Scientific quarterly journal ISNN 2083-1587; e-ISNN 2449-5999

Agricultural Engineering

2015: 4(156):25-33

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.156.148

EVALUATION OF CHANGES IN TRACTION PROPERTIES OF A DRIVE WHEEL ON THE SOD UTILIZED BY VARIOUS MEANS

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ARTICLEINFO

Article history:
Received: June 2015
Received in the revised form: August 2015
Accepted: August 2015

Keywords:
drive tyre
traction force
traction efficiency
slip

ABSTRACT

The paper presents research results, the objective of which was to assess the traction properties of a wheel equipped with a drive tyre on sod with a varied species composition of plants and various usage level. Based on the measurements carried out with the use of a unique stand for traction research, the slip, traction force and efficiency were determined. It was proved that the species composition of sod and usage level resulted in varied values of the analysed parameters. Higher values of the traction force were obtained on sod I at the usage level of 50 and 100%. Maximum values of the traction efficiency on both sods, regardless the usage level, occurred at the wheel slip lower than 20%. In order to describe the condition of facilities, where traction research was carried out, moisture, compaction and maximum shearing stresses were measured.

Introduction

Wide use of farm tractors both in agriculture and in areas which are not related to farming results in the need to analyse issues concerning the impact of driving mechanisms on the surface. These issues have a particular meaning on sodded surfaces, where introduction of new technologies, machines with high mass and a considerable demand for the towing power may be related to occurrence of shear and bulk moduli of soil, which on the other hand may influence the green mass yield (Gajda et al., 1999).

Obtaining a high yield is presently particularly significant because, except for good quality fodder for animals, green mass from sodded areas is a precious raw material for biogas production (Rutkowska et al., 2006). It enforces the requirement of exploitation of machine sets in varied terrain conditions, and the technological processes continuance as well as efficiency, are absolutely related to ensuring appropriate traction performance of tractors which work there.

Issues related to the influence of drive wheels on deformable surfaces were the object of the research studies carried out by numerous authors. They concentrated mainly on the results of influence of driving mechanisms of tractor aggregates on the development and plant yield (Brosman et al., 2005; Burt, 1989; Douglas et al., 1997; Minner, 1993). Less papers deal with the tractive performance of drive wheels and in particular with the analysis of the process of developing traction forces. The available research results discuss the construction and exploitation methods concerning the increase of traction forces (Botta, 2002). Possibilities of introducing structural changes in driving mechanisms, a suitable selection of air pressure in tyres and vertical load of wheels are indicated. The least research papers concern tractive properties of tractors in variable exploitation conditions and such approach to the issues of cooperation of a drive wheel with the surface may be particularly important. The obtained results may carry information on restrictions in the vehicles move in the non – utilized ground conditions, which on the sodded surface may limit damage to plants and influence maintenance of species diversity (Sveistrup et al., 1997; Trenholm et al., 2000).

Objective of the paper, methodology and conditions of the research

Absence of a complex perspective of issues related to the use of sodded surfaces induced the research studies, the objective of which was to assess the traction properties of a wheel equipped with a drive tyre on the sod which differed with a species composition of plants and the usage level.

The research was carried out in facilities of the Agricultural Experimental Institute Swojec belonging to the Wroclaw University of Life Sciences. Soil, on which the research studies were carried out, is a fen soil, which formed from loamy sand. The tests were carried out on two types of sod, set up by sowing grass mixtures (sowing standard 30 $kg \cdot ha^{-1}$). First sod (sod I) was formed from the species which occur on meadows, the second one (sod II) from species which occur on pastures. The percentage share of the sowed mixture and the botanical composition of green plants for meadow sod was presented in table 1 and for the pasture sod in table 2.

Shortly before the traction tests were carried out, grass was mowed to the height of 35 mm and parameters which define the surface condition were measured. The soil compaction was measured with Eijkelkamp penetrologger with a cone penetrometer with a 60° vertical angle and the surface area of the base of 0.0001 m^2. Moreover, soil moisture was determined with Theta Probe ML 2x probe which constitutes additional equipment for the penetrologger.

Table 1

Percentage composition of the sowed mixture and a botanical composition of meadow green plants

		Composition of the sowed mixture	Botanical composition of green plants
Species name	Cultivar	Participation (%)	Participation (%)
Perennial rye-grass	*Licampo*	30	40
Meadow fescue	*Limosa*	20	19
Timothy grass	*Lischka*	10	13
Red clover	*Nike*	20	12
White clover	*Hula*	10	10
Kentucky bluegrass	*Bila*	10	6

Table 2
Percentage composition of the sowed mixture and a botanical composition of pasture green plants

Species name	Cultivar	Composition of the sowed mixture Participation (%)	Botanical composition of green plants Participation (%)
Italian ryegrass	*Livictory*	15	18
Perennial rye-grass	*Licampo*	45	54
Meadow fescue	*Limosa*	20	18
Timothy grass	*Lischka*	20	10

The maximum shear stresses were made with a shear vane Vaen H -60 by Geonor company. A measuring probe of the vane was placed in the sod then a rotation was made to the moment the surface was cut off, the value of stresses was read from the scale with the measurement scope from 0 to 260 kPa. Measurements of compaction and maximum shearing stresses were carried out on three depths in the layer of 0-0.15 m.

The change of the usage intensity (compaction) of the sod was obtained by a varied number of trips of a shaft, on the circumference of which, spurs of 0.014 m diameter and 0.02 m height were screwed in. This shaft, which was loaded respectively, ensured unit pressures at the level of 30 kPa. By a respective number of trips with a shaft, three levels of sod usage were obtained. Level 0% meant non-compacted sod, fifty trips with a shaft meant a 50% usage level and 100 trips meant 100% of the usage level (Białczyk et al., 2013).

Table 3
Technical parameters of the tested tyre

Tyre	Mitas 11.2R24 
Seat diameter, (mm)	610
External diameter, (mm)	1060
Width, (mm)	285
Carrying capa city, (kg)	1215

Traction tests were carried out for a wheel with the 11.2R24 tyre, technical parameters of which were placed in table 3. Tyres with a radial structure prevail in scientific research, because their use allows minimization of unfavourable changes in the ground (Tuner, 1999; Upadhyaya, 1989; Gee-Clough, 1997).

The vertical load of a wheel was within the catalogue loads and was 4300 N and the air pressure in tyre was 0.15 MPa. The investigated wheel was mounted on a unique measurement stand (Białczyk et al., 2013). The stand enabled recording of the towing power value, driving torque and theoretical and actual route of the investigated wheel. Based on the obtained parameters, values of the traction force, traction efficiency and slip were calculated. The obtained results were subjected to the statistical analysis; a two-way ANOVA at the level of α=0.05 and the Fisher NIR test were carried out.

Analysis of the results

Table 4 presents values of the measured parameters of the sod soil. The increase in the soil moisture on higher levels of sod utility was reported. Sod I, due to the species composition, which favours soil shadowing (presence of clover) allowed maintenance of higher soil moisture, which resulted in the decrease of compaction and maximum shearing stresses in comparison to sod II. The least susceptible to compaction caused with the usage was the surface layer of soil (0-0.05 m), rich in organic mass.

Table 4
Parameters of the sodded surface on the researched facilities

Layer of soil (m)	Usage level (%)	Average compaction of layer (MPa)		Maximum shear stress (kPa)		Moisture (%)	
		Sod I	Sod II	Sod I	Sod II	Sod I	Sod II
0-0.05		1.9	2.0	158	142		
0.05-0.10	0	2.8	2.9	224	212	15.4	14.3
0.10-0.15		2.4	2.7	236	228		
0-0.05		2.3	2.4	154	168		
0.05-0.10	50	3.2	3.5	224	246	16.5	15.7
0.10-0.15		2.8	2.9	252	264		
0-0.05		2.5	2.8	188	196		
0.05-0.10	100	3.4	3.8	250	258	17.2	16.8
0.10-0.15		3.1	3.2	274	278		

Figure 1 presents course of changes of traction force of the 11.2R24 tyre as a function of slip for specific usage levels of sod I. The investigated tyre achieved varied traction force values in the analysed part of the slip. The lowest values of this parameter were reported for the non-used sod (0%); the maximum value of 1050N was achieved at the considerably high slip of 14.7%. The increase of the usage level, which resulted in plant damage, allowed reduction of the wheel slip and obtaining higher traction forces values; for 100% of usage, traction force of 1600N was reported even for the 9.1% slip.

Figure 2 presents the courses of traction force of the 11.2R24 tyre as a function of slip for particular usage levels of sod II. Higher values of soil compaction were reported on this surface, which reduced possibilities of its penetration by tread grooves of the investigated tyre. On the other hand, higher values of maximum shearing stresses for 50 and 100% usage level proving higher resistance of the surface in the horizontal surface were not significant enough to make traction force values higher than the forces obtained on sod I.

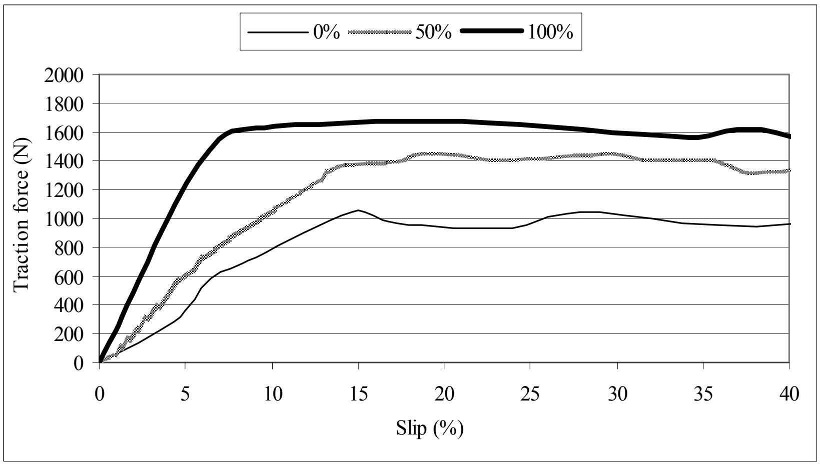

Figure 1. Courses of traction force as the function of slip for particular usage levels of sod I

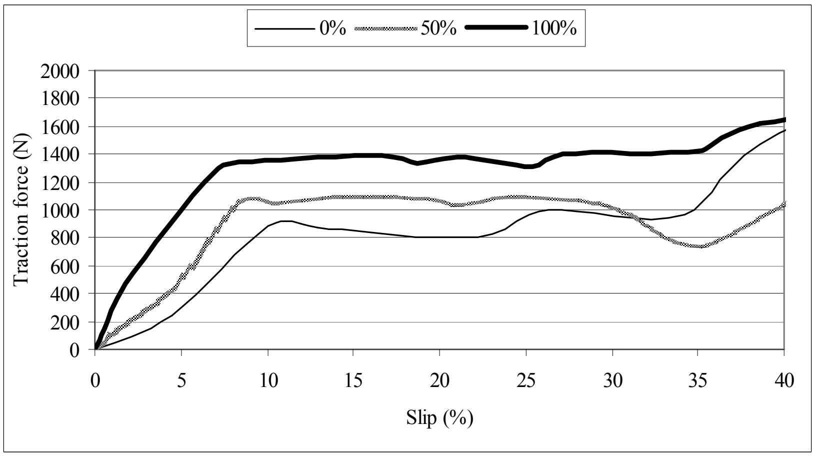

Figure 2. Courses of traction force as the function of slip for particular usage levels of sod II

When analysing the nature of the obtained courses, one may state that for this sod, explicit the surface resistance was clearly exceeded and the sod was sheared with tread grooves at the 0 and 50% usage level – traction forces equal of 892 and 1058 N for the slip from 8 to 11% were obtained. The change of the traction force nature may be reported when the slip of 7% is exceeded. From that value for the slip of approx. 35%, a stabilization of the traction force value is reported (from 1350 N to 1410 N). For all the analysed usage levels, exceeding the 35% slip (inadmissible from the agrotechnical point of view) results in a dynamic increase of the traction force. It may prove considerable sinkening of tread grooves in the sod and its destruction.

Figure 3 presents the courses of traction efficiency of the 11.2R24 tyre as a function of slip on particular usage levels of sod II. As a result of the increase in the usage level, higher efficiency could be obtained, mainly on account of the surface compaction, which reduces the movement resistance of the investigated tyre. For the slip exceeding 20%, the highest efficiency of 69% was obtained on the sod with the highest usage level (100%). The energy losses, related to the increase of the movement resistance of the investigated tyre, reduced the traction efficiency for the 0 and 50% usage level to the values of respectively 56 and 61%.

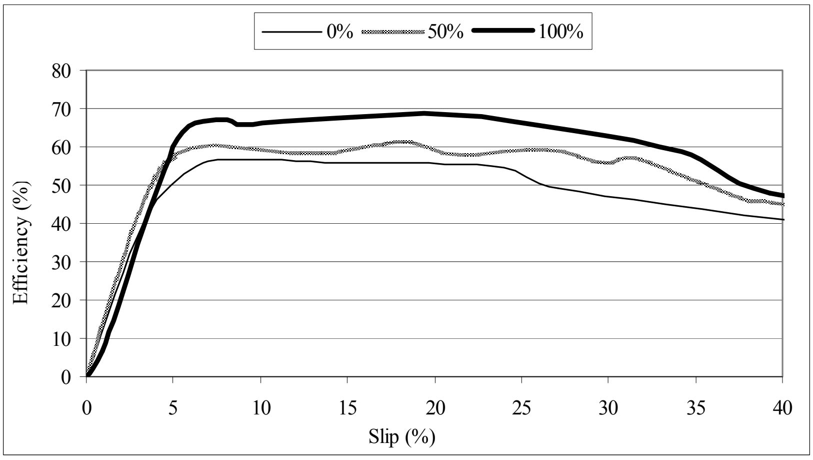

Figure 3. Courses of traction efficiency as the function of slip for particular usage levels of sod I

Figure 4 presents the courses of traction efficiency of the 11.2R24 tyre as the function of slip for particular usage levels of sod II. The analysis of the presented graph may allow the statement according to which higher values of this parameters were obtained at the 0 and 50% usage level, namely in conditions, where the flora may influence the traction abilities of the investigated tyre. The maximum values of the traction efficiency, that have been reached on these usage levels, also at the slip lower than 20%, were respectively 62 and 64%. Despite lower values of the traction force obtained on this surface, limited resistance of movement (higher compaction) allowed obtaining high values of traction efficiency.

Figure 5 presents average values of the traction force and efficiency determined for the entire analysed scope of slip (0-40%). Based on the obtained results, a general similarity of changes in the analysed traction parameters on both sods, displaying on both sods with the increase of the traction force value as a result of the increase of the intensity of use and obtaining the lowest values of traction efficiency on the non-used sods, was proved. In case of sod I, the biggest differences in the traction force values were between 0 and 50% usage level, whereas on sod II between 50 and 100%.

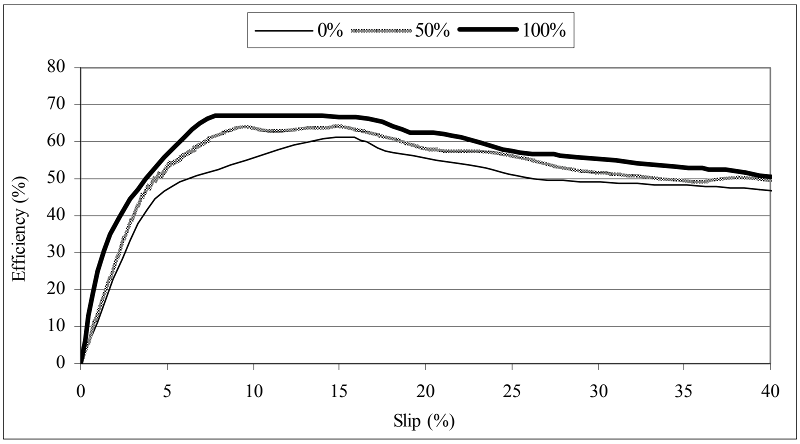

Figure 4. Courses of traction efficiency as the function of slip for particular levels of usage of sod II

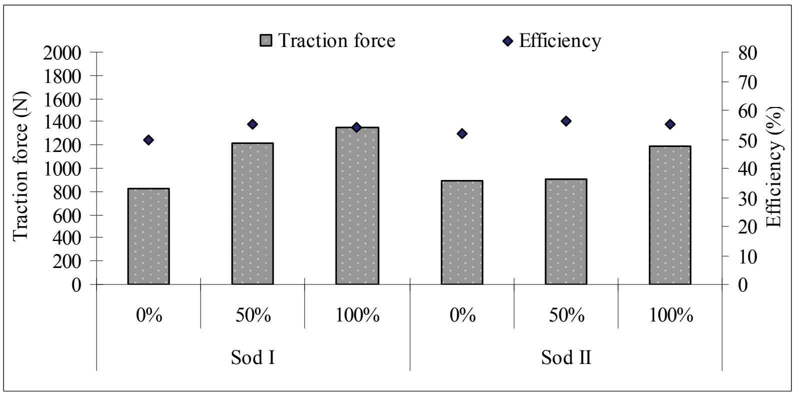

Figure 5. Average values of the traction force and efficiency calculated for the slip within the range of 0-40%

On both sodded surfaces, the biggest differences in the obtained values of traction efficiency of the investigated tyre occurred between the usage at the level of 0 and 50%.

The obtained results were subject to the statistical analysis (table 5) a type of sod and the level of its use were assumed as the sod type. The analysis, which was carried out, proves that both factors had a significant impact on the traction force and the traction efficiency values of the investigated tyre. Based on the tests of uniform groups, significant differences in the values of traction parameters obtained on particular types of sod (each sod in a separate group) were proved. Significant difference between the traction force values obtained on each usage level were reported. No significant differences in the traction efficiency values on the usage levels of 50 and 100% (these levels were included in the same uniform group) were reported.

Table 5
Results of statistical analysis

Factor	Traction force		Traction efficiency	
	F	p	F	p
Sod type	9.359	0.008493	11.49	0.004408
Usage level	30.100	0.000009	42.07	0.000001

Conclusions

1. It was proved that both the botanical composition of sod as well as the utility level significantly influenced the investigated traction properties of the 11. 2R24 tyre. Higher values of the traction force were obtained on sod I with a species composition typical for meadows and the traction efficiency values obtained on both sods were less varied.
2. Intensity of the use of each sod, resulted in the increase of the traction force value obtained by the investigated tyre but on sod I the highest increase of the traction force was determined for the 50% usage level, where botanical composition of plants allowed the maintenance of higher moisture of soil which favoured penetration of the sod soil with the tyre tread. On the other hand, in case of sod II, the highest growth of the traction force was reported at the 100% usage level, where the traction force mainly results from the tyre friction on the compacted surface.
3. Higher values of traction efficiency were reported on sod II, where higher compaction resulted in a lower in-depth impact of the investigated tyre. Regardless the type of sod and the usage level, maximum values of this parameter were obtained at the wheel slip lower than 20%.

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OCENA ZMIAN WŁAŚCIWOŚCI TRAKCYJNYCH KOŁA NAPĘDOWEGO NA DARNI O RÓŻNYM SPOSOBIE UŻYTKOWANIA

Streszczenie. W pracy przedstawiono wyniki badań, których celem była ocena zmian właściwości trakcyjnych koła wyposażonego w oponę napędową na darni różniącej się składem gatunkowym roślin oraz poziomem użytkowania. Na podstawie pomiarów wykonanych przy użyciu unikatowego stanowiska do badań trakcyjnych wyznaczono poślizg oraz siłę trakcyjną i sprawność. Wykazano, że skład gatunkowy darni oraz poziom jej użytkowania skutkowały zróżnicowaniem wartości analizowanych parametrów. Wyższe wartości siły trakcyjnej uzyskano na darni I, przy użytkowaniu na poziomie 50 i 100%. Maksymalne wartości sprawności trakcyjnej na obu darniach, niezależnie od poziomu użytkowania występowały przy poślizgu koła mniejszym niż 20%.W celu scharakteryzowania stanu obiektów, na których prowadzono badania trakcyjne wykonano pomiary wilgotności i zwięzłości oraz maksymalnych naprężeń ścinających.

Słowa kluczowe: opona napędowa, siła trakcyjna, sprawność trakcyjna, poślizg