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Fuel Consumption during Tillage Work

Modelling in Comparison to Measured Values

The amount of fuel consumed by agricultural tractors has gained in importance since fuel costs have increased and ecological reasons like greenhouse gas emissions and conserving natural resources have become more important. To estimate reduction potentials and to catalogue reduction opportunities, an exact model for investigating various factors is needed. The aim of a project at the University of Hohenheim is to set up such a model, to validate using measurements and to calculate the demanded results.

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Summarized contribution to LANDTECHNIK. You will find the long version under LANDTECHNIK-NET.com

Keywords

Fuel consumption, tractor model, drive train

Literature

Literature references can be called up under LT 04414 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Fuel consumption from the use of tractors is influenced on the one hand by the demanded drawbar pull of the implements, on the other hand by the engine-, transmission- and tractive-efficiency of the tractor. The tractive efficiency is of special interest, since it is low with values between 30 % and 70 % [1, 2] and varies strongly with changing soil and tractor parameters. Measurements alone are not enough to estimate the importance of all the parameters, because the soil varies strongly over short distances. Thus, an exact vehicle model is needed to investigate single influencing factors.

The subject of this article is the tractor model, drawbar pull is used as input parameter. For further calculations the tractor model will be combined with different drawbar models (implement models).

To validate this model the calculated values of fuel consumption are compared with measured values. Therefore a specially equipped tractor was used.

The vehicle model

The model was set up to investigate the influence of multiple influencing factors, thus a high accuracy and the consideration of many parameters is important.

In particular the influence of the following parameters should be displayed:

- Influence of drawbar pull and driving velocity
- Slope in driving direction and lateral slope
- Geometry of the tractor (e.g. wheelbase) mass, centre of gravity, point of application of the drawbar pull
- Using of 2WD, 4WD and differential locks
- Influence of a self locking differential
- Differing tractive behaviour of all wheels
- Influence of the driving strategy (speed control, velocity, gear, ...)

The influence of these parameters is strongly different, however they have all to be investigated exactly. After that the most important ones can be selected for further investigations.

The model was optimised to compare different driving conditions and to calculate the above-named parameters, as the calculating time has to be kept short.

A scheme of the model is displayed in *Figure 1*. On the left side the input parameters are displayed, in cases of drawbar pull and tractive behaviour they can result from separate models. On the right side the modules of the vehicle model are displayed. These are the tyre load model, drive train model, trans-

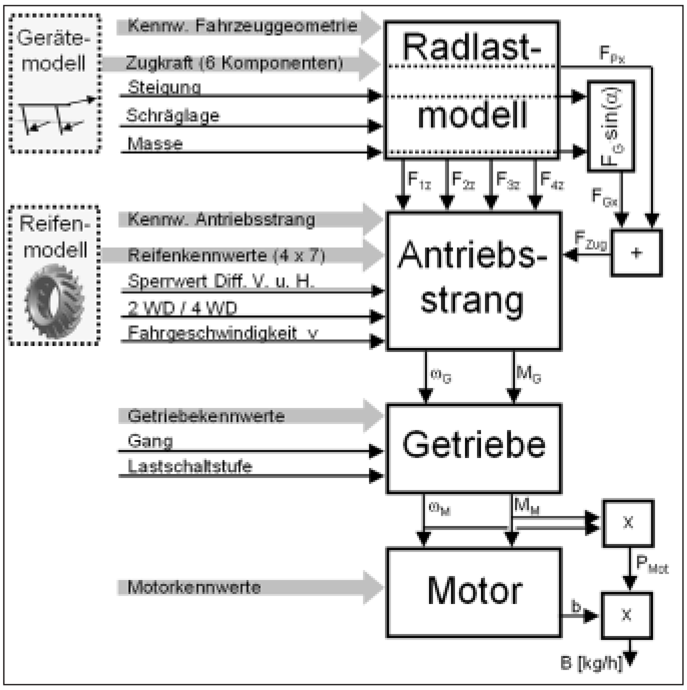

Fig 1: Sheme of the vehicle model with the input parameters

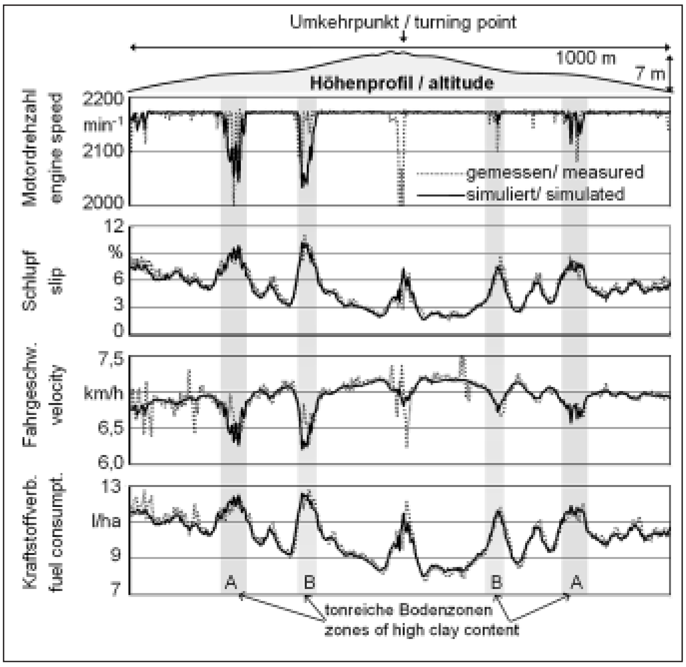

Fig 2: Comparison of the modelled and measured values

mission model and the engine model, from which the fuel consumption is calculated.

In between the modules the passing parameters are displayed. Compared to the number of input parameters these are only a few. The input parameters are identified with expanded arrows when there is more then one parameter. The exact function of the modules can not be explained in this article, in LANDTECHNIK-NET (ATF) [3] it is illustrated in detail.

Measurements to validate the model

To measure drawbar pull and fuel consumption for tillage work a tractor was equipped with measurement devices [4]. The tractor was a "John Deere 6620" with a cultivator "Lemken Smaragd 9/300". The basic components of the measuring system was a RTK-GPS, 6 components force measurement frame between tractor and implement, value logging from the tractor's CAN-Bus like fuel consumption and a device to measure the working depth of the implement. The considered values are results from the 2nd stubble tillage, the working depth was ~15 cm.

Model Validation

To validate the model the firs step is to edit the data from the measurements, following the draught force, lateral and longitudinal slope can be used as input parameters for the model to calculate the further values for the tractor, like driving velocity slip and engine speed, finally the fuel consumption. The results are displayed in *Figure 2*. The left half displays the track upwards, the right half the parallel track downwards. In the middle, after about 500 meters there is the turning point. The results are displayed like this, to show the influence of slope for similar draught forces in the parallel tracks.

The first curve shows the engine speed, kept constant by the speed control, which is based on the transmission output speed. Mere the zones of maximum draught forces show a decreasing engine speed, because the limit of engine power was reached. This effect occurs stronger at the track upwards, although the draught force behaves almost laterally reversed to the turning point. This becomes obvious by the zones of high clay content (A and B), which are passed at both tracks.

The slip, displayed in the second curve shows the maximum values at the points A and B, also the influence of the slope can be seen. The input values for the tractive behaviour, which are one of the major criterions for deviant simulations, were very well estimated for the dry stubble field and could be kept constant for the whole field. That is one reason, why the calculated values are that good.

The curve fort the driving velocity has a good correlation, as engine speed and slip. Short fluctuations can result from inexactness of the measurements or from speed reductions, which are not the result of high draught forces, like at the turning point. The tractor reduced speed to turn, this was not considered in the model.

The calculated fuel consumption displayed in the last plot shows values similar to the measured ones. These good values are a result of the tractive force as an input parameter and the tractive conditions easy to model, anyhow it shows that the model calculates realistic values for the tractor and good results can be achieved.

To calculate the fuel consumption for the whole field, the turning activities and the work on the headlands have to be considered, too. Therefore different approaches can be chosen, which use the size and sometimes the shape of the field to estimate an addition to working time and fuel consumption. In the simplest case a flat addition is used. Set-up time and changeover time can be considered by more or less specific assumptions, but for the optimisation of the working process itself they are not of importance.

First results of the modelling

The objective of the modelling is the influence of single input parameters on the fuel consumption. As an example the influence of the slope is displayed. The influence of the longitudinal slope is strong, but for tillage it can be assumed that it has to be driven as much upwards as downwards. Thus, the average of the values for the same slope upwards and downwards were taken to show the influence of longitudinal slope. In the resulting *Figure 3* lines of iso-fuel consumption are displayed, in this case it was a 4 wheel drive tractor and the differential gear was not locked. Further tractor parameters were taken from the calculations before.

It can be seen, that longitudinal slope up to 5° and lateral slope up to 10° has minor influence on the fuel consumption with an increase of less than 3%. For higher slopes it becomes more important. The influence of the lateral slope, caused by high slip values for the upper wheels, can almost completely be eliminated by the use of differential locks. In simple equations to calculate the fuel consumption, lateral slope must not be necessarily considered. Longitudinal slope could be included in such equations by a quadratically increasing extra fuel consumption.

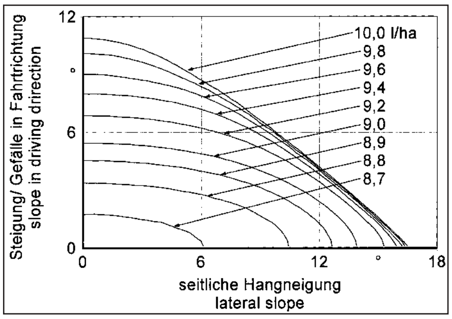

Fig 3: Fuel consumption in dependence on lateral and longitudinal slope, mean values of driving up and down

Conclusions

The model performs its tasks in exactness and calculating time, so the influencing factors on the fuel consumption can be analysed. The model validation showed a good analogy between measured and calculated values. Further calculations have to be made to get all the demanded results. In cooperation with a task force of the KTBL a list of reduction opportunities will be set up. The results of the exact modelling will be used as the base to set up simple equations to calculate the fuel consumption with a good accuracy without the need of complex models.