RESEARCH CONCERNING THE DESIGN AND TESTING OF A LABORATORY RIG FOR THE STUDY OF THE WHEEL-SOIL INTERACTION

CERCETĂRI PRIVIND PROIECTAREA ŞI EXPERIMENTAREA UNUI STAND DE LABORATOR PENTRU STUDIUL INTERACŢIUNII ROATĂ-SOL

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Abstract. *It is known that physical degradation of soil due to the interaction with the wheels of the agricultural units consists mainly in its compaction, but also in the deterioration of its structure. Experimental studies should be developed in order to establish the values of the wheels' working parameters leading to soil degradation and to establish the relationships between the wheels' working parameters and the indices related to soil compaction and structure. In order to solve the above-mentioned problems the Agricultural Machinery Department of the University of Agricultural Sciences and Veterinary Medicine has designed, built and tested a laboratory rig. The rig is composed of a soil channel, the wheel carriage and the carriage traction implement. Tests were carried out in order to validate the design of the rig and the conclusion was that all the imposed requirements were achieved.*

Key words: tractor wheels, contact surface, soil pressure.

Rezumat. *Se cunoaşte faptul că degradarea fizică a solului determinată de interacţiunea roţilor agregatelor agricole cu acesta, constă în special în compactarea lui dar şi în deteriorarea structurii. Trebuie să se efectueze studii pentru a vedea la ce parametri de funcţionare ai roţilor începe degradarea solului. De asemenea, este necesar să se stabilească legătura ce există între parametrii de funcţionare ai roţilor utilajelor şi indicii privind compactarea solului şi structura acestuia. În vederea rezolvării problemelor menţionate, la Universitatea de Ştiinţe Agricole şi Medicină Veterinară din Iaşi, în cadrul disciplinelor de mecanizare a agriculturii, s-a proiectat, realizat şi experimentat un stand de laborator pentru efectuarea studiilor necesare. Standul este format din canalul de sol, căruciorul pentru susţinerea şi antrenarea roţii motoare şi dispozitivul pentru tractarea căruciorului. S-a efectuat experimentarea acestui stand, prin care s-a constatat că au fost realizaţi parametrii constructiv-funcţionali stabiliţi prin proiectare.*

Cuvinte cheie: roţi de tractor, suprafaţă de contact, presiune pe sol

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INTRODUCTION

It is known that soil physical degradation is due to its interaction with the wheels of the agricultural units and consists in compaction and structural damage (Căproiu et al., 1982; Jităreanu et al., 2007; Ţenu et al., 2010). Researches are needed in order to evaluate these effects and to establish the values of the wheel's working indices leading to soil degradation. The connection between the wheel's working indices and the indices related to soil compaction and structure must be established (Căproiu et al., 1973; Drăgan, 1969 Neculăiasa, 1971; Şandru et al., 1983).

In order to solve these problems a laboratory test rig was designed, constructed and tested, aiming to investigate the interaction between the wheels of agricultural equipment and soil.

MATERIAL AND METHOD

The test rig (figure 1) consists of the frame of the soil channel (1), the soil channel (2) and the carriage (3), on which the tyre wheel (4) and the compacting roller (5) are mounted. The electric cable drum (6) tows the carriage (3) by the means of a cable (7). The electric cable drum (6) consists of an electric motor (8), a cylindrical gear drive (9), a mechanical coupling and a drum (10). An electrical control panel and electric cables are used in order to feed the test rig with electricity. The carriage (figure 2) is composed of a frame (1), on which the tyre wheel (2), the compacting roller (3) and the wheel driving mechanism are mounted. The compacting roller (3) is used in order to achieve a certain level of soil compaction before the rolling the tyre wheel. A screw mechanism (4) is used in order to adjust the vertical position of the compacting roller. The tyre wheel unit (2) is provided with the screw mechanisms (5), allowing the adjustment of the wheel vertical position and load. When the carriage is towed by the means of the cable, the wheel (2) rotates due to its interaction with the soil and thus the conditions for a driven tractor wheel are simulated. When the carriage is not towed, the wheel (2) becomes a driving one, being driven by the electrical motor (6) by the means of a cylindrical gear drive and of a trapezoidal belt drive (7). Thus, the driving wheel of the tractor is simulated. Four upper trundles (8) – two in the front and two in the back – and four lower trundles (9) - also two in the front and two in the back - are mounted on the carriage frame; the trundles are rolling on rails, mounted on each side of the soil channel frame.

The towing cable is connected to the carriage by the means of two strain gauge load cells, allowing the measurement of the traction force needed to displace the carriage.

The electrical control panel is used in order to feed the test rig. The electrical motors are controlled by the means of a frequency converter, allowing the adjustment of the rotation speed when the frequency is modified between 3 and 50 Hz. The dynamic braking principle is used in order to stop the carriage at the end of travel. Switches on the control panel allow the selection of the feeded electric motor (the carriage towing motor or the tyre wheel driving motor), as well as its forward or reverse motion.

Two strain gauges load cells (1000 daN maximum force) are used in order to measure the carriage towing force; the load cells are connected to an electronic controller, which displays the averaged value of the traction force.

The laboratory test rig has the following features:

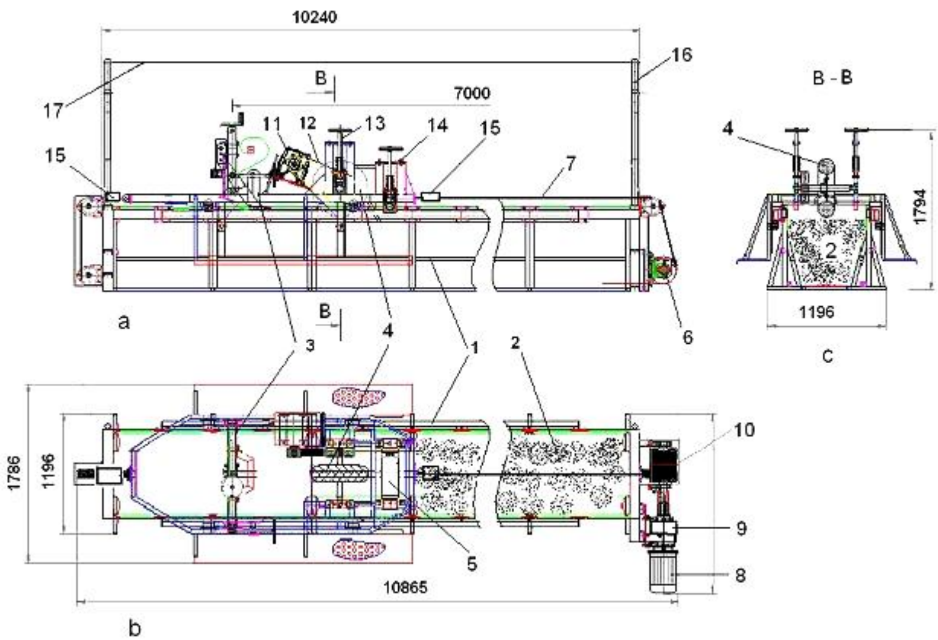

Fig. 1 - Laboratory test rig for the study of wheel-soil interaction:
a – *side view*; **b** – *upper view;* **c** – *front view; 1* – soil channel frame; *2* – soil channel; *3* – carriage; *4* – tyre wheel; *5* – compacting roller; *6* – cable drum; *7* – towing cable; *8* – electric motor; 9 – cylindrical gear drive; *10* – drum; *11* – gear drive; *12* – belt drive; *13* – mechanism for the adjustment of the vertical load over the wheel; *14* - mechanism for the adjustment of the vertical load over the compacting roller; *15* – load cells; *16* – supporting poles; *17* - electric cable.

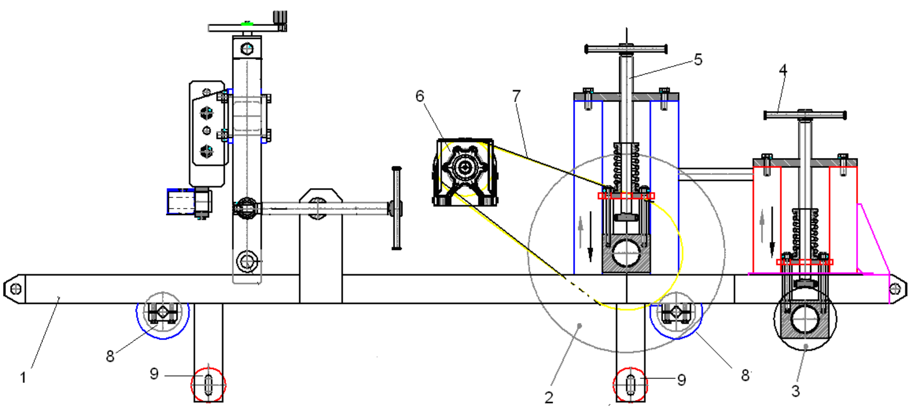

Fig. 2 - Carriage of the laboratory test rig**:**
1 – carriage frame; *2* – tyre wheel; *3* – compacting roller; *4* – screw mechanism for the adjustment of the vertical position of the compacting roller; *5* – screw mechanisms for the adjustment of the vertical wheel load; *6* – electric motor + cylindrical gear drive; *7* – belt drive; *8* – upper trundles; *9* – lower trundles.

- the tyre wheel on the carriage: 5,00 – 12,4 PR tyre (width = 127 mm, outer diameter = 569 mm), with V shaped lugs;
- the carriage towing electric motor: 5.5 kW and 1000 rev/min;
- the tyre wheel driving motor: 3 kW and 1000 rev/min;
- the carriage travel: 7 m;
- the carriage towing cable: D8 6x19 Seale IWR ISO 2408 (8 mm diameter, with 6 strands, each having 19 threads);
- overall dimensions of the soil channel: 0.8x0.8x10 m (width x height x length);
- overall dimensions of the test rig: 2035 x 10865 x 1764 mm;
- gear ration of the towing mechanism: 24.31;
- gear ration of the wheel gear drive: 28.76;
- overall ratio of the wheel driving mechanism: 57.

RESULTS AND DISCUSSIONS

The wheel-soil interaction laboratory test rig was tested in order to check the achievement of the imposed parameters. As a result, the following parameters were obtained:

- carriage speed (when towed by the cable): 0.5 – 1.55 m/s (1.8 – 5.58 km/h);
- tyre wheel maximum vertical load: 500 daN;
- carriage maximum towing force (at 0.55 m/s): 800 daN;
- cable breakdown point: 40.83 kN.

It was concluded that there were no significant differences between the design parameters and the achieved ones.

Experimental tests were performed in order to evaluate the working parameters achieved for the driving wheel condition of service; the effect of the wheel speed, soil compaction and wheel vertical load over the carriage speed, wheel slip and traction force were evaluated. The experimental results are presented in table 1.

An electronic penetrometer (Penetrologger, Eijelkamp Holland) was used in order to evaluate the soil penetration resistance. A soil penetration resistance of 0.2 MPa was recorded for the loosened soil and of 0.4 MPa for the compacted soil.

Based on the experimental results it was concluded that the increase of the wheel's rotational speed led to the increase of the carriage speed and to the decrease of the wheel slip, while the traction force diminished.

The results showed that an increased soil penetration resistance resulted in an increased carriage speed, due to the increased wheel-soil adhesion and a decreased wheel slip (Popescu, 1993; Roş, 1984; Roş, 1978). In the meantime, the increased wheel-soil adhesion due to the higher penetration resistance led to an increased traction force of the driving wheel (Scripnic, Babiciu, 1979).

As long as the vertical load over the wheel was concerned, it was established that its increase had the effect of increasing the wheel-soil adhesion, leading to the above mentioned results (diminishing of wheel slip, increasing of carriage speed, increasing of the traction force).

Table 1

Main working parameters of the test rig, for the driving wheel condition of service

Wheel rotational speed (rev/min)	**Soil penetration resistance** (MPa)	**Wheel vertical load** (N)	**Carriage speed** (m/s)	**Driving wheel slip** (%)	**Driving wheel traction force** (N)
20	0,2	500	0,50	17	230
		750	0,51	15	360
		1000	0,53	14	580
	0,4	500	0,51	15	290
		750	0,52	15	442
		1000	0,54	13	610
30	0,2	500	0,75	16	220
		750	0,76	15	350
		1000	0,79	12	570
	0,4	500	0,76	15	285
		750	0,77	14	438
		1000	0,79	12	600
40	0,2	500	0,99	15	220
		750	1,01	14	340
		1000	1,02	11	560
	0,4	500	1,01	14	280
		750	1,01	13	410
		1000	1,04	10	580

CONCLUSIONS

The experimental tests confirmed that the working parameters imposed by the design theme were achieved.

It was concluded that the increase of the wheel's rotational speed led to the increase of the carriage speed, the decrease of the wheel slip and the increase of the traction force.

An increased soil penetration resistance resulted in increased wheel speed and traction force, while wheel slip decreased.

An increased vertical load over the wheel resulted in increased wheel speed and traction force and a decreased wheel slip.

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