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Vertical loads on the tractor front axle in front loader work

The greatest vertical stresses on tractor front axles and tyres occur in front loader work. The demands expected of tractors are rising because standard tractors with front loaders must increasingly compete against telescope loaders. The following report shows the influence of different parameters on the vertical stress. In conclusion, a first rough Rainflow total load spectra for the front axle load in front loader work will be presented.

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The increasing importance of frame-based construction in tractor building was the reason for starting a research project „Measuring and simulation of tractor body load spectra“ [1] (support from the DFG and from industry). In the course of the work, the writer concentrated on the experimental part whilst a second scientist concerned himself more with new simulation methods [2]. Aim of the project is a practical specification for testing tractor frame chassis.

The following report presents first results for the vertical load (also „bridging load“) on the front axle during front loader work.

For measuring wheel loads, extension restraining strips were put onto the front axle of the tractor (Fendt 509 C, 70 kW, 5400 kg, wheelbase 2328 mm, *fig. 1*) near the axle journal. This position was chosen so that horizontal forces had no influence. A calibration followed using the institute’s own traction-pressure-test equipment.

As long as the safety stop is not reached, the dynamic development of the wheel loads left and right is evenly distributed in front loader work. In that one can ignore the load support role of the front axle, it is possible to arrive at a very good estimate for the bridging load through totalling the loads on the wheels.

Test results

In order to investigate the influence of individual parameters, the whole process was divided into various parts with each part identified and isolated. During reversing (dynamic change in the direction of travel) the marginal conditions could, from test to test, be kept very constant. This means that this process of dividing-up a complete operation for comparative study is increasingly employed. The forces appeared with every change in driving direction in front loader work and also reflected well the dynamics of the complete vehicle.

Different positions of the front loader arms were investigated: front loader at maximum height, around middle height and bucket about 0.5 m above ground level.

The emptying of the loader far out in front produced a higher static stress on the wheels compared with the loader in a high position. This is easy to recognise from the static load distribution. The dynamic load situation is different: if the tractor was slowed down, for instance, constant speed reduction resulted in the load on the front axle increased in relation to the increased height of the loader (leverage effect).

The trial tractor had hydropneumatic suspension with suspension regulation. The suspension is operated via an hydraulic cylinder and two nitrogen reservoirs. The pressure in the reservoirs is matched to the load (levelling control), the hardness of the suspension increases in direct relationship to the load. At very high load, the oil pressure reaches a maximum level (pressure limitation valve), the suspension system stops and the remaining free travel decreases. Where the suspension is blocked, the crank is hydraulically pressed into the stop bed (absolutely no suspension). This results in the dynamic behaviour being comparable to that of a tractor with no suspension, apart from the additional material (arm and hydraulic cylinder) on the front axle support. Where the front loader has very little or medium loading, a positive influence from the suspension could be established: the load peaks are smaller. Where loads are heavier, this influence becomes very small because of the increasing stiffness and the reduction in suspension travel distance.

When braking the vehicle and front loader, the driver has an enormous influence on the production of stress loads. If, during the braking operation, the braking force is reduced and then once again increased (interval braking), this causes a rocking of the vehicle. The load peaks increase steeply, medial braking actions are tendentially lesser when compared with continual braking (continual full braking effort).

It is obvious that, with increasing load amounts, the static forces on the front axle also rise. Where the forces are dynamic, however, a smaller increase in these forces could be observed than would otherwise be

Fig. 1: Research tractor with front end loader (Fendt 509 C, 70 kW, 5400 kg, wheelbase 2328 mm)

expected. This effect of shock factor reduction with increasing load has also been determined in other work [3].

With no rear ballast and with bucket full (around 800 kg load), the driving stability of the tractor was not good enough. A satisfactory driving performance was achieved with 800 kg rear ballast whilst a very heavy ballast of around 1600 kg brought no further increase in driving stability, but also no worthwhile relief. The increase in rear ballast reduced static forces on the front axle (leverage effect). Dynamically, the load forces increased in that, with stronger braking (lifting of the rear axle), a higher total load had to be supported on the front axle.

Total load spectra

The working-durability method is very well suited for the load-relevant processing and presentation of the investigation results. In such a method, load development is classified through an appropriate calculation system and compared with a performance curve for the particular part of the axle. Up until now, the Rainflow method is regarded as the best system [4].

In order to be able to use load spectra on other machines as well as on the trial tractor, these should be always standardised if possible. This working principle is met when the loads (average load and arm length) are measured on the static unmoving axle load „empty“ (23.50 kN).

Figure 2 shows a first rough total load spectra for 1000 hours front loader work (without extreme shock loads). The following shares were established (with respective time shares): the working loads on the front loader light (44.3%) and heavy (40.0%), travelling (10.6%) as well as the exceptional stresses „abrupt reversing“ (2.3%), „emergency braking“ (1.2%) and „hard front loading action“ (1.7%). The estimated probability was calculated as 50%, exceptional stresses (for instance driving with heavily-loaded front loader over a high step, stresses occurring at the safety stop, have not yet been taken account of here.

In order to use the load spectra for a damage calculation, damage to individual parts must be calculated for every class (beam). In that no Wöhler curve is available for the tractor axle in question, it can only be qualitatively tested to show which classes in the main lead to the damage. From the results, a W“hler curve can be estimated. For other, parallel running, W“hler curves other part-damages are established. The distribution of the damages remains, however, the same. The rise in the example-Wöhler curve represents, according to the average load, 6.5 to 9. With these readings, a damage load spectra can be calculated in which case the damage accumulation hypothesis is used with extension according to Miner-Haibach.

For the total load spectra from *figure 2*, it is apparent that the damage-relevant load shares appear by average loads of 250% and arm distances from around 400 to 500% (these are, roughly seen, large threshold loads). Despite the minimal frequency of these load shares they are mainly responsible for damage. Arm lengths under 250% have almost no influence any longer on the damage.

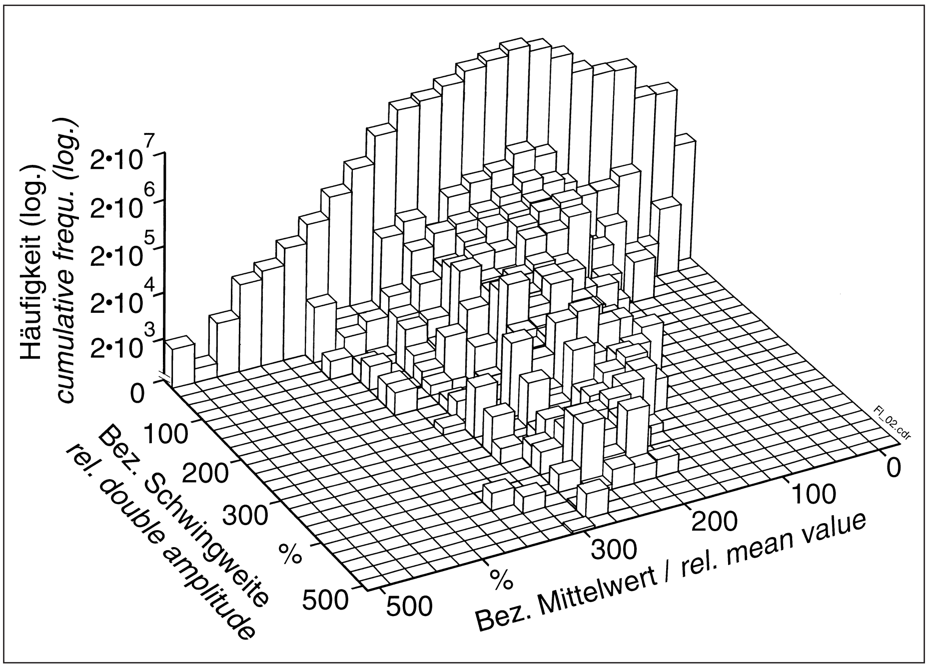

Fig. 2: Rain flow load spectra for front axle load using a front end loader, represented time: 1000 hours, based on an estimated probability of about 50 % (no shock loads)

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