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Measuring Tyre Deformation from Various Wheel Loads and Inflation Pressures

Large surface contact area between tyre and soil means low contact area pressure and contributes to soil preservation. However the contact area cannot be measured or set directly. Therefore, suitable secondary data points are being researched, which correlate closely to the contact area, are simple to measure and make it possible to regulate the contact area.

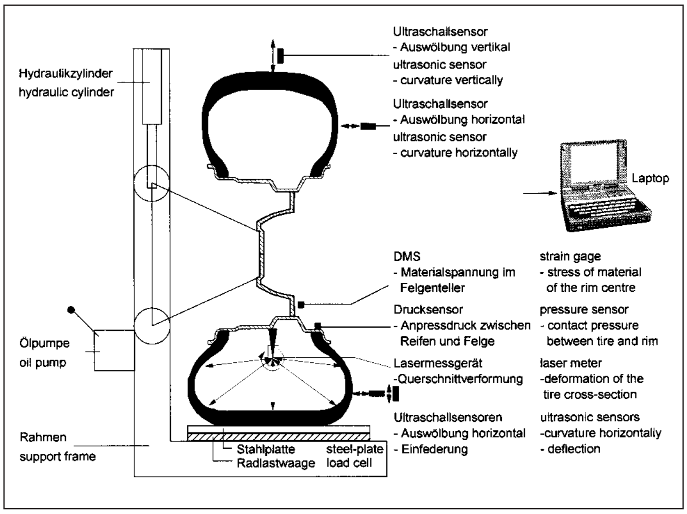

Fig. 1: Wheel test rig

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Keywords

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In recent decades the performance and the efficiency of agricultural vehicles have been increased considerably which, at the same time, raised their total weights and wheel loads and, in effect, aggravated the risk of damage to the soil. Therefore some experts demand legal limitation of wheel loads of agricultural vehicles. Rigid limits, however, are not meaningful, as they cannot take into account the current soil condition. Seeking technical solutions able to react flexibly to changing soil conditions and wheel loads would be much more beneficial.

On a field the contact area between tyre and soil should be as large as possible. The contact area pressure is the basic datum point for the ground pressure. At increasing depth the pressure is degraded in the soil. A low contact area pressure therefore results in a correspondingly low ground pressure and thus contributes significantly to the conservation of the soil.

A large contact area is achieved by choosing the largest feasible tyres and by setting the appropriate tyre inflation in pressure.

The inflation pressure of the tyre corresponds well with the ground pressure. In a depth of 10 cm the two are the same. Thus the inflation pressure is highly suitable to identify soil-preserving technology.

The appropriate inflation pressure

is determined primarily by the wheel load and the speed of the vehicle. Also, however, the ground condition should be considered. The wetter and softer the soil, the more sensitive it will react.

The deformation of the tyre is dependent not only on wheel load but also on the physical constitution of the ground. At the same wheel load and the same tyre inflation pressure it will be deformed more on hard ground than on soft ground. Therefore the deformation of the tyre is a first approach for a control system, which would include the condition of the ground into its control criteria.

The purpose of this project

is therefore to develop a control system that always sets the optimal contact area by means of the tyre inflation i pressure, considering the continuously changing conditions of ground and wheel load.

As the target parameter, the contact area, cannot be measured or set directly, first suitable auxiliary parameters have to be found, which must be related as closely as possible to the contact area, which are simple to measure and which allow the operation of a control system. The contact area grows with the deflection of the tyre. This flattening of the tyre decreases its volume at this point. The displaced air should therefore either deform the tyre at another place or change the inflation pressure. Consequently the curvature of the tread and the tyre side-wall, the tyre cross-section and the contact pressure between tyre and wheel rim are measured.

Investigations

At first the investigation is carried out at a non-turning wheel in a wheel testing rig. Measurements are carried for wheel loads of 6 to 12 tons, corresponding to wheel loads of current heavy-duty vehicles.

The tyre used is also typical for this type of equipment: the Continental tyre 800/65 R 32 AC 70H mounted on a rim DW 27 AX 32.

The data and the corresponding sensors are shown in *Figure 1*.

The investigations are effected at three inflation pressures: „Adjusted inflation pressure“ means the tyre inflation pressure is adjusted to the respective wheel load according to the manufacturerís settings. Those settings are for cyclical wheel loads at speeds of up to 10 km/h.

A constant inflation pressure of 3.1 bar is the highest listed in the tyre tables. A vehicle

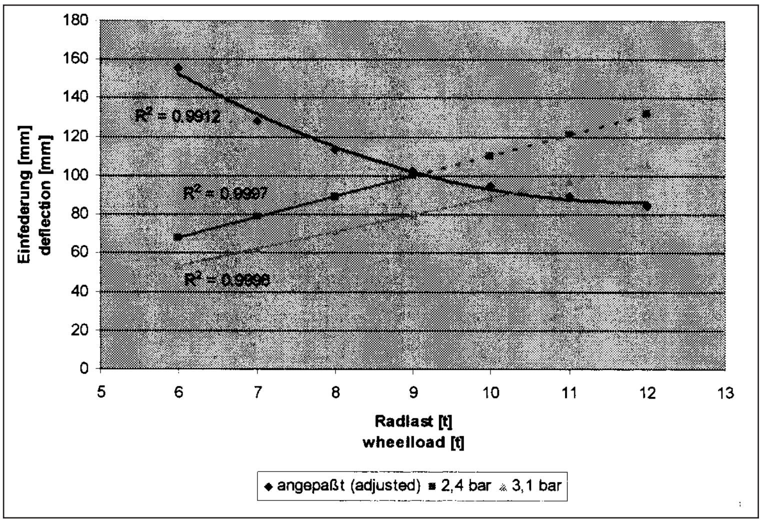

Fig. 2: Deflection at various wheel loads and inflation pressures

without a tyre-inflation pressure setting system would have to be run constantly at this pressure to avoid damage to the tyres. This pressure, however, is too low for a wheel load of 12 tons. If you project the data form the tyre tables to a wheelload of 12 tons, this results in an inflation pressure of 3.8 bar.

A constant inflation pressure of 2.4 bar is entirely normal for everyday use. At wheel loads of more than 9 tons this tyre pressure is too low, which means a risk of damage to the tyres in the long run.

Measuring the deformation in the upper part of the tyre would have the advantage in normal use that the ultrasonic sensor may be mounted in the upper part of the wheelhouse and could measure the tread or the tyre-wall from there.

The tyre reacts clearly stronger to the wheel load in the contact area. Measuring the deformation of the tyre from the outside however is problematical, due to the nearness of the sensors to the ground and the creation of tracks in the soil. Measuring inside the tyre requires mounting the metres inside the tyre as well as the supply of electricity and the transfer of data between the revolving wheel and the stationary vehicle. This method causes far more demanding technical solutions.

Results

The deformation of the tyres corresponds closely to the wheel loads at all measuring points investigated. In its upper areas the tyre reacts very little to changes of the wheelload. The data change only by 0,2 or 2 mm per ton of difference of wheelload. With such little changes measurements would be distorted by dirt on the tyres. This method therefore is not suitable.

The curvature of the tyre side-wall changes by 2 to 8 mm per ton in the contact area. Deflection shows the strongest reaction. Depending on the inflation pressure applied there are changes of 4 to 27 mm/t. Thus deflection appears to be the most suitable parameter.

The reaction of deflection to various wheel loads at the three inflation pressures tested is shown in *Figure 2*.

As expected, deflection increases with rising wheel loads at constant inflation pressures of 2.4 and 3.1 bar. When adjusting the inflation pressure to the respective wheel load deflection decreases at rising wheel loads due to inflation pressures which range from 0.8 bar at 6 tons wheel load to 3.8 bar at a 12-ton wheel load in this test series. To make entirely sure that there will not be any damage to the tyres at heavy wheel loads, a higher than normal increase of inflation pressure is set to reduce deflection.

The contact area changes corresponding to the deflection.

At 2.4 bar the maximum load-capacity of the wheel is ~ 9 tons. Higher wheel loads will lead to damage to the tyre at long term. Lower wheel loads will flatten the tyre less with an accordingly smaller contact area. In this way adjusting the inflation pressure according to the manufacturerís settings offers additional potential to preserve the soil at lower wheel loads, at higher wheel loads there will be further potential to save the tyres.

If the control system sets the inflation pressure to the current wheel load for soft ground, i.e that the deflection capacity of the tyre permitted is not fully exploited, therefore the tyre pressure could be lowered more than stated in the table without risking damage to the tyre resulting in an even larger contact area. The deflection can be connected to the contact area for geometrical reasons.

The outline of the contact area is rectangular. The width remains more or less constant due to the hard surface of the test rig, but its length changes very much. Therefore the contact area can be calculated from the data of the laser (*Fig. 3*). The wheel resting on the ground is considered as a circle cut through by a secant. The position of the secant is determined by measuring the deflection respectively the height of the cross-section. This height corresponds to the distance measured by the laser when measuring vertically downwards. The result is a rectangular triangle of which side b is known. The length of the second side c is the distance measured by laser at 0 wheel load. The length of the third side which is half the length of the contact area can now easily be calculated.

The above calculation is valid for a hard undeformable surface. The reaction of tyres on soft deformable ground has still to be investigated.

Summary

The deformation of tyres is determined by the wheelload, tyre inflation pressure and the condition of the ground. On firm ground there is a close connection between the wheel load and the deformation of the tyre in various places. Deflection shows the strongest reaction. These data enable the calculation of the contact area on a hard surface. We expect that based on deflection, the control of the contact area will also be possible on soft soil.

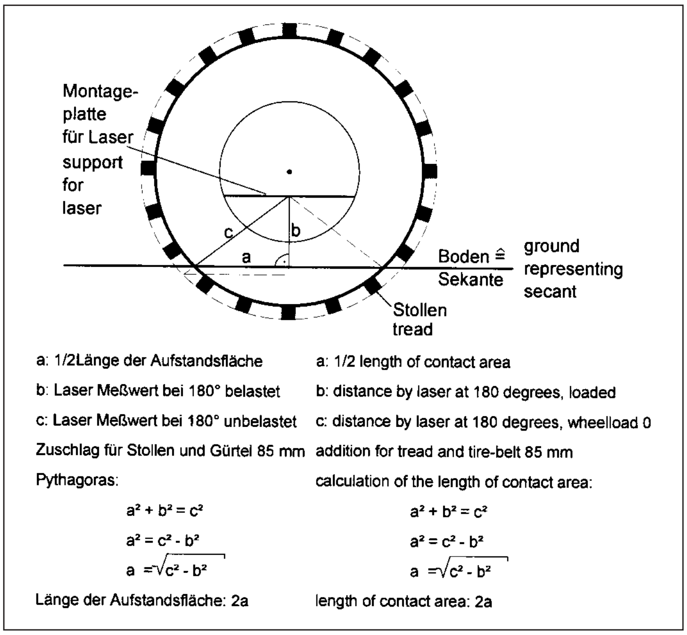

Fig. 3: Calculation of the length of the contact area