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STUDIES ON A LONG SOIL BIN FOR SOIL-TOOL INTERACTION

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ABSTRACT- In this scientific paper we presented a soil- tool interaction testing device, which was projected, built, instrumented and evaluated. This soil bin has been designed to study on the soil–tool interaction. It features a 23-m long by 2 -m wide by 1-m deep. An electric drive system was used to pull a carriage by two chains. The carriage has a capacity of testing three prototypes of tools at each run. The testing tools on the moving carriage are pulled or pushed in the soil channel through a chain drive system. Respective transducers were positioned at various localities interfaced to a data acquisition system to measure and save the various measurement parameters such as forces, speed, moments and displacements. The system of data acquisition was able to receive the measured signals in real time, display on the monitor screen and record them into a computer. The performance of the testing facility was evaluated and validated during some initial tests.

Key words: soil bin, soil– tool interaction, tillage, traction

REZUMAT – **Studii privind lada pentru sol, folosită în studiile de interacţiune în cadrul sistemelor sol-utilaj.** În lucrare se prezintă un mijloc de testare a interacțiunii în cadrul sistemelor sol-utilaj, care a fost proiectat, construit şi evaluat. Lada pentru sol a fost proiectată pentru a studia interacțiunea în cadrul sistemelor sol-utilaj. Ea are o lungime de 23 m, o lăţime de 20 şi o adâncime de 1 m. A fost folosit un sistem de conducere electric, care, prin intermediul a două lanțuri, poate asigura deplasarea echipajulului. Acesta are capacitatea de a testa trei prototipuri de utilaje la fiecare deplasare. Transductorii au fost aşezaţi în diferite locuri, pentru a măsura diferiți parametri de măsurare, precum forța, viteza, deplasarea. Sistemul de interceptare a datelor este capabil să primească semnalele în timp util, să le afişeze pe ecranul unui monitor şi să le salveze într-un computer. Prin câteva incercari iniţiale, a fost evaluată şi validată uşurinţa testării.

Cuvinte cheie: ladă pentru sol, interacţiune în cadrul sistemelor sol-utilaj, lucrările solului, tracţiune

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INTRODUCTION

There have been intensive research efforts to obtain a better understanding of the soil- tool interaction due to the complex problems of interaction between the various devices (tillage tools, wheel, etc.) and various type conditions of soil surfaces. Tractive performance of tractors has been a challenging problem for many engineers. The soil-tool tests usually are determined using experimental methods. The tests are conducted either on soil bin found in indoor testing facilities or by performing real field testing. Usually, the soil parameters in soil bins such as variation of cone index and soil compaction level are more constant (Naderi *et al.,* 2009). Generally, a soil bin facility consists of soil bin, tool carriage, drive system, instrumentation and data acquisition systems. Soil bins are grouped into two design classes. One class of soil bin consists of straight or circular rails, movable soil bin in which the tested tool remains stationary. Another class involves fixed soil bin with a carriage that travels over the soil. The advantages of soil bin are well described by ASAE (1994).

Soil bins, where soil is brought to the tester, have been used to acquire a significant amount of data. (Upadhyaya, 1986). Nichols (1920) developed and used soil bins to study basic soil–machine. This experience with small soil bins had led to the suggestion for the large soil bin facility that is now the National Soil Dynamics Laboratory, Agricultural Research Service, US Department of Agriculture (NSDL, ARS and USDA). In 1984, there were about 36 different facilities in 12 countries that had 90 soil bins constructed (Wismer, 1984). There may have been about 150 soil bins in use around the world with only several new soil bins built since 1983. (Wood *et al.,* 1983 and Onwualu *et al.,* 1998). Some examples of these facilities are the National Soil Dynamic Laboratory (NSDL) in USA, Cranfield University at Silsoe in UK, University of California at Davis in USA, University of Hohenheim in Germany and IMAG of Wageningen in Netherlands (Yahya *et al.*, 1998).

MATERIALS AND METHODS

The soil bin that is built in this study features a 23-m long by 2 -m wide by 1-m deep. An electric drive system is used to pull a carriage by two chains and an inverter is used to control a 22 kW driver electromotor. Carriage travel speed is variable within 20 km/h.

Figure 1 showed the general arrangement of the soil bin testing facilities. The facility has a moving carriage that moves on rails using two chains above a soil channel (*Figure 2*). Forward and reverse movement of the carriage is made possible by using a chain drive system. This chain runs from the drive sprocket at one end and an idler sprocket at the other extreme end with two 24m chains located between these two ends; forward and reverse movement of the carriage are made possible. An inverter that is located at the main control console closed to the set-up facility controls the moving carriage. For measuring the horizontal force, vertical force, depth and other testing parameters, it can be equipped with various transducers. Data acquisition system is able to receive and control the information, measurement of signals in real time, display the information on a monitor screen and finally record the information into a storage medium in real time.

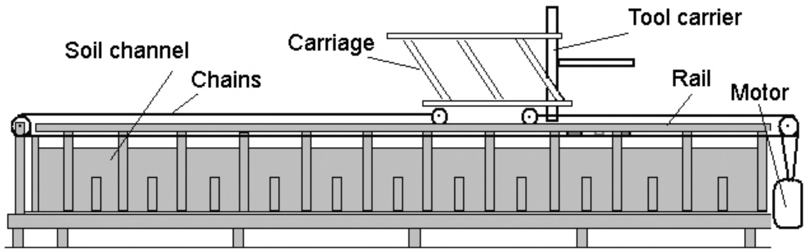

Figure 1 - Schematic diagram of soil bin facility

Figure 2 - Main components of facility (a) moving carriage drive unit; (b) soil channel; (c) soil

Moving carriage assembly. The soil bin has a general carriage for mounting any tillage or traction devices such as traction or towed wheels. The carriage dimension is 1.90 m × 2m × 0.95 m with total weight of 144 kg. *Figure 2(c)* shows the moving carriage with its auxiliaries. The moving carriage is a double frame type with a U-shape frame that could rotate around two joints of the main frame vertically. The moving carriage can travel forward or reverse conditions on the carriage rails located above the soil channel. The moving carriage driving unit is driven by a 3-phase 22 kW at 1457 rpm motor and an LG inverter reducing unit (variable frequency drive-Stravert iS5) through a chain-drive system that can change the motor speed in a wide range. The output shaft of the motor is connected to the drive shaft of the chains that pull the carriage forward or reverse.

As the carriage driving unit moves, the sprocket on the carriage driving unit turns and an optic tachometer sends the carriage speed signal to the data acquisition system and displays the travel speed of the moving carriage. The speed control unit on the inverter can set the moving carriage speed to any desired speed from 0.05 to 5 m/s. The acceleration and deceleration time of the carriage moving can be changed to a present transient time via multi-function inputs of the inverter. The emergency knobs are placed on the soil bin when triggered could instantaneously cut the power supply to the moving carriage driving unit. Such available provision acts as a safety measure for the operator under emergency circumstances while running the test facility. The digital LED units on the front panel of the inverter displays the moving carriage speed real time. Output power and frequency are the other parameters that can be shown on the inveter board at any time.

Soil channel and fitting equipment. The soil testing facility is equipped with a 23 m × 2 m × 1 m size soil channel having filled with clay loam soil classification. The channel is located to enable the tested tire to rotate on the soil surface at any position of the channel width. The soil in the channel is prepared to the desired test conditions before each test run. Initially, the soil surface is loosened to at least 150 mm depth with a small cultivator (connected to the soil bin carriage) and then the surface is levelled with a small carriage leveller. A variable weight roller compactor is driven on soil surface in the soil channel to get the desired soil density in the test runs. By controlling the compactor speed, compactor weight and the numbers of passes, different soil strength can be obtained for the test runs. The roller is made of a steel drum of 0.5 m long with either 280 mm diameter sizes. The roller weighs 21 to 80 kg by adding oil into the roller. Additional weights had been added to the roller to get the desired soil strength for the test runs.

Data acquisition system. The data acquisition system for the test facility is located on a special place on the carriage (*Figure 2(d)*). This dedicated system is made up of some sensor outputs interfaced to a computer system. The computer system can receive, monitor, display and store the measured signals from the respective transducers. A C program is used to retrieve and read the stored data, and compute the average, standard deviation and variance of the needed tire performance measurements.

An optic tachometer that is located on the main drive shaft of the carriage driving unit measures the moving carriage speed. This unit can detect revolutions in digital values without making direct contact. In detecting revolutions, the optic tachometer senses the special color sign that is located on the revolving shaft and detects signals equals to the numbers of revolution of the rotating main drive shaft.

A notebook is used for data acquisition system, monitoring and real time control of the system. In any mode, data acquisition system may perform at different sampling rates. The display of data is available to user at real time on the computer monitor screen and the data could be permanently stored in a defined file in the computer.

RESULTS AND DISCUSSION

For evaluating the system operations, some initial tests were done. Carriage no- load force was measured using two S- shape load cells located between drive chains and carriage. The load cells were calibrated using dead weights before connecting. For each dead weight loading, the variance and average standard deviation were calculated. Measurements were also taken for the unloading of dead weights. Output of regression analysis was used to find the relationship between dead weight and output voltage. Static calibration tests on load cells showed excellent linearity with coefficients of determination (r^2) of close to 1 (*Figure 3*). All of these calibrations were preceded for three replicates and the regression analysis was done. *Figure 4* shows the total horizontal force for pulling the carriage at 1m/s speed. Because of mass inertia of the carriage, a greater force is necessary for moving the carriage at first point of the motion.

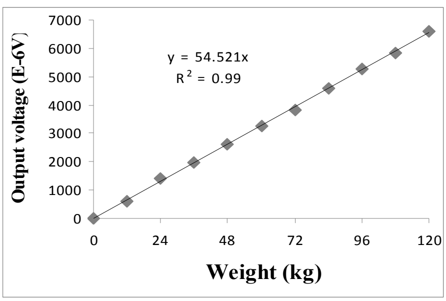

Figure 3 - Calibration curve of one of the used load cells for determining the carriage no- load motion resistance

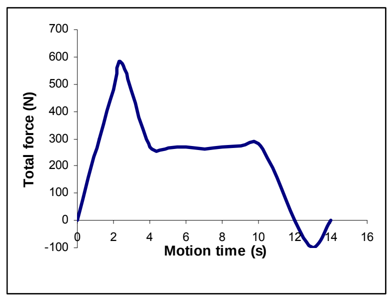

Figure 4 - Total horizontal force for pulling the carriage at 1 m/s speed

The results of this study are about evaluating the facility performance and some initial tests were conducted using the soil bin facility to determine the carriage motion resistance without any load. The soil channel was filled with clay-loam soil and the soil surface was prepared for each test run using some tillage tools that were carried with the soil bin carriage. The width of the soil channel in soil bins is an important parameter of these facilities. In most traction and soil compaction experiments conducted in the soil bins, the minimum lateral spacing from one tool centreline to the next is twice the tool section width.

The great range of lateral positions of the test tire is one of the abilities of this work and it is possible to use the great size of wheels and changing the side position of the tire to the right of the left edge of the soil in the soil channel for various test repeat ions. The developed facility was successfully tested to determine motion resistance of carriage.

CONCLUSIONS

A soil- machine testing facility was designed and developed to spearhead fundamental research on soil- tool interaction with any tillage or traction devices. This available facility consists of a moving carriage with a cantilever-mounted tire that moves in either forward or reverses directions on rails well above a soil channel.

Vertical and lateral position of the working tool is adjustable in this facility using a screw system. The main tool carrier can rotate about upper joints for no- work conditions (*Figure 2(c)*). With the high-speed feature, this soil bin can meet the requirements for the study (Because of the Long soil bin length) and allows the greater carriage speed with acceleration and deceleration times.

To conduct 2-way tillage operations, the carriage can run forward and backward. Combination of the bin capacity and special design of the tool carriage provides the function of simulating tillage operation at different conditions.

All parts of the soil bin such as structure and drive system were selected or built based on mechanical design. Only description of the facility and its operations are presented to demonstrate the capability and value of the facility.

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