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Influence of tyre pressure on load spectra in the tractor driveline

The dimensioning of driveline elements in tractors and farm machinery according to the random load fatigue method requires load spectra recorded under representative operational conditions for the machine. In the following paper the influence of the tyre pressures is specially highlighted in order to be able to estimate the effect of modern tyres and their parameters on transmission dimensioning.

To meet the increasing demands on driving wheel tyres for tractors (economy, load bearing capacity, soil structure protecting), tyres are developed with highest load bearing capacity at low pressure and especially large air pressure adjustment ranges. Low tyre pressures improve operational efficiency on the field whilst high pressures are advantageous on the road [1].

Background to the continuous investigations carried out within a project at the Chair for Agricultural Machinery, TU Munich (Garching) supported by the German Research Society is the question of whether the improvements in the area of tractor tyres as well as the application of on-board tyre pressure adjustment equipment leads to an increase in tractor drive line stresses.

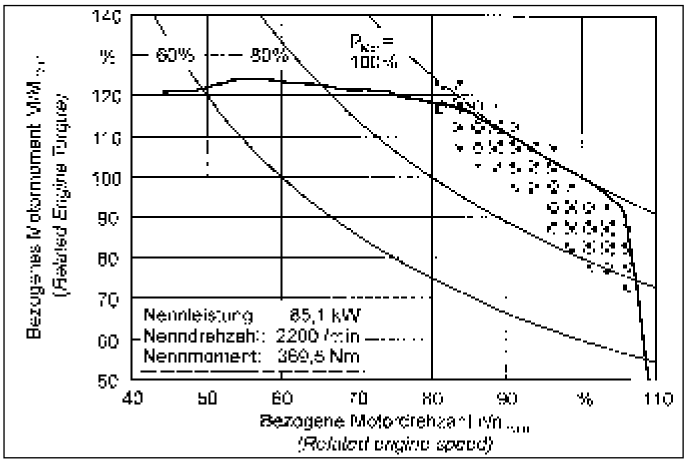

Fig. 1: Matrix of exceedance time of engine utilization concerning load spectrum ζ=100% (fig. 2 and 3). 36/36-transmission with three power shift gears, no shifting, no start and lifting operations, no head land operation. Loads with high frequency are smoothed.

Changes in typical transmission load spectra were observed by Vahlensieck, e.g., after replacement of stepped transmissions by stepless automatic ones [2]. Especially useful as comparative measures have proved to be the standardised load spectra given by Renius in [3].

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Keywords

Tractor, drive line, load spectra, tire inflation pressure

Method

Inner pressure is regarded as most important tyre parameter. Because of this the measurements within the project up until now were concentrated on the load spectra changes caused by adjusting tyre pressures.

A Valtra Valmet 8050E standard tractor equipped with a comprehensive range of sensors was used for recording driveline stresses. Alongside torque on rear wheels and front axle the transmission input moment was measured. The respective rpm and absolute driving speed were recorded.

The tractor was fitted with a central tyre pressure adjustment system of own construction. This enabled both comfortable manual adjustment of tyre pressure during drive as well as automatic tyre pressure management.

Operations involving high draught forces are especially interesting for studying drive line stresses and for this reason measurements during ploughing and harrowing are presented here, i.e., a slow, and a rather more rapid, cultivation process. The spectra produced represent these operations with, in each case, 50% time proportion. In order to separate the influence of the tyre pressure the first measurements were observed without gear changing. Also not taken into account here at first were the headland work, lifting and inserting the plough at the beginning and end of each pass. The comparability of the results was ensured through measurements taking place in each case in the same gear with the same implement setting (working depth and width) and around the same engine power level. This ensured that the recorded work was constant. Unfortunately, this sort of work with draught force limits cannot be done for all tyre pressure levels those, e.g., which increase when tyre pressure is decreased. This is because the stepped transmission means no suitable control is available. The author regarded, however, the chosen method as practical for the isolation of the tyre pressure influence.

Load spectra

For cyclically stressed construction components such as gear wheels, roller bearings and shafts with directional changes, time synchronised numerical systems are well suited when rpm does not vary significantly [3]. This means that for the measurements discussed here, an evaluation according to time proportions with regard to rpm can also be understood as frequency proportioning of the load range.

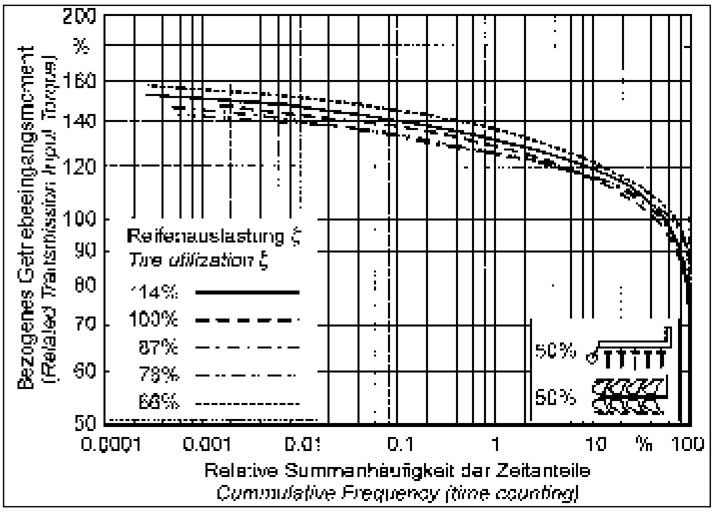

Fig. 2: Comparison of load spectra of transmission input torque for the same tasks with different tire utilization (adapted by the tire inflation pressure). 100% load means rated engine torque.

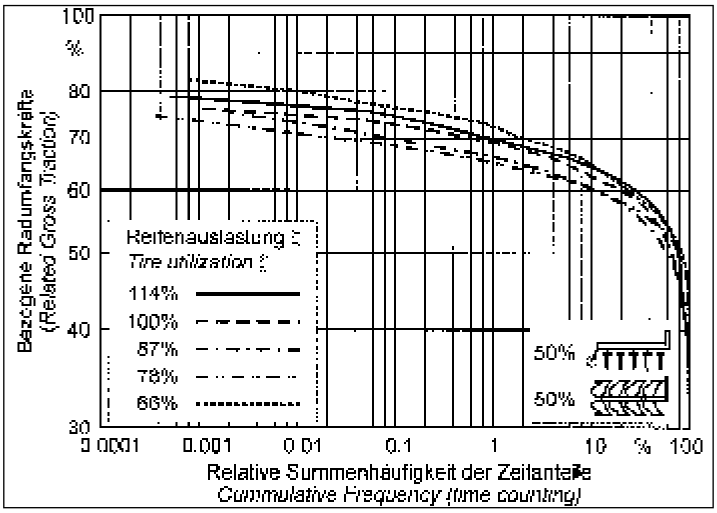

Fig. 3: Comparison of load spectra of the gross traction for the same tasks with different tire utilization (adapted by the tire inflation pressure). 100% load means tractor empty weight.

Additionally, the evaluation in the form of time proportions is as single parametrical numerical system also well suited for comparison of the spectra and for judging the influence of the observed parameter.

For classifying respective engine utilisation levels during recording, so-called matrix of period length serve the engine characteristics as already presented by Vahlensieck [2]. *Figure 1* shows the measured engine characteristics of the tractor used on the roll test stand of the Chair (a report on this is in preparation) as well as the time period during the basic recording of the spectra with 100% tyre pressures (high frequency stress amplitudes for the matrix of period length, evened-out, but nevertheless taken account of by the load spectra).

In order to enable general application of the spectra, suitable standardisation must be found. According to Renius [3] it is recommended that transmission torque be deduced from the engine torque (here: 369.5 Nm at 2200 min^{-1}) According to [3] wheel torque was brought together with the respective static tyre half measurements (here: 0.78 and 0.60 m) for the sum of the wheel circumferential forces based on the vehicle net weight (here: 50 kN). Through this the spectra can be used on all standard tractors with different performances and net weights.

Results

The tyre utilisation ζ serves for the standardisation of tyre stresses [4]. Currently these are based on permitted wheel load at applied tyre pressure and maximum speed of 10 km/h.

Figures 2 and 3 show the introduction of time proportional spectra for the applied transmission input torque and the applied wheel circumferential force. Measurements for five tyre utilisations (66 to 114%) were compared.

The results showed that the load spectra at transmission input *(fig. 2)* as well as on the wheels *(fig. 3)* lie very near to one another. Various effects are caused by the adjustment of tyre pressure there appear to partly compensate one another.

The increase of the tyre utilisation through pressure reduction brought an improvement in drive force coefficient. At the same time rolling resistance was reduced because of the larger tyre footprint and smaller tracking. The sum of rolling resistance and driving force, i.e., the wheel circumferential force, increases only a little, however, which leads to a slight increase in the drive moment. On the contrary, reduction in tyre pressure caused the rolling radius, i.e., the lever of the wheel circumferential force, to be reduced.

Established tendentially is that a too small utilisation as well as an overloading of the tyre leads to an increase in load spectra. The ground for this is the driving gear efficiency, i.e., the relationship out of draught performance and wheel hub performance. This depends decisively on the tyre pressure in that wheel slip and power transfer coefficient agree directly. Both increase, however, with increasing tyre utilisation. Should, as in the case presented here, draught performance (draught force and speed) remain the same, the increase in driving gear efficiency leads to a tendentious reduction in load spectra in the driveline. Under-utilisation of the tyres (too much wheelslip) and the overloading of tyres (high rolling resistance) reduce running gear efficiency.

Summarised it can be established that tyre pressure has only limited influence on the driveline load spectra. Very decisive is, whether through choice of gear or implement set-up in the given soil conditions and the optimum tyre utilisation, it is possible to optimise engine utilisation. If this is successful then sharper spectra can be expected for high tyre utilisation.

Literature

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