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Dynamic load simulation on the drive test station

Control strategies for a tractor with electrical individual wheel drive and the system's influence on driving characteristics and on resultant work quality, area performance, fuel consumption and exhaust emissions were investigated on a drive test station. A simulation model was developed for this purpose. Through this, the dynamic drive resistances occurring in practice could be represented over load machines through their reaction to the performance of the drive units. Thus, a tool is created which enables the comparison of developed strategies under near-practical conditions and ones which, contrary to field trials, also make possible identical reproducible conditions.

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A drive test station (*fig. 1*) allows the investigation of characteristics of a drive system under defined load. The application of the load can be stationary, abrupt or dynamic. Stationary loads allow reference values to be recorded. Abrupt load changes give information over the dynamic characteristics of a drive system. In order to represent the loads on a drive system under practical conditions one can measure those under real situations and from the measurement results calculate values for the load machines. This is, however, only justifiable when it applies to measured drive systems on the test station which are at least similar. This is because a system which is principally different reacts in another way to drive resistance, and therefor would lead to completely different drive resistance figures. In order to be able to investigate a new type of drive system for which no values are available the drive characteristics of the driven vehicle must be simulated from a defined initial condition, the drive resistance over the actual time interval calculated, and the drive machine operated accordingly.

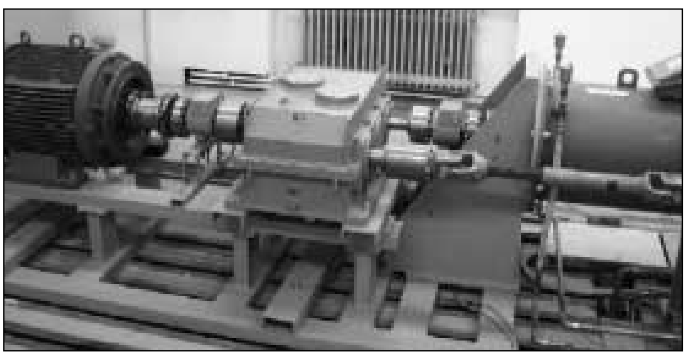
Drive system

The drive system to be investigated consisted of a diesel engine-generator unit as well as two drive units which could be powered purely electrically or via electrical-mechanical power split. The aim of the investigation was the development of a control strategy for individual wheel drive with regard to agritechnological and ecological demands [1]. From this aim, demands on the vehicle simulation model concerning especially traction, rolling resistance and load distribution, as well as load introduction, allow themselves to recorded and given as values through the working equipment. In that a drive system with individual wheel drive was to be investigated, it was not possible to simplify the vehicle model through a summary of each right and left wheel. Instead, load and traction characteristics had to be investigated for each individual wheel.

Simulation models

For the simulation of the drive characteristics of a vehicle two types of simulation systems are currently available: in multiple body simulation systems (MKS) the modelling takes place via definition of volume bodies and their characteristics as well as the connections of the bodies with one another. Equations for the calculation of the inner and outer forces and the movement of the object being investigated is created and resolved through simulation system methods. At the same time a continual checking of the object for plausibility takes place. In the case of equation-oriented systems, the characteristics of the model are described through applied paramaterised differential equation systems. The quality of the simulation results depends on the exact modelling of the physical connections as well as the observation of all occurring forces and moments and their direction. Such a model has to be precisely verified. For the application on a test station the simulation must take place in real time. This is possible through the application of an equation-oriented system. The model presented here (fig. 2) was created in MATLAB-SIMULINK. It consists of a rigid body on which the surrounding and side forces of the tyres – modelled here as suspension-absorber elements – apply, as well as the outside forces, as defined co-ordinates. Concerning the steering wheels, the steering axis is simplified in that it is accepted as running parallel to the vehicle's vertical axis. The castor assembly radius was also taken account of.

Fig. 1: Drive unit with accumulating transmission and load generator



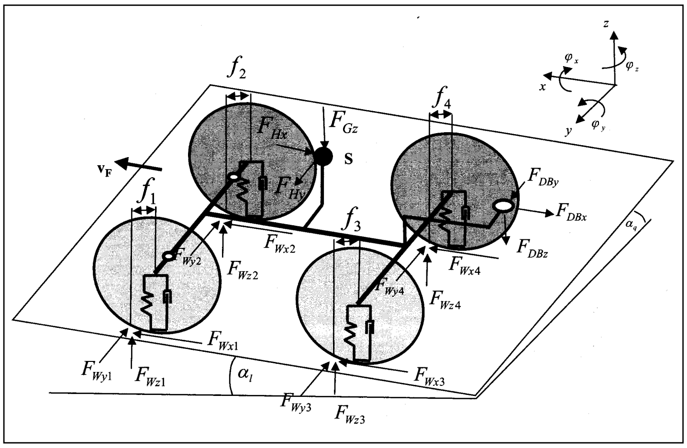


Fig. 2: Structure of simulation model

Simulation

For the calculation of the movement characteristics along the three axes through the centre points (pulling, lifting, pushing), all the forces acting on the vehicle were split into the components acting parallel to the axes and totalled. For the determination of the movement of the vehicle bodies about the axes (up-and-down, side-to-side, unsquare to direction of travel) the moments about the centre point were calculated. The wheel rolling resistance forces were determined from the resistance forces of the tyres to the overlapping nodding and wavering movements on the wheel resistance points. After the activating of the model, it is possible for the drive to initiate a torque on the wheels or to begin a rolling procedure. From the number of wheel revolutions, represented on the testing station by the revolutions of the connecting shaft of the accumulated transmissions, and the active rolling radius calculated from wheel resistance force and suspension constant of the tyres, the wheel circumference speed was determined. This is compared with the tangential speed of the wheel centre in order to determine the degree of wheel slip. The running angle position of the wheel is determined from the direction of the tangential speed of the wheel centre and the direction of the circumferencial speed. For the determination from wheelslip and running angle of coefficients for rolling resistance, draught and side force, an empirical model is used for the tractor tyre wheel-ground contact according to [2].

While the now-known longitudinal and lateral forces are used for the calculation of the movement characteristics, the sum of draught coefficients and rolling resistance coefficients multiplied by the active rolling radius represents a value for the resistance moment affecting the wheel. The acceleration of the wheel is given by the difference of the moment resulting from the drive system and the calculated resistance moment.

Adjustment of the load moment

With testing station investigations there occurs commonly the problem that the inertia of the rotating masses is greater than in a real system. This applies to rolling testing stations (inertia of the rollers) as well as to the testing station being looked at here with a solidly-coupled, high-rpm load machine, in that the rotating inertia of the additional masses applies as the square of the conversion. Through the correction of the torque on the load machine the dynamic relationship of the real drive system can also be reproduced on the testing station. The parameter of the correction value depends upon the relationship of the inertia forces.

Verification of the models

In that the investigations as to vehicle steering were not based upon any concrete vehicle, no verification of the equation-based simulation model in relation to available data could be attempted. Because of this, a second model with identical parameters in MKS „DADS" was set-up for checking. Both models were driven by the same drive software from „SIMULINK" and the drive characteristics were compared. A very good agreement between the two was achieved.

Test example

In *figure 3* the starting-off of the vehicle (straight ahead drive on the level) is represented. In this case only the rear wheels were driven by a pre-established torque value. The drive power is constant and then reduced until the vehicle free-wheeled to a stop. From the simulation calculations, the resistance moment acting on the wheels was found. The free moments, those which accelerated the wheels, are almost identical. Because of drive slip, the revolutions of the rear wheels were more than those of the front wheels. On rolling, the revolutions and the free moments come together.

Conclusion

The online simulation of the driving characteristics and associated control of the load machine(s) on a drive test station enabled representation of real stresses. Using the system enabled comparative investigations under reproducible conditions. Through the free tendency of the accepted resistance level, investigations of special operational cases , for instance turning on a slope, are also able to be carried out. Requirement for the application of online simulation is an exact positioning of the given load moments through the hardware.

Literature

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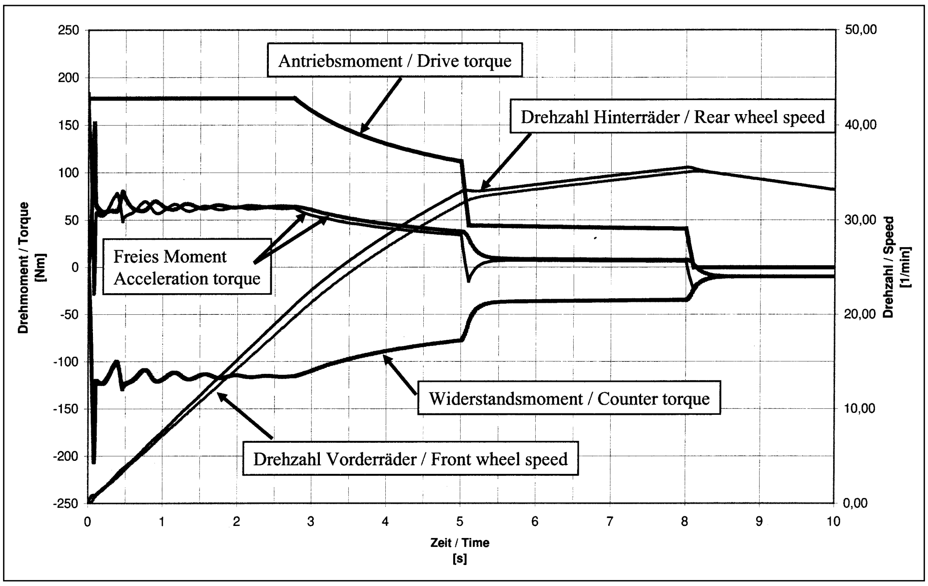

Fig. 3: Acceleration of vehicle represented in torque/rpm vs. time chart