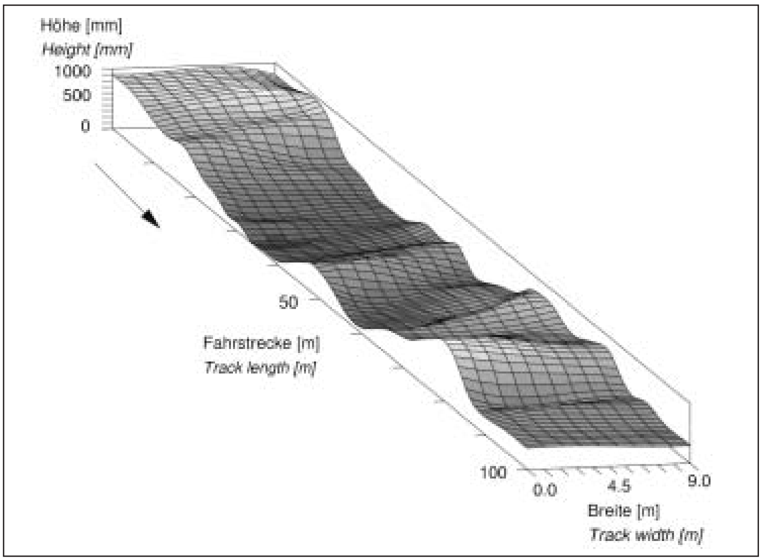

Fig. 2 :A ground profile generated from measured points

Conducting such trials in a constructive way depends on long experience, although improvements, or even just optimisations, have proved very time and material demanding so far.

Results

At the Chair of Agricultural Machinery, TU Dresden a simulation model was developed in cooperation with the company GKN Walterscheid GmbH in Lohmar. This allowed the preliminaries to ground tracking to be reproduced via computer in an easily-understandable manner. Special worth was laid on achieving a generally acceptable and comprehensively parameterised modelling with open interfaces to external programs. For this reason the use of available commercial software packets for simulation of the multibody system was avoided.

The required kinematic equations were to a large extent analytically presented and converted to programming language C/C++. Selected for the three dimensional representation was the industrial standard OpenGL. The carrier vehicle was characterised by the parameters wheelbase, track, and tyre size. Alongside the mowers', or other implements', geometrical measurements, their relative positions in relation to the vehicle, as well as type and mode of action of the attachment points, could be varied through simple alteration of parameters.

The ground profile to be tracked is screened in the form of a grid based on measured and arbitrary values. A ground profile generated with the aid of spline interpolation from measuring points, and upon which trials with real machinery has been superimposed, is shown in *figure 2*. Alternatively, artificial ground profiles comprising sine form undulations of alterable height and length can be used.

The simulation model was operated in almost real time on PCs under UNIX or WINDOWS. Operation can be interactive or script based. All movements generated by driving over the ground profile are visible on-screen and are simultaneously stored as angles or length alterations in table form. A further evaluation and subsequent calculations of forces or speeds can take place with standard software such as MATLAB or SCILAB.

Figure 3 uses the example of the setting angle of the three mowers to demonstrate the simulation's evaluation possibilities. Driving over the very uneven ground profile of figure 2 using the non-optimised self-propelled vehicle from figure 1 leads to a change in the setting angle compared to the predetermined value for the even ground in the given example. Additionally, different reactions occur for every mower unit varying between the extreme values -9° and +6°. Other possible results involve, e.g., the lift height and the lateral angle of mower or the changes in length of the hydraulic cylinder. Through systematic variation of the adjustment point and the length of the attachment links, an optimising of the kinematics of mower setting angle or load pressure force is possible. At the same time, length and angle changes occurring during ground tracking can be recorded as well as the way in which passive or active absorption components are set- up.

Summary

For testing the simulation software field trials were carried out with a commercially available vehicle. These demonstrated a good agreement between measured and simulated movement parameters. The simulation model enabled a rapid and simple evaluation of ground tracking possibilities with different ground profiles using systems which are either available or in development. Limitations and weak points can be demonstrated as well as information delivered to help solve the problems. Manufacturers of mower combinations or vehicles which have interest in simulations featuring their products are earnestly requested to make contact. Further simulation results are to be presented as part of a paper at this year's Agricultural Engineering Conference in Halle, October 10 and 11.

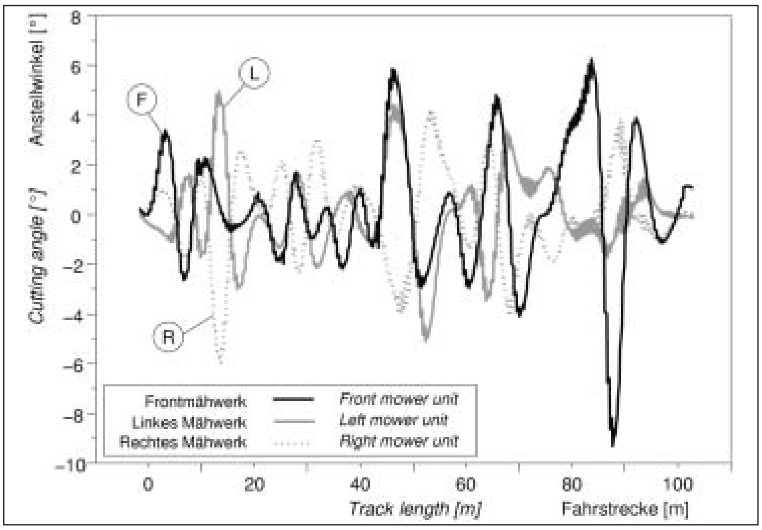

Fig 3: Calculated cutting angles of the three mower units versus track length