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Process Simulation

Possible Applications and Results

In industry and increasingly in agriculture, simulation makes it possible to test and precautiously plan machinery and equipment under conditions, prior to their acquisition. Furthermore, trends in industrial product development can be investigated and assessed by using process engineering simulation software. The following article points out possible applications of such software and presents some first results.

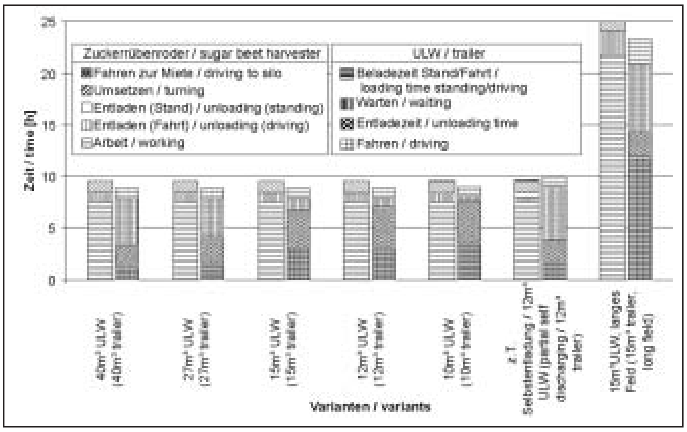

Fig. 1: Part times of a sugar beet harvester in connection with different trailers (left columns) and part times of different sugar beet trailers (right columns)

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Simulation is an alternative tool to published tables and other guidelines to help in choosing the right machinery for one's specific conditions. Although simulation software may contain optimisation algorithms, it is not by nature a pure optimisation tool and rarely applied for that purpose. With our simulation software certain input parameters can be adjusted by iteration to reach a solution near the optimum for the problem under investigation. A full optimisation may result in a solution, which is not applicable in practice.

Different field structures and processes can be simulated. By variation of the relevant machinery parameters different characteristics of the equipment to be procured can be assessed (e.g. working width, grain tank volume, etc.). The results obtained in several simulation runs are then analysed and the machinery specifications of the best solution taken as the basis for tenders. This approach not only benefits large farms, where several pieces of equipment may work on a field simultaneously, but also small ones.

To illustrate the application of our simulation software the use of a grain trailer in connection with a combine harvester is looked at. Frequently a grain trailer is purchased without knowing the precise specifications required for the purpose it is intended for. One consequence may be an oversized grain trailer, which needs a lot of tractor power, but will only become partially full. Another may be an undersized grain trailer, which is cheaper in price, but not sufficient for the process. Therefore, follow-up costs may arise, for example from dead-time of combines or their recurrent grain discharge while standing.

At present it is advisable to test the equipment, which was identified by simulation as the best choice, in the field, because initially only technical data provided by the manufacturer can be used in a simulation. If this data is "over-ambitious" the machinery will not achieve the simulated performance in a field experiment. Then the manufacturer has to explain to the customer, why his claims cannot be fulfilled.

Figure 1 demonstrates this for the example of the sugar beet harvest. Here a 6-row sugar beet harvester with a storage volume of 40 m^3 and a throughput of 90 t/h is employed on a field 540 m in length. Sugar beet trailers with 40, 27, 15, 12 and 10 m^3 loading capacity were investigated.

The waiting time of a trailer decreases with a declining loading capacity, while the harvester never has to wait for the trailer. From this follows that, when using a single sugar beet harvester on a field of this length, a sugar beet trailer with 10 to 15 m^3 capacity is sufficient.

To allow a statement for very long fields one with a length of 1200 m was investigated, too. A sugar beet harvester with the same specifications as on the shorter field and a 15 m^3 trailer were assessed. Despite the very long field, this small trailer was again able to serve the harvester without dead times.

This shows that it is sufficient to operate a small trailer to serve one sugar beet harvester, which is easier on the soil than a larger trailer. However, with a larger one the number of trips and the total distance travelled is less: with a 40 m^3 trailer (variant 1) there were only 26 trips covering roughly 17

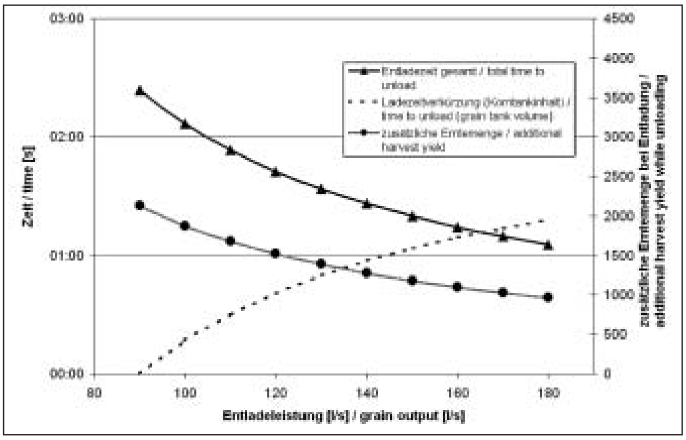

Fig. 2: Effect of the combine's grain discharge rate on total unloading time

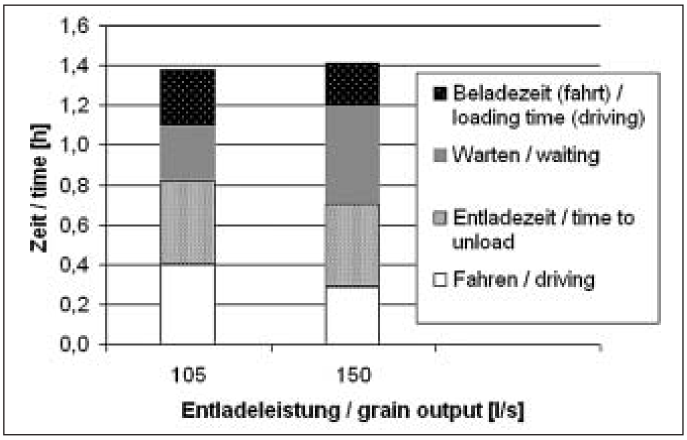

Fig. 3: Part times of grain-reloading wagon, depending on discharge rate

km distance, but with a mean load of 29 t, while with a 10 m^3 trailer (variant 5) there were 98 trips with a total distance of about 60 km and an average load of just 7.6t. Hence, there is a choice between a large number of lighter or a small number of heavier transports. Note that less tractor power is needed for smaller loads.

Industrail benefits of process simulation

By using simulation software and preceding field investigations, operational parameters (e.g. field dimensions, yield) can be quantified and machinery parameters (e.g. working width, grain tank capacity, driving speed) can be co-ordinated. Simulation software makes it possible to study the interactions between several pieces of machinery (e.g. several combine harvesters and trailers) under different conditions. Thus, the costly development of products, which have no chance on the market, as well as expensive field tests can be avoided. This was proven by the above example.

Furthermore, the simulation software provides the opportunity to "play" with the parameters of the machinery and the processes under investigation. It is possible to alter parameters and study the effect on the total process, which can't be done with the same ease and accuracy with conventional software (e.g. EXCEL®). For example, bigger grain bunker volumes or unloading capacities (grain discharge rates) > 70 t/h and their effect on the different stages of the transport route are reasonable extensions from a process engineering point of view. Simulation can show how they alter performance and at what costs.

The following example shall illustrate this: the grain tank capacity of the combines in action enables a temporary "de-coupling" from transport units, while the rate of grain discharge determines how long combine and the transport unit are in parallel action. An increase in transport capacity can be achieved, if a trailer is filled more often during the day, which requires an increase in the grain discharge rate of the harvester with a nearly filled buffer. The importance of a good co-ordination of grain tank and transport capacity becomes obvious, if there are recurring dead times due to a mismatch.

If a combine continues harvesting while unloading, the grain volume passed on to a trailer may be larger than the grain tank volume of the combine. Hence, a trailer may not be able to service as many combines as the nominal capacities of the trailer and the combine bunkers may imply. The buffer effect of the harvester is then passed on to the transport chain. The effect is amplified with increasing combine throughput and the grain discharge rates remaining the same.

Figure 2 depicts the grain volume harvested during unloading of the combine bunker, the resulting total unloading time, and the reduction in unloading time by increasing the grain discharge rate. The following values were used to generate the figure:

grain tank volume:	12 m^3
grain tank filling at start:	90%
grain throughput (harvest):	40 t/h
(assumed yield: 7.5 t/ha)	
working width:	9 m
travel speed:	5.9 km/h

The maximum grain discharge rate according to manufacturer information is 105 l/s. This results in 2.4 min total unloading time, based on the above values. If the maximum discharge rate would be increased to 140 l/s, the total unloading time would be reduced by 58 s to 1.43 min. If one assumes three combines per trailer, the total trailer loading time would be reduced by almost 3 min, which leaves more time for other tasks.

This time saving appears marginal at first. Hence, is was studied more closely with the simulation software. *Figure 3* displays the partial times for the trailer employed on the 540 m long field mentioned above. Two combines with the same parameters as in *Figure 2* were used.

It becomes obvious that waiting time increases with increasing grain discharge rate, while driving time decreases and unloading time remains constant. In this example a saving just in waiting time of 12.9 min is achieved. Altogether the time saving for the trailer amounts to 23.8 min for virtually the same total process time.

Conclusions

The possibilities for using simulation software rise with the number and quality of the algorithms contained in it, and with the ability to verify the results with field data. Cost savings on the manufacturer's side, e.g. by developing more suitable products, coupled with the ability to provide more specific advice to an individual customer, lead to a fruitful relationship between both partners. For consultants, too, the use of such a software can be an instrument to deliver better solutions for an individual problem, both for large agribusinesses and small farms.