Savremena poljoprivredna tehnika
Cont. Agr. Engng. Vol. 36, No. 3, 247-255, July 2010

Biblid: 0350-2953 (2010)36, 3: 247-255 Originalni naučni rad
UDC: 620.171:631.43 Original scientific paper

MEASUREMENT OF SOIL COMPACTION WITH HORIZONTAL AND VERTICAL CONE PENETROMETER
MERENJE SABIJANJA ZEMLJIŠTA HORIZNONTALNIM I VERTIKALNIM PENETROMETROM

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SUMMARY

This contribution is focused on soil compaction measurements with use of horizontal penetrometer in field conditions based on two parameters comparision method. It deals with system design, such as the frame, and with design of measurement and writer unit. The whole device was in the end tested and the results had been analyzed.

Because of increasing efforts to accelerate the processing of large number of measurements, the use of automated penetration systems together with location of measurements with GPS are more and more practiced. This allows us to quickly map the actual conditions of soil environment and their incorporation into the soil maps.

Key words: soil compaction, continual measurement

1. INTRODUCTION

Nowadays, all technological operations in crop production are performed with use of agricultural machines. This has got plenty of pros such as the low cost per hectare, but one of main cons is the soil compaction side effect. The machines in use today are larger, and heavier but they also have more power and are more effective. They maintain longer contact with soil than ever before. This effects the soil bunk density. Soil compaction results in changes in water and air movement and also affects the root growth (Ponjičan et al, 2009). Finally, it also affects the yield crop (Savin et al, 2009).

Presently, in crop production, between 100 to 200% of land is treaded by tractors and other agricultural machines. This also depends on the type of crop which is cultivated (Nozdrovický 1989). Šarec (1997) reports that it varies from 120 up to 450% depending on the time of year. Hadžic (1993) reports that it amounts to 90% in the top soil which is affected by tractor wheels at the time of land preparation, 25% at the time of seeding and 60% during harvest. This has become normal situation in agriculture, and is presently considered as normal factor (Voorhees, 1977), having both good and bad effects. The influence of this factor should be measured not only through soil compaction but also through frequency of rides, horizontal deposit, speed of ride and slipping of wheels.

This is the reason why it is necessary to control soil penetration and minimize the rides on the field.

2. MATERIAL I METHODS

One of the possible methods for measuring soil compaction is to measure the soil resistance forces against the solid object which penetrates it. This resistance is influenced by soil bulk density and space arrangement of small soil particles. It has been shown that the designed and tested penetration devices could be used only for vertical in field measurements.
This description is suitable for vertical penetrometers. Methods of continual measurement of soil compaction are not common, although they have been tested so far (Alihamsyah, Humphries, Bowers 1990, Nadlinger 1992). From the practical point of view, it is necessary to obtain objective results by use of the simplest possible measuring method. In most cases the influence of agricultural machinery on soil is measured. The two-parameter comparison method was considered as ideal in this case.

2.1. Measuring device for the two-parameter comparison method

The two-parameter comparison method involves continuous measurement of two variables; one is the characterized compaction before exposure of the soil to negative factors of soil compaction, and second one takes into account the effect of these negative factors after soil compaction.

Currently, there are different types of horizontal penetrometers in use. Five years ago, at the Department of Transport and Handling at Technical Faculty at SPU Nitra, a new type of horizontal penetrometer was developed. After testing in field conditions, it was redesigned with the changes mostly pertaining to knives, force sensor and recording unit.

2.2. Setup of measuring device

Due to the fact that the previous measuring equipment was based on outdated measuring technology, it was necessary to make some adjustments to the measuring device which would allow more accurate measuring and recording. This was done in order to satisfy present technical standards. Modification of the measuring device consisted of an adjustable frame which allows force sensors to be attached. This was necessary because the new sensor is of different dimensions and because the authors wanted to get a more accurate angle adjustment for the knives. It was also necessary to design and produce new knives with standardized dimensions, in order to ensure accurate measurement results, (knives angle = 30°) and because of increased strength against bending. The proposed changes are illustrated in Fig.1,2 where the frame for attaching of force sensor EMS 150 – is shown.

Via the support frame, the measuring device (Fig. 1) is attached to the tractor three-point hitch. The frame consists of the three “U“ profiles which are welded together. It is attached to a support frame with two bolts and is adjustable in four positions. In this way it is possible to adjust the position of knives in the track, respectively, outside of the wheel (belt) track. This depends on the used model of tractor. Two shafts are pivotally attached to the beam using bearings. Measurement of soil resistance with knives is performed in the following way: the force applied on knives causes torques at the axes of both shafts, which is transferred to force sensor (5) via lever (7) - Fig. 2.

2.3. Proposed measuring and recording techniques

Data from the original ring strain sensors (manufactured by ZTS, Martin) were collected using a measuring amplifier PCLD - 770 and stored into the memory unit MC 23 by BMC Messsysteme, Berlin. The data saved in the memory unit had been processed using the NexTView software and exported to Microsoft Excel. In this program, the measured data were further statistically processed – Ďurák (2000). The new recording and measuring equipment is shown in the block diagram - Fig. 3, where the new force sensors EMS 150 (after their calibration) and a new handheld digital unit HMG 2020 for the processing of obtained data are used.

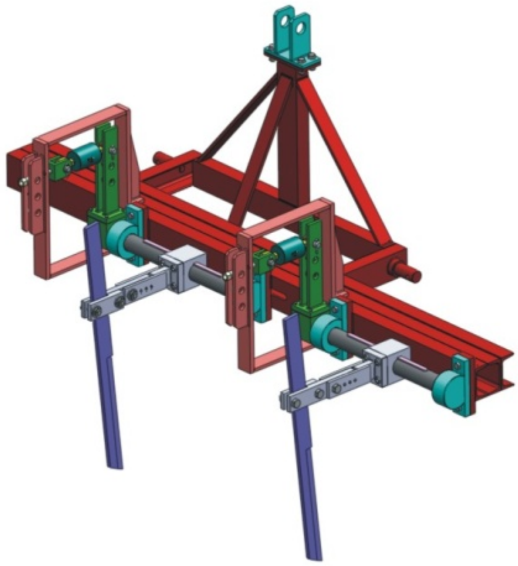

Fig. 1. Measuring device for two parameter comparison method
Sl. 1. Merni uređaj za postupak dvoparametarskog poređenja

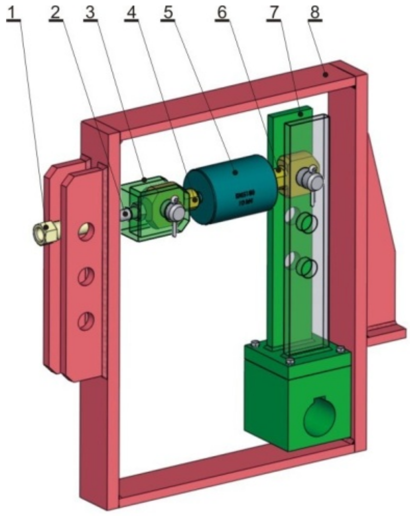

Fig. 2. Frame for force sensor unit

1 – screw for adjustment,2 – screw M 12 x 70 STN 02 1101,3 – sensor holder,4 – adapter for force sensor EMS 150 – 10 kN,5 – force sensor EMS 150 – 10 kN,6 – adapter for force sensor EMS 150 – 10 kN,7 – leaver,8 – frame

Sl. 2. Noseći ram senzorske jedinice

1 – vijak za podešavanje, 2 – vijak M 12 x 70 STN 02 1101,3 – držač senzora, 4 – adapter senzora sile EMS 150 – 10 kN,5 – sensor sile EMS 150 – 10 kN,6 – adapter senzora sile EMS 150 – 10 kN,7 – poluga, 8 – ram

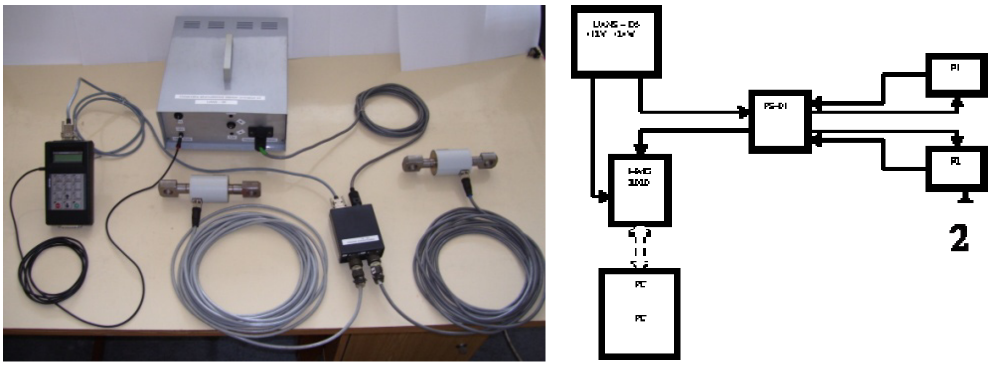

Fig.3. Block diagram of the measuring unit and photograph of assembly

UANS – 05: battery, HMG 2020: handheld digital unit HYDAC 2020, PS – 0: connection unit, F_1 and F_2 : force sensors, PC: personal computer

Sl.3. Šema merne jedinice i fotografija sklopa

UANS – 05: baterija, HMG 2020: ručna digitalna jedinica HYDAC 2020, PS – 0: priključna jedinica, F_1 i F_2 : senzori sile, PC: personalni računar

3. RESULTS AND DISCUSSION

Measuring equipment and the proposed measurement technique were practically tested in the school workplace Kolíňany. Measuring unit for the two parameters measuring and the recording device ware attached to the tractor, New Holland T 6070 Fig. (4 to 6). Measurement results are recorded in the comparison chart Fig. 7. The upper curve shows the normal operating power on the blade of the knife in the tractors wheel track and the lower curve in the track besides tractors wheel. In figure 8 you can see the trajectory of knives in soil after the measurement.

From the comparison graph it is clear that the resistance of soil in the tractor wheel track is bigger than in the outside wheel track of tractor. The soil under the wheel is compacted, which is reflected in its increasing resistance to the knife blade. Compaction of the soil depends on various factors such as size and duration of load, size and design of the wheel type, and tire pressure, wheel pressure per unit area of land, the number of crossings on the land, speed of crossings etc. To this issue should be given bigger attention in the future, as in theory so also in the experimental way.

Fig. 5. Horizontal penetration device attached
Sl. 5. Prikpočavanje nosača horizontalnog penetrometra

This measuring device allows continuous measurement of soil resistance in a maximum depth of 0.5 m, with the possibility of flat depth settings. It is applicable to all types of tractors equipped with three-point hitch and with track wide from 1000 to 2000 mm.

The measuring equipment may be available for all standard size tires, which are used for agricultural tractors, allowing continuous record of two measured values using available recording equipment. This allows continuous measurement of the degree of soil compaction.

Fig. 4. Field test
Sl.4. Ispitivanje u polju

Fig. 5 shows the way of attaching the penetration system, while Fig.6 illustrates the way of attaching the measuring unit.

Fig. 6. Measuring unit HMG 2020 attached
Sl. 6. Postavljena merna jedinica HMG 2020

Results are in fig. 6. Upper level comes from force against knife in track of tractor, while the down one is from track outside of tractor wheel. From this graph is easy to see the differences between compacted soil (in track of tractor wheel) and no compacted.

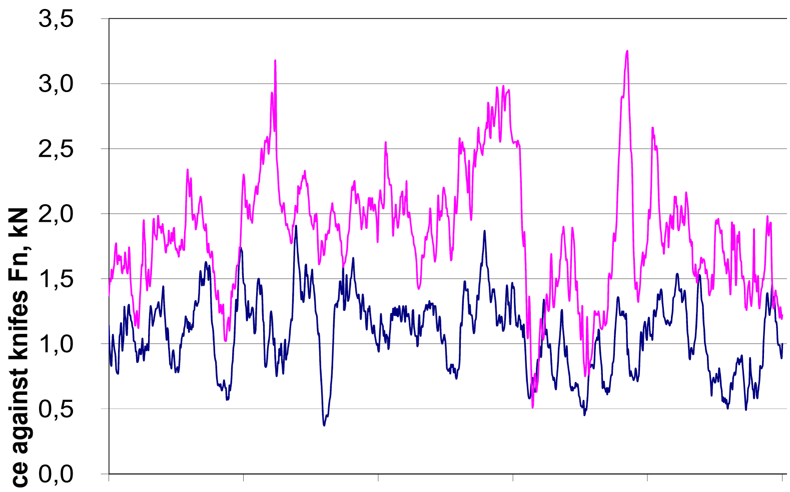

Fig. 6. Graphical result
Sl. 6. Grafički prikazani rezultati

Due to the fact that the vertical penetrometer is presently tested in laboratory conditions, we are only able to suggest further way of its use. The results thus obtained should be compared with those reported by other researchers. It would also be essential to compare the results with the data measured by horizontal system. After this, it would be possible to form hypothesis and draw practical conclusions for its further use. In Fig. 7 it is possible to see the trajectory of knives in soil after the measurement.

Fig. 7. Trajectory of knives
Sl. 7. Putanja noževa

4. CONCLUSION

Changes in physical soil conditions, in time of growing need to protect it and establish procedures for land conservation, require acquisition of the largest possible amount of information about its condition. That information could be acquired by various methods, but some of them require a large number of measurements. Scientists are constantly searching for new, more efficient methods, which can easily and quickly characterize soil conditions.

Because of increasing efforts to accelerate the processing of large number of measurements, the use of automated penetration systems together with location of measurements with GPS are more and more in use. This allows us to quickly map the actual conditions of soil environment and to incorporate them into soil maps.

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MERENJE SABIJANJA ZEMLJIŠTA HORIZNONTALNIM I VERTIKALNIM PENETROMETROM

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SAŽETAK

U vezi sa predloženim mernim uređajem treba istaći, da prilikom njegovog postavljanja na prednji hidraulični podizni sistem, traktor može da se agregatira sa svim ostalim mašinama koje se prikopčavaju u tri tačke na zadnji hidraulični podizni sistem, ili za ostale načine prikopčavanja, kao što je, na primer, poljski transport pomoću prikolice. Međutim, kada je merni uređaj postavljen na prednji hidraulični podizni sistem, nije moguće kontinualno merenje sabijanja zemljišta na tragu točkova, nego je moguće merenje sabijanja zemljišta sa dva merna elementa, koja su međusobno postavljena na proizvoljnom rastojanju. Ovakav način merenja omogućava dobijanje objektivnijih rezultata o sabijanju zemljišta na celoj površini ispitivanog zemljišta. Sledeća prednost postavljanja mernog uređaja na prednji hidraulični podizni sistem sastoji se u tome da je moguće meriti sabijanje zemljišta točkovima raznih poljoprivrednih mašina, a posebno mašina za ubiranje, na koje nije moguće postaviti merni uređaj. Pored već navedenih prednosti i mogućnosti korišćenja mernog uređaja, moguće je ovaj uređaj koristiti za konkretno merenje otpora zemljišta radnih alata poljoprivrednih mašina i uređaja za obradu zemljišta, npr. nagrtača, kultivatorskih motičica, ali i raonika sejalice. Tako da preporučen i eksperimentalno ispitan merni uređaj ima univerzalnu primenu i moguća je njegova primena za potrebe ispitivanja u poljoprivredi.

Ključne reči: sabijanje zemljišta, kontinualno merenje otpora zemljišta

Note: This contribution was realized under the agreement of solution of grant project VEGA MŠ SR No. 1/0462/09 „The Elimination of Negative Operation Impacts of Machines on Agricultural Land, Water and Atmosphere“

Primljeno: Prihvaćeno: