An instrumentation system for the measurement of performance parameters of a no-till seeder

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Gerber, W.A., Misener, G.C. and Campbell, A.J. 1994. **An instrumentation system for the measurement of performance parameters of a no-till seeder**. Can. Agric. Eng. **36**:079-084. An instrumentation system was developed and installed on a custom made tool carrier to measure the effects of seeding depth on the draft and vertical force acting on a double disk seeder. The system used a portable computer connected to a data logger. Conditioning instrumentation was designed to facilitate the interfacing of the transducers to the data logger. The data were collected at 70 Hz and stored for later analysis. The trials were conducted in fields with established sod conditions and uniform texture. A regression equation was developed which described the force-depth relationships of the draft and the vertical force acting on the opener. The depth of the opener was found to vary considerably from the theoretical value.

Nous avons développé un système de mesure continue de la profondeur d'opération ainsi que des forces verticale et horizontale exercées sur des ouvre-sillons de semoirs. Ce système comporte un ordinateur portatif relié à un enregistreur de données. Des senseurs de profondeur et de force sont reliés à l'enregistreur de données par l'intermédiaire de circuits de conditionnement des signaux. Le système a été utilisé pour mesurer la profondeur de semis ainsi que les efforts vertical et horizontal exercés sur un ouvre-sillons à doubles disques sous une fréquence d'acquisition des données de 70 Hz. Les essais ont été conduits dans des champs où le couvert végétal ainsi que la texture du sol étaient uniformes. Deux équations de régression ont été dérivées afin de prédire les valeurs respectives des forces verticale et horizontale agissant sur cet ouvre-sillon particulier en fonction de sa profondeur d'opération. Les relevés de profondeur ont permis de constater des écarts considérables entre la profondeur de semis mesurée de l'ouvre-sillon et la profondeur théorique telle que déterminée par son mécanisme de contrôle de la profondeur.

INTRODUCTION

No-till seeder design has developed through different approaches, some based upon agronomic performance with others based on mechanical performance. Work by Baker (1976), Choudhary and Baker (1981), and Lindwall and Erbach (1983) sought to define and measure the seed slot characteristics in terms of the agronomic requirements of the seed, moisture, temperature, and oxygen diffusion rate. Other authors (Danfors 1987; Baker and Mai 1982a, 1982b; Tessier et al. 1991) worked on defining the seed slot in terms of soil physical properties (bulk density and shear strength) required for germination and emergence. In the case of no-till, the desired conditions must be achieved by the opener assembly interacting with the soil in field conditions with no prior tillage.

Researchers have worked with soil bins under controlled conditions to measure draft and vertical forces so as to model the performance of opener components (Schaaf et al. 1979; Gray and MacIntyre 1983; Choi and Erbach 1986; Nieuwenburg et al. 1992). No-till opener assemblies are seldom made up of a single component. Morrison et al. (1988) outlined the many and varied components which can be combined to produce opener assemblies. Baker et al. (1979) and Stephens and Johnson (1991) described complicated opener assemblies designed and tested to produce consistent results.

Sowing depth is considered by many to be one of the more critical aspects of seeder performance (Tessier et al. 1991; Wilkins et al. 1981; Norris 1985; Kaviani et al. 1985; Campbell and Baker 1989). Campbell et al. (1985) and Morrison and Gerik (1985a, 1985b) describe the case in conventional seedbeds where tillage is used to provide a uniform soil condition. Opener depth is generally achieved by applying a down force on the opener in excess of the resisting force of the soil. In the no-till case, openers are required to adjust to varying soil conditions while maintaining a constant working depth. Depth control is achieved by the same principle as in conventional tillage and is generally assisted by depth wheel or bands which carry any excess down pressure.

In eastern Canada, no-till planting is a very important practice. In particular, sod-seeding is required due to the problems associated with conventional tillage practices where limitations such as rough topography, stoniness, and shallow bedrock are common occurrences (Bélanger and Winch 1985). No-till planting is an effective alternative to planting and reseeding entire fields for selective regeneration of areas where winter kill occurred (Taylor and Allinson 1983).

Much of the data collected on no-till seeders has been on components and been conducted under laboratory conditions. Previous field studies have been based on crop emergence rather than on machine performance such as seed depth measurements (Moller 1975; Morrison et al. 1988). While this provides much of the information required for design, it does not furnish the complete picture. The objective of this project was to develop an instrumentation system to measure the forces acting on, and the depth of operation of, a no-till opener assembly under field conditions.

MATERIALS AND METHODS

System description

The system was mounted on a tool carrier which was supported by wheels and towed by a tractor. The entire seeder opener assembly was supported by a biaxial force transducer which in turn was clamped to the tool carrier. A linear displacement transducer was provided for measurement of operating depth. A signal conditioning system and computer based data logger were provided to filter and record signals from the force and depth transducers.

The overall system included a 12 V battery, transducer signal conditioning circuits, software, a control computer, and data logger (Fig. 1). The transducers used to measure forces were connected to conditioning circuits which attached to the data logger input channels. The depth transducer was connected to an excitation voltage and then to a data logger input channel.

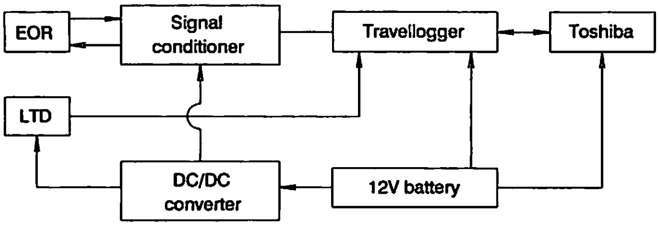

Fig. 1. Block diagram of instrumentation system.

Transducers Tool forces were measured by using an extended octagonal ring transducer (EOR) similar to that described by Godwin (1975). The unit was designed for a maximum force in each axis of 3 kN. The device was capable of measuring two forces and two moments: F_x, F_y, M_{xy} and M_{xz}, but only F_x and F_y were measured during this experiment. The transducer was calibrated by the developer (Department of Engineering for Agriculture, Silsoe College, Cranfield Institute of Technology, Silsoe, Bedford, England).

The depth of the opener was monitored by using a linear displacement transducer (LDT). The depth measuring device consisted of a 200 mm diameter wheel mounted on a lever arm which was connected to the opener. The length of the lever arm was adjusted such that the wheel and opener were at ground level at zero depth. A linear transducer (model PT-101-15A, Celesco Transducer Products Inc., Canoga Park, CA) was used to measure the displacement of a cable connected to the metal wheel. The device was connected directly to the opener, thus enabling the reaction of the opener to the contours of the soil to be monitored.

Data logger The data logger consisted of a Travellogger (Dianachart Inc., Rockaway, NJ) and a Toshiba 1200 microcomputer with 1 Mbyte of memory and a 20 Mbyte hard drive operating under DOS 2.3. The Travellogger was a 14 channel data acquisition unit. It measured 14 inputs either single ended or differential channels and had 10 digital inputs and 10 outputs. On board strain gage excitation and multiple output voltages were available. An input for manually triggering the start and stop points of acquisition was also available.

The Toshiba microcomputer controlled the Travellogger through its printer port. DOS compatible software (Acquisitor, Diannachart Inc.) was used for programming of the data acquisition unit. The software allowed the collected data to be sent to the screen for viewing after acquisition. The software could operate in two modes, real time where data could be viewed as they were sampled or high speed mode where data were immediately stored in RAM. In high speed mode, data were stored in binary format, then transferred to a permanent storage media.

The data could be converted to ASCII files for subsequent analysis by electronic spreadsheets. The software had the ability to compensate the data for zero offset and convert the data to appropriate engineering units.

Conditioning circuit The conditioning circuits were mounted on the tool carrier in a separate instrument box. The circuits consisted of two Analog Devices-1B31 signal conditioning amplifiers (Analog Devices, Norwood, MA) and an isolated power supply of 15 V.

The strain gage conditioner used hybrid circuit technology which encompassed a combination of IC (integrated circuit) and discrete components mounted in a DIP (dual inline package). A minimum of external components was required to facilitate the monitoring of the opener. These components included a precision instrumentation amplifier, an adjustable two-pole, low pass filter, and an adjustable transducer excitation voltage. Gain and zero adjust were also available within the circuitry.

The filter cutoff frequency was set at 10 Hz. This frequency was considered to be above the theoretical maximum range of soil tool interaction frequencies (Siemens et al. 1965). A 10 V excitation voltage in conjunction with the gain adjustment of the amplifier gave an output of 1 V/kN.

The DC/DC converter was an Analog Devices Model 966, which gave an output of 15 V for an input range of 11-13.2 V.

Tool carrier The data acquisition system with isolated mountings was positioned at the rear corner of the single opener tool carrier (Fig. 2). The basic tool carrier was a trailed machine with walking beam axles located outside the

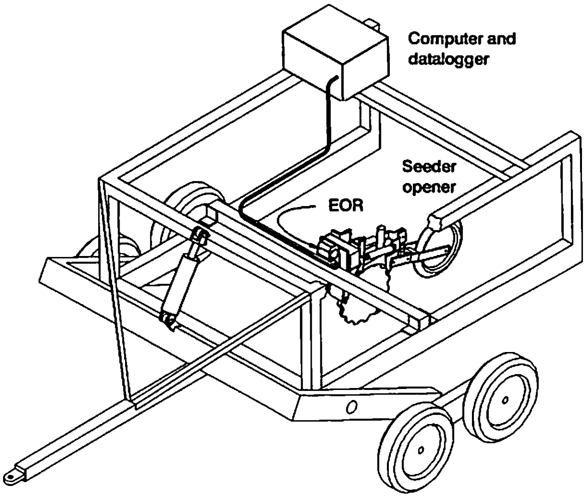

Fig. 2. Double disk opener mounted on tool carrier.

frame which provided a stable operating platform. The height of the platform was controlled by a single hydraulic cylinder located at the front. The opener was bolted to the transducer which was bolted directly to a 100 mm by 100 mm square tube beam running across the tool carrier.

Field study

The seeder opener chosen for the field study was a double disc type with shoe using offset notched 381 mm diameter coulters set at a 7° angle (Fig. 3). Depth setting was carried out by fixing the narrow rounded press wheel at the desired height. This was done by a manual adjustment using a removable pin which was inserted through the control arms of the packer wheel and the seeder body (Fig. 3). Control was theoretically provided by the action of the springs, which would compensate for changes in the soil contour.

The EOR was calibrated by applying a known force in the x and y directions using a system consisting of weights and pulleys. Sensitivity to moments was thus determined by the application of known weight to lever arms attached to the transducer prior to going into the field. It was found to be insensitive to the moments within operating parameters. The EOR was zeroed without the seeder attached. The seeder was then attached and its weight zeroed out. The end of the LDT cable was positioned at the level coinciding with the bottom of the opener and a reading was then taken. This reading was later subtracted from the data to give a zero reference.

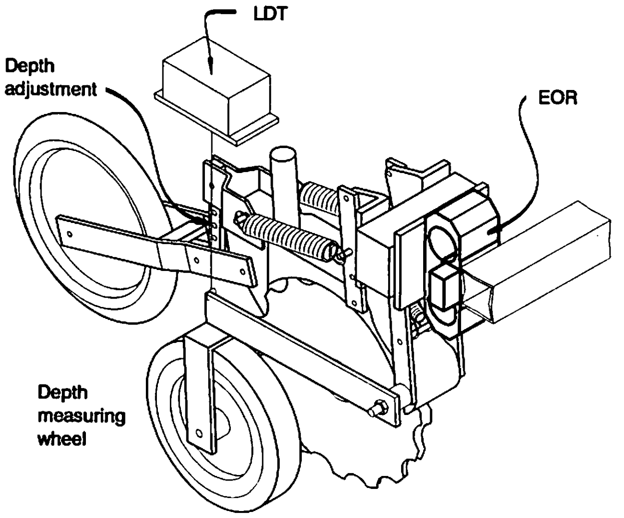

Fig. 3. Double disk opener with octagonal ring transducer and depth transducer mounted.

The experiment was conducted in a Fundy Marine soil at 14.2% moisture content, dry weight basis. The soil type was very homogeneous in nature. It consisted of firm to very firm clay loam to nearly clay. It was fine textured, coarse fragment free, and had a shallow available rooting zone over a dense compact subsoil. It had a bulk density of 1.4 Mg/m^3 (Rees and Fahmy 1984). The field was in sod (Timothy) and had been clipped and raked prior to the experiment. The forces acting on the opener, F_x and F_y, and the depth of the opener were measured for two theoretical seeding depths of 15 and 60 mm. The depth was set by placing a block of wood of the appropriate size on a board under the packing wheel. The depth adjuster was then fixed at the proper setting. The forward speed was held constant at a typical seeding speed of 4.5 km/h during the experiment. The plots were 9 m long and 1.6 m wide. Six randomized replications were utilized in the experiment.

Data were sampled at 77 Hz as suggested by Kocher and Summers (1987). They found that the sampling frequency should be 6-10 times that of the highest frequency in the signal.

Data were smoothed using the Sovitskey-Golay method. This method is based on least squares quartic polynomial fitting across a moving window within the data. It uses point count as its base. The moving window used in this case contained 250 points. Smoothing and regression analysis were performed using Tablecurve (Jandal Scientific, San Rafael, CA) curve fitting software.

RESULTS AND DISCUSSION

Large variations in depth occurred when the opener operated at a depth setting of 15 mm (Fig. 4). Although the depth was set at 15 mm, the measured depth under field conditions tended towards 30 mm (Fig. 5). There was little difference in the actual depth measurement at the 60 mm setting of the opener as compared to the 15 mm setting. This was also observed in similar studies which showed standard deviations of up to 100% in many field situations (Norris 1985). Morrison and Gerik (1985b) found that the rear mounted depth control wheel produced the most inconsistent results, based on plant emergence, compared to front mounted, linked, and side wheels. All the methods of depth control produced poor results.

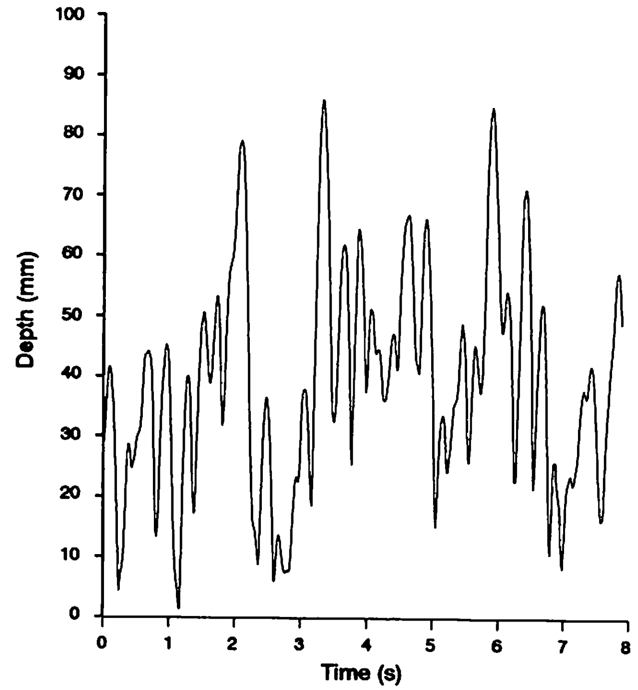

Fig. 4. Depth versus time at 15 mm depth setting.

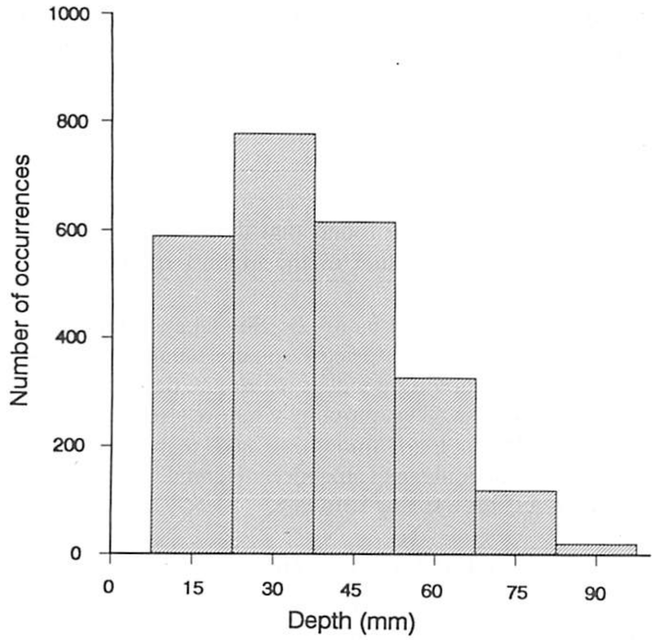

Fig. 5. Distribution of depth of the opener.

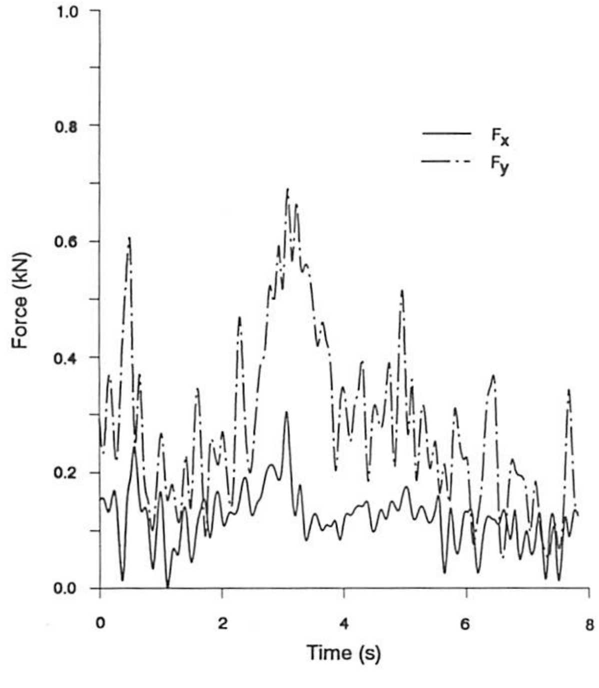

Fig. 6. Opener forces versus time at 15 mm depth setting.

Table I. Regression coefficients

Equation	Constants			R^2	Standard error
	a	b	c		
Draft force	0.15	0.087×10^{-3}	1.64	0.82	0.011
Vertical force	0.26	0.027×10^{-3}	1.10	0.86	0.028

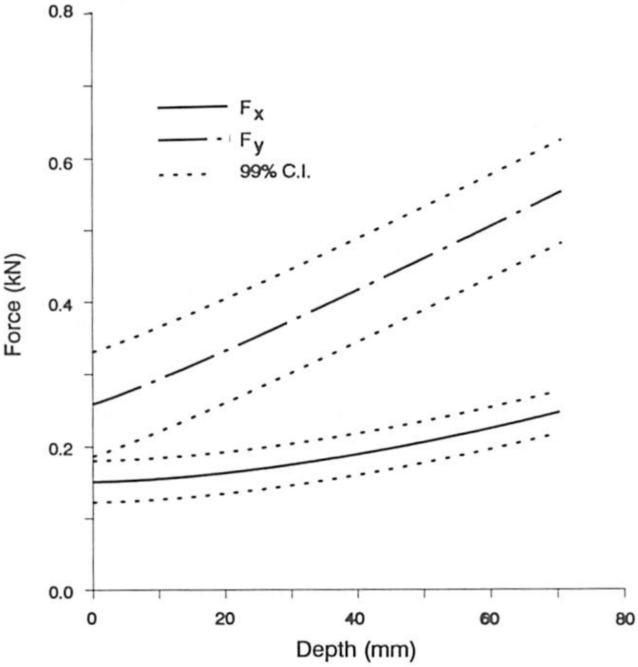

Fig. 7. Predicted forces acting on opener

The magnitude of the forces in the x and y directions with respect to time of the opener set at 15 mm are presented in Fig. 6. Considerable variation was observed in both F_y and F_x,; however, F_y tended to vary more than F_x. The standard deviations for F_x and F_y were determined to be ± 0.026 kN and ± 0.075 kN, respectively. Variations in the depth of the opener appeared to be influenced by the deviation in the uniformity of the soil surface profile. The opener was unable to respond to the changes in the surface profile.

Based on static laboratory tests comparing down forces on no-till drills, Gray and MacIntyre (1983) developed an exponential relationship between force versus depth. Using this non-linear relationship, coefficients were derived from the regression analysis which expressed the forces in the x and y directions as a non-linear function of depth. Data collected at the depth settings of both 15 and 60 mm were combined for the analysis because the actual operating depths were in the same range due to the large variability of this parameter.

$$F_x = a_x + b_x d^{c_x} \tag{1}$$

$$F_y = a_y + b_y d^{c_y} \tag{2}$$

where:

F_x = force in x-direction, draft (kN),
F_y = force in y-direction, vertical (kN),
d = depth of opener (mm), and
$a_x, b_x, a_y, b_y, c_x, c_y$ = regression coefficients.

The regression constants and statistical parameters are presented in Table I. Figure 7 shows the result of the regression. Tice and Hendrick (1991), in a soil bin study of disk coulter operating characteristics versus depth, found that the vertical force and draft increased in a similar fashion.

The results from this study and in previous laboratory and field tests suggest that better mechanisms to control the depth of the opener need to be developed. Using the relationship developed between down-force, draft, and depth, an electronic based control system could be realized to improve depth control.

CONCLUSIONS

The micro-computer based instrumentation system functioned well under field conditions. The forces acting on the disc opener F_x and F_y and the depth of operation of the opener could be monitored at a frequency of 70 Hz.

Results from the field trials suggest that depth control varies considerably from the theoretical setting. The relationship between depth and force can be described by a non-linear equation (Eqs. 1 and 2).

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