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Effects on Soil Structure caused by Various Undercarriages with the Same Contact Area Pressure

The trend towards more efficient farm machinery often means growing vehicle mass. Wheel loads have increased in recent years, especially in self-propelled harvesters. The agricultural machinery industry is responding to this by developing new running gear technologies and undercarriage concepts. Modern radial-tyres, high volume wide tyres, rubber belts and axles running offsets distribute high wheel loads on farmland and reduce the risk of subsoil compaction.

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Keywords

Soil compaction, soil stress, rubber belt carriage, hose type pressure transducers

Literature

Literature references can be called up under LT 07SH04 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

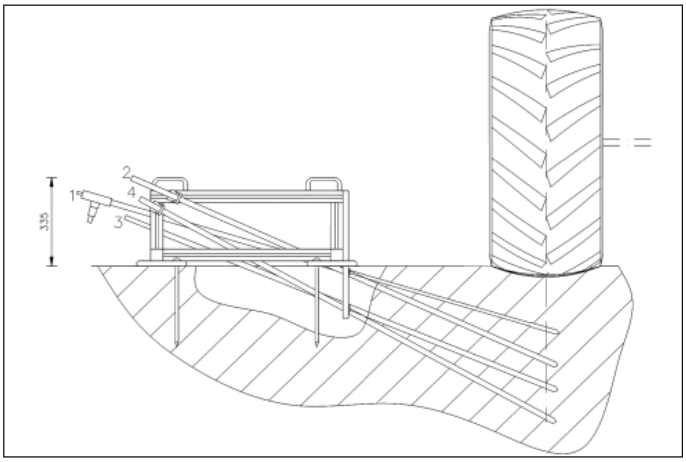

Fig. 1: Measuring arrangementof the soil pressure sensors for four the sampling depths

Undercarriages with tyres are characterized by multi passing which is assessed differently in the literature regarding the influence on the soil structure. Weißbach determined that the soil pressure is rising with every additional pass [1].

In contrast Keller detected in his investigations on multi passing no increase in soil pressure [2]. The use of rubber belt drives at heavy harvesting machines for soil protection is also discussed controversial. Ground settlement measured by Brunotte showed no differences between high loads on wheels and rubber tracks at sugar beet harvesters [3].

Ansorge detected significantly lower soil deformation, using a rubber belt in his investigations in the soil bin [4].

The availability of high capacity and soil protecting machines is enormously important for agriculture. Therefore an own investigation with a strictly systematic projection was carried out. The following question should be answered: "Does a modern rubber belt drive stress the soil less than multi passing with radial high volume tyres, if both systems carry the same load and have the same ground contact pressure?"

Aim

of the investigation was to determine the effects of different undercarriages with
- similar ground contact pressure and
- identical load

on soil stress (soil pressure) and soil deformation in the topsoil and the subsoil under field conditions.

Material and method

Three different undercarriage configurations were defined to test this hypothesis. They are based on a single pass with a modern rubber belt track, a double pass with a high volume radial tyre and a quadruplicate pass with standard radial tires (*Table 1*).

The load of the wheels allowed to realise nearly identical inflation pressure of the radial tires. The ground contact pressure of all three variants should be identically. First of all, this was tested with the calculation model TASC [5].

In spring 2006 a randomized field trial with six repetitions of each tracking situation (*Table 1*) has been carried out. The soil moisture of the sandy loam corresponded

Table 1: Concept of experiment

Treatment	Dimensions of tracks or tyres	Number of passes	Load per track or wheel [kN]	Mean ground contact pressure [kPa]
1. 1-time track	890 x 2000 mm	1	100	0.5
2. 2-times wheel	1050/50 R32	2	50	0.5
3. 4-times wheel	620/70 R25	4	25	0.5

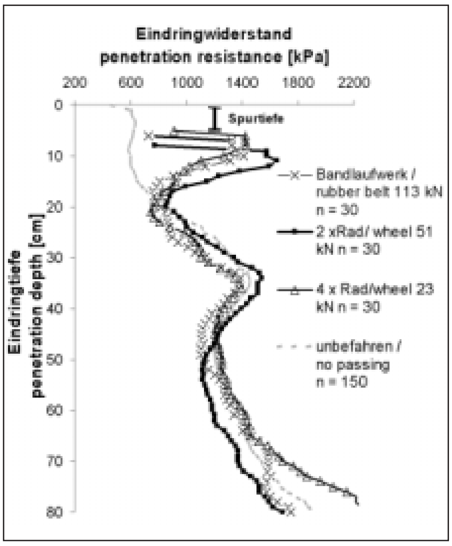

Fig. 2: Penetration resistance beneath the load variants

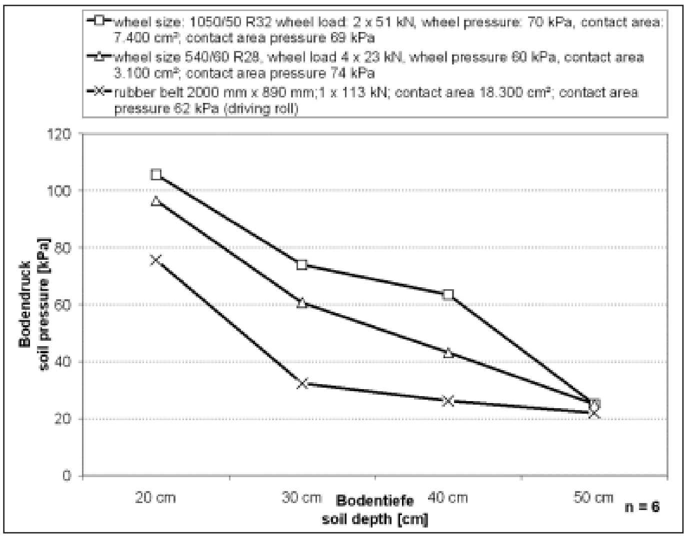

Fig. 3: Measured maximum vertical stress in four soil depths for the respective load levels

with field capacity. Before passing over, the loads of each wheel and of the track were recorded and also the ground contact area was measured by spreading lime around the footprint. Soil pressure during the passing over was recorded by hose type pressure transducers in depths of 0.2, 0.3, 0.4 and 0.5 m (*Fig. 1*).

Penetration resistance was measured with a cone penetrometer in and beside the trail of each treatment. To determine soil deformation 600 undisturbed soil samples were taken out of two depths (0.15 to 0.20 m and 0.40 to 0.45 m; 300 in and 300 beside each trail). Bulk density, total and coarse porosity and pneumatic conductivity of these samples have been analysed in lab. The results and details of the soil physical analyses will be presented in another publication.

Results and discussion

Table 2 shows the technical parameters of the undercarriages determined in the field. The rubber belt track with 113 kN load had the lowest mean ground contact pressure.

The analysis of the penetration resistance measurements shows a huge differentiation between the trails and the areas which have not been passed (*Fig. 2*). All treatments caused an increase of penetration resistance in the topsoil. Thereby the largest effects were detected for the double pass (wheel 1050/50 R32) with a wheel load of 51 kN. A marginal deeper trace was measured with the rubber belt compared to the quadruplicate pass (wheel), but both showed identical distributions of the penetration resistance in the topsoil. Penetration resistances of all undercarriages had nearly the same level at and below the depth of 0.22 m.

The analysis of the mean pressure peaks measured using hose type pressure transducers shows a reduction of soil pressure in each treatment with increasing soil depth. The phenomenon of rising soil pressure, which is described by Weißbach et al [1] was detected with all multi passing undercarriages. A considerable differentiation between the treatments can be identified (*Fig. 3*).

The highest pressure in the three depths of 0.20, 0.30 and 0.40 m was detected with the double passing of the wide tyre (1050/50 R32). The highest pressure reduction took place between the depths of 0.40 and 0.50 m.

Quadruplicate passing with wheel loads of 23 kN produced lower mean pressure peaks in the upper 3 depths than the double passing of the wheel with 51 kN load. The highest pressure reduction by quadruplicate passing took place between 0.20 and 0.30 m depth.

The lowest pressure level in all depths was detected with the rubber belt. Between 0.20 and 0.30 m the highest reduction of about 50 % was measured. The mean pressure peak in the depth of 0.40 m was a little bit higher than the pre-pressure (22 kPa).

Treatment	Dimensions of track or tires	Load per track or tire 19. 4. 2006	Tyre inflation pressure [kPa]	Ground contact area [cm^2]	Mean ground contact pressure [kPa]
1. 1 time track	890 x 2000 mm	113 kN	-	18300	62
2. 2 time wheels	2 x 1050/ 50 R32	2 x 51 kN	70	2 x 7400	69
3. 4 time wheels	4 x 540/ 60 R 28	4 x 23 kN	60	3100	74

Table. 2: Measured parameters of carriages

Summary

In the topsoil (down to 0.15 m) an increase of the penetration resistance was detected for all three treatments. The double pass (wheel, load 51 kN) produced higher penetration resistance than the single pass with the rubber belt and the quadruplicate pass (wheel, load 23 kN). With all treatments no effects on penetration resistance could be determined below the plough pan.

Soil pressure measurement by hose type pressure transducers showed explicit pressure peaks in the depth of 0.20 m under the rubber belt (113 kN), similar to all wheel passes. With increasing depth the pressure beneath the rubber belt was reduced faster than beneath both wheel variants. For all treatments in a depth of 0.50 m there was no pressure peak higher than the pre-pressure in the tubes of the transducers (22 to 25 kPa).

Conclusions

The investigation shows the different effect of various undercarriage concepts firming up a nearly identical load. Penetration measurements document considerable deformations in the topsoil (until 0.20 m depth).

Although mean ground contact pressures are similar in all treatments, the higher wheel load (51 kN double pass with wheel) caused soil stress with a deeper sphere of action. The rubber belt with 113 kN load cannot be put on a level with the quadruplicate pass (4 • 23 kN), even though all four wheels marked pressure peaks. The high tension of the rubber belt makes it able to firm up load to the soil also between the idlers, mid wheels and drive wheels driving and turn around wheels. The determined considerable differences between rubber belt and radial tyre support the assumption that the pressure distribution is unequal under the radial tyres with a concentration of pressure in the centre of the footprint. Degrell [6] measured these effects with a thin-film tactile pressure measurement system.