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FARMLAND PROTECTION THROUGH TYRE LOAD RATING

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Introduction

This paper deals with technical measures aiming at restricting the detrimental soil compaction by loaded wheels from the very beginning – the manufacture of agricultural machinery. Soil condition is expressed in terms of soil dry bulk density ρ_d (kg·m^{-3}). The up-to-date attempts to legalize measures reducing soil compaction were based either on the stress limits at certain depths [RUSANOV 1988] or on a general wheel loading limit [HÍKANSSON, PETELKAU 1994] At present, the stress state is still not conclusive for soil deformation, nor is the soil compaction without specifying the condition of soil prior to loading; the problem is that local changes of soil bulk density in the undisturbed ground are of the same order as the increments of density due to external loading.

A reasonable way of how to overcome this nuisance and produce convincing arguments is to measure soil compaction under controlled conditions. Our research programme in 1993–1995 under the sponsorship of the Grant Agency of the Czech Republic [GREČENKO et al. 1997] studied the soil compaction increments due to wheel loading in the field and then modelled them in the laboratory compactor with encouraging results, so that the logical consequence was to propose the modelling technique as an **autonomous procedure** to evaluate the compaction potential of the off-road tyres in terms of **compaction number** (CN) rating, which is the main object of this paper.

Fundamentals of the compactor modelling technique

Basic components of a laboratory compactor (Fig. 1) are the cylindrical **testing soil-bin** (inner diameter 460 mm, inner height 435 mm) and the **compacting head** with dynamometer holding round exchangeable **compacting plates**, marked a (diameter 150 mm), b, c and d (diameter 300 mm). The compacting force is produced by a hydraulic cylinder.

A model of soil compaction has to satisfy the following conditions with respect to the situation in the field:

a) the same soil type,
b) very similar initial soil bulk density and moisture content,

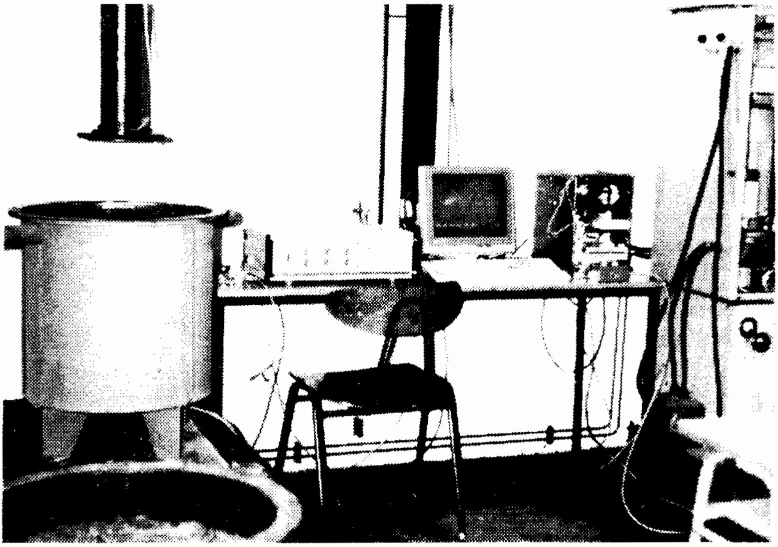

Fig. 1. Configuration of the laboratory compactor: from left to right: testing soil-bin and lower part of the compacting head, measuring instruments, hydraulic oil generator

Rys. 1. Układ stanowiska laboratoryjnego do zagęszczania gleby od lewej do prawej: pojemnik glebowy z dolnym fragmentem głowicy zagęszczającej, aparatura pomiarowa, aparatura hydrauliczna

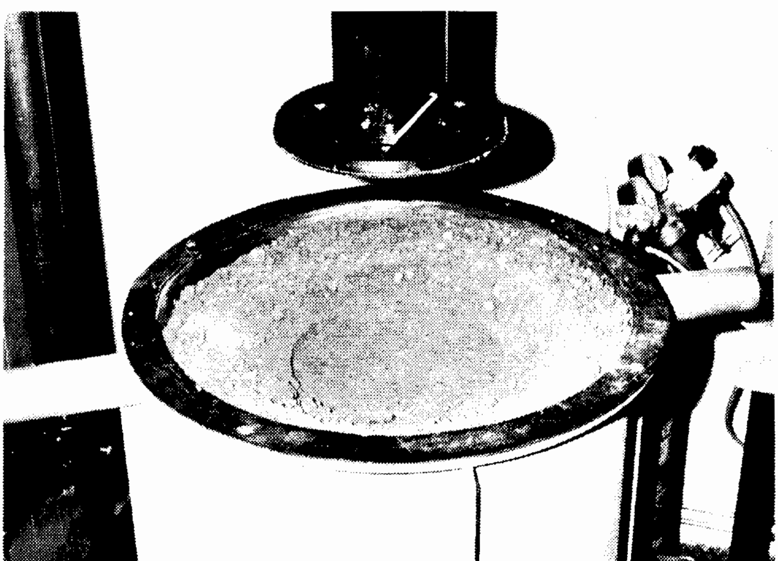

Fig. 2. Detail of the testing soil-bin filled with pre-compacted soil and of the compacting head holding the compacting plate size b

Rys. 2. Fragment pojemnika napełnionego glebą wstępnie zagęszczoną, wraz z głowicą i zamocowaną płytką zagęszczającą o wymiarze b

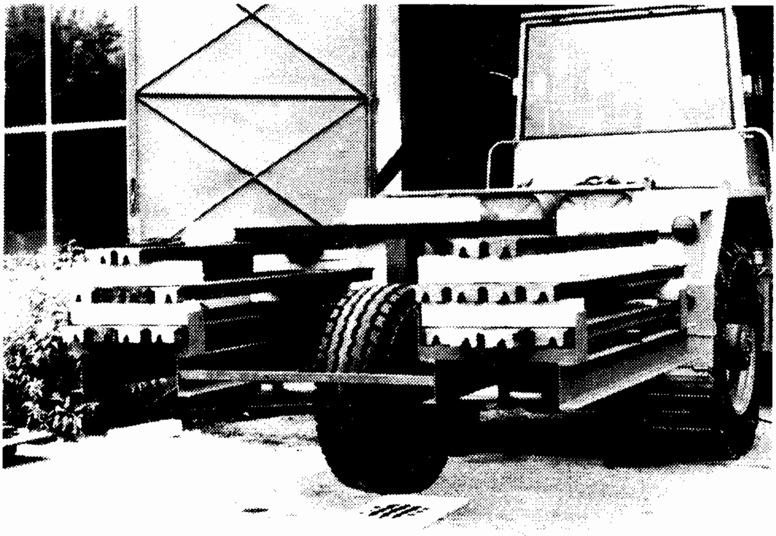

Fig. 3. An imprint of the loaded tyre Mitas 14.5/80-18 on hard ground (1994)

Rys. 3. Odcisk obciążonej opony Mitas 14.5/80-18 na twardym podłożu (1994)

c) compacting plate versus tyre: the same mean contact pressure,
d) the depth ratio **testing bin / field** depends on the ratio of contact areas plate/tyre:

$$z_p/z_t = (S_p/S_t)^{1/2}.$$

The testing bin is filled with specified soil processed to the specified moisture content (our soil is clay loam, required m.c. 19.6–20.7%), which is gradually pre-compacted by the plate d to the limit dry bulk density ρ_{dl} (critical density, [LHOTSKÝ et al. 1984]) satisfying the specified density corridor over the height of the formed soil profile (in our case, the average $\rho_{dl} = 1400^{\pm 10}$ kg·m^{-3}). Then a chosen smaller plate makes the **modelling imprint** with the mean contact pressure q_s equalling that of the evaluated tyre on hard ground (Fig. 2). Next follows the procedure of taking soil samples along the axis of the compacted soil column to evaluate the dry bulk density $\rho_d = f(z_p; q_s)$ termed **compaction function**. To evaluate the **compaction number** CN of a tyre, it is possible (not necessary) to transform this function into the **compaction profile** $\rho_d = f(z_t; q_s)$, which serves to calculate the „above-average" dry bulk density ρ_{ds}:

ρ_{ds} = (sum of the ρ_d values at z_t = 20, 30, 40, 50 cm plus twice the maximum ρ_{dm} value within this depth interval) / 6.

Finally, the CN equals:

$$CN = 1000\,[(\rho_{ds} / \rho_{dl}) - 1]\ (‰).$$

CN = 0 would rate the tyre as absolutely **soil-friendly**, whereas CN = 100 may stand for a tolerable limit at present (meaning that ρ_{ds} is 10% higher than ρ_{dl}).

The tyre mean contact pressure is determined from the imprint of the loaded tyre on hard ground (perimetric area), which requires the appropriate equipment and technique (Fig. 3).

Compaction number (CN) rating of off-road tyres

In fact, the CN evaluation procedure for a group of tyres is a lot more simple, because a limited number of compaction functions for different q_s can serve to determine the CNs of the whole group, each tyre at different **load Q / inflation pressure p** combinations according to the data in the tyre catalogues (e.g. specifications of the European Tyre and Rim Technical Organization, Brussels), so that the CN rating is capable of becoming an integral part of these catalogues for agricultural tyres (example given in Table 1).

Table 1; Tabela 1

Catalogue data (inflation pressure p, load Q) of the Czech-made transport tyre Mitas 14.5/80-18 complemented by the CN rating of the tyre compaction potential

Dane katalogowe (ciśnienie p, nośność Q) opony Mitas 14.5/80-18 oraz wartość CN

p (kPa)	150	200	250	300	325	350	375	400	425
Q (kg)	2035	2365	2690	3010	3175	3330	3495	3660	3850
CN	34	55	74	93	101	107	114	121	128

High load capacity and big tyres can have an acceptable CN rating if their mean contact pressure is reasonably low.

Conclusion

Further development of this technique would benefit from the cooperation of enthusiastic research teams carrying on along the lines as indicated in this paper and with similar size of basic equipment. This may lead to an adoption of tyre CN specifications, which would hold liable the manufacturers of tractors and machinery and thus help to safeguard the ecological situation of a farmland.

A detailed and comprehensive description of this novel approach accompanied by the necessary reasoning will soon appear in the Journal of Terramechanics, Pergamon Press.

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Key words: agricultural tyres, soil compaction modelling, compaction number, tyre rating

Summary

The state sponsored research project, designed to study the increments of soil compaction by loaded wheels in the field and laboratory in the years 1993 – 1995, corroborated the idea that physical modelling under controlled conditions, complemented by an adequate evaluation procedure, has a promising potential to predict a full-scale ground compaction and become a sound basis to practical measures. This paper describes the laboratory equipment, testing technique and the way of evaluating the compaction potential of tyres in the terms of soil dry bulk density, leading to Compaction Number (CN) rating of **individual** tyres. Practically, the CN rating for **soft ground** is assigned to complement the load capacity / inflation pressure values on **hard ground** in agricultural tyre catalogues (e.g. ETRTO specifications).

OCHRONA GLEBY PRZED UGNIATANIEM POPRZEZ SZACOWANIE NOMINALNEGO OBCIĄŻENIA OPON

Słowa kluczowe: opony rolnicze, modelowanie, ugniatania gleby, wskaźnik CN, ocena opon

Streszczenie

Sponsorowane przez państwo badania nad zwiększeniem zagęszczania gleby przez obciążone koła, prowadzone w warunkach polowych i laboratoryjnych w latach 1993–1995 wskazują, że pomysł fizycznego modelowania w warunkach kontrolowanych, uzupełniony przez odpowiednie sposoby oceny daje możliwość wyznaczania pełnowymiarowego zagęszczania gleby wykorzystywanego dla celów praktycznych. W artykule opisano wyposażenie laboratorium, techniki badawcze oraz sposób oceny możliwości ugniatającego działania opony, wyrażanego gęstością objętościową gleby i wartością liczby CN dla poszczególnych opon. W prakty-

ce wartość CN oceniona dla podłoża miękkiego jest pomocna przy wyznaczaniu nośności i ciśnienia w oponach dla twardego podłoża zamieszczonych w katalogach opon.

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