

Simulation of Down Force for No-Till Seeder Using Ultrasonic and Arduino Elements

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ABSTRACT

A simple electronic device, using ultrasonic and Arduino technique, is designed and created as traditional method for measuring and evaluation a process for no-till opener under down force system. The design connected with prototype of helical spring-loaded for un-parallel linkage was verified in laboratory and field conditions. To evaluate the prototype performance, field experiments carried out in sandy loam soil with two different moisture contents of 18% and 28% w.b. at Tractor and Farm Machinery Test and Research Station in Alexandria, Governorate. The results of helical springs were evaluated and calibrated in laboratory. The developed device was experimentally investigated as a function of change in two tractor speeds of 3.0 and 4.0 km/h and three different helical wires diameter of 3.5; 4.5 and 5.5mm. The results indicated that the used electronic device is suitable for estimating the down force related to operating time.

Keywords: ultrasonic, Arduino, no-till, opener, down force.

INTRODUCTION

Successful planting/seeding with no-till equipment depends on specially designed systems that can uniformly places seed inside a heavy residue or into film soil or in moist soil. This target needs a special of up-down forces expended on the furrow opener to make it capable of penetrate the soil at adjusted depth. This up-down force ranges in between 700N to 2300N relative to soil conditions of field (Schaaf *et al.*, 1979). Robert *et al.* (2009) and Gratton *et al.* (2003) developed a mathematical modeling for the design of a no-till opener down force system. They achieved two systems for the replacement of a hydraulically loaded down force system. The first one, is a spring-loaded single linkage and the second is a spring-loaded with parallel linkage. On the other side, they compared the hydraulically loaded parallel linkage with the spring system. They found that the hydraulically loaded parallel linkage approximately 50% smaller changes in down force than that the spring system.

A prototype punch planter for no-tillage corn is developed to provide different seed spacing. Plant distribution per unit area adjusted by changing planter punch connecting rod (Ismail - 2011). The seed placement of two double disc openers were identified by Janelle *et al.* (1993) under three different down forces (669, 1338, and 2007 N). They reported that the smallest down force resulted in insufficient seeding depth and consequently reduced crop yield. On the other side, increasing down force generally increases seeding depth. Tajudin and Balasubramaniam (1995) judged on five different furrow openers (shoe, wedge, hoe, single disc and double-disc) under up-down forces of 0.0, 78.5, 157.0 and 245.0 N by adding dead mass on helical spring. They found that the single-disc furrow openers gave the best performance index mainly due to lower unit draught, i.e. draught per unit area of furrow. Wedge-type openers required the maximum power. Double-disc openers had lower unit draught but the performance index of the opener was affected due to poor penetration. While, Troger *et al.* (2012) indicated that the six different types of hoe furrow opener in direct seeding. They determined low of down forces in narrow furrow openers and high down forces in wide furrow openers. Down forces per openers of furrow were 749, 845, 660, 661, 555 and 477 N in the study. While, Ismail (2015) investigate a seeder equipped with

seeds delivery mechanism depending on an oscillating motivation unit was constructed and tested under indoor experiments. The main components of investigated prototype are; seeds delivery mechanism equipped with oscillating unit, metering device and mobile trolley as power unit.

Karayel and Šarauskis (2011) reported that the optimal conditions to get good seeds germination are the seeds should be placed at a uniform depth, with good seed-to-soil contact, and with uniform seed, spacing but they not explain how to do that? But, Hanna (2009) reported that when planting in wet soil the amount of down force applied can become problematic. Similar to planting in firm soils, if too much pressure is applied when planting in wet soils it can create compaction problems that will adversely impact root structure as the roots attempt to grow into the compacted soil. It is essential to find the right balance of pressure to provide adequate seed to soil contact, but without causing over-compaction. In report of Adam (2013) about why is down force a big deal? He explain that, much down force mean that seed trench compaction consequently, seedling can't push up through the soil, soil dries out and opens up drying out the seed and also, roots cannot grow out into the soil to take up water and nutrients. While, the correct amount of down force is equal optimum planting. However, little down force mean that shallow planted seed i.e. seed not planted at proper depth consequently improper seed trench closure; inadequate soil moisture prevents seed from growing and poor root development.

A little work has been done to determine the optimum down-force for different furrows opener design. In addition, there is no suitable technique available for measuring the down force or drill depth especially on open fields.

Therefore, the specific objectives of this research were to:

- Construct a simple and effortless device for measuring and recording the displacement of helical spring that connects with furrow opener mechanism,
- Calibrate the displacement of helical spring to up-down forces,
- Evaluate three types of helical spring under two travel speeds of seed drill.

MATERIALS AND METHODS

Field experiments were carried out at Tractor and Farm Machinery Testing and Research Station, Sabahia, Alexandria Governorate, Egypt in (2016). The specification of soil was found as a uniform sandy loam texture (47.11% sand, 30.14% silt and 21.55% clay). Moreover, the organic matter percentage in the soil was 1.2%.

Seeder specification

The local industrial seeder as a direct seeding machine was constructed in small workshop with technical dimensions of 3460mm; 1450mm, 1700mm

and 100 kg for length, width, height and net mass respectively.

The seeder is connected with three point hitch on hydraulic system of Romanik 35 HP (26.1 kW) tractor. The shoe furrow openers of seeder connected with the spring-loaded single linkage as shown in Fig. (1). Three different spring are connected with vertical single link. Inside the helical spring, the vertical shaft is located. The free side of shaft connected with the show furrow opener by special connection. While, the other side of shaft connected with the fixed guide along the seeded breadth.



Fig. 1. Preparing the seeder to operate in field

Designation of system evaluation

Mainly, the system as shown in Fig. (2) collects of Arduino UNO processor, an ultrasonic distance sensor and an LCD display shield with a keypad for Arduino.

- Arduino-UNO board is based on an Atmel 8-bit AVR microcontroller, mostly running by a 16 MHz crystal oscillator. The board contains a 5V regulator, and many peripheral parts and a microcontroller with a self-programming pre-loaded code. The Arduino-UNO boards, a USB interface is available through a RS232-USB converter on the board. From total 20 i/o pins, 6 of them may be used for analog input as well as digital i/o. Another 6 pins can generate pulse-width-modulated (PWM) output as well as digital i/o. PWM outputs may be converted to an analogue output by only filtering the pulses with an RC filter.
- Ultrasonic ranging module HC-SR04 provides 2.0 – 400.0 cm non-contact measurement function, the ranging accuracy of 3mm. The basic principle of work are using "IO" trigger for at least 10 US high level signal, the module automatically sent 8 cycles at 40 kHz and detects is a signal pulse back and if the signal back, through high level, time of high output "IO" duration is the time from sending ultrasonic to returning.
- The wire connecting as 5V supply, Trigger Pulse Input,

Echo Pulse Output and 0V Ground.

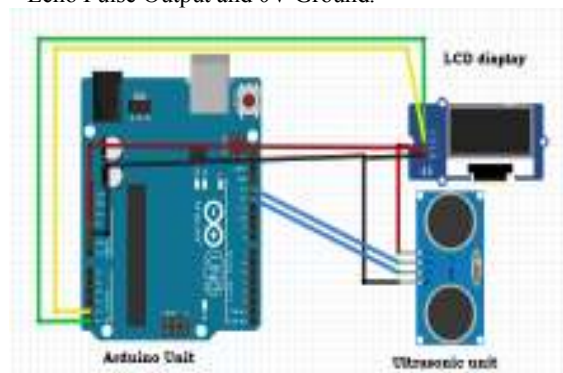


Fig. 2. The electronic device

- The electrical parameter as working voltage, current, frequency, max. range, min. range, measuring angle, trigger in-put signal; echo out-put signal were DC 5 V; 15mA; 40kHz; 4.0m; 2.0cm; `5 degree; 10µs TTL pulse and input TTL lever signal and the range in proportion respectively.
- Arduino software, IDE code is called a "sketch". The code editor has advanced features such as syntax highlighting, automatic indentation, brace matching. Arduino IDE codes are written in C or C++. Many library

routines come with "Wiring" library, which are written before the development of Arduino IDE. A program that runs in an endless loop is constructed by two functions: setup (), and loop ().

Building of measuring system

- Once, the Arduino board installs with the ultra-sonic sensor, sensor trig pin is connected to Arduino pin 13, sensor echo pin is connected to Arduino pin 11, Sensor Vcc pin is connected to Arduino pin 5v, and Sensor GND pin is connected to Arduino pin GND. The system connected with the furrow opener and mother board (Fig. 1) to record spring displacement in field.
- To start measurement, Trig pin of SR04 must receive a 5V pulse for at least 10 μs to start the sensor to generate an ultrasonic burst of 8 cycles at 40 kHz. Sensor measures the reflex time of the reflected ultrasonic burst until it is detected by the receiver. Then, it sends a positive pulse from echo pin for a period proportional to the measured fly time. The distance is calculated using the speed of sound in air, which is known almost 340 m/s. Since the ping travels twice of the distance. Then, d

= T V / 2, where the units of the distance and time shall be meters, and seconds.

- The microcontroller shall be coded with a program to; a) Initialize the ports and shields, b) Start to repeat the following tasks forever by i. Read the flying time T, from the sensor to the disk; ii. Calculate the distance the speed of sound in air, which is 340m/s and iii. Display the distance on LCD module.

The construction was built as shown in Fig. (3) to calibrate the recorded spring displacements of load. Pre experiments were carried out to expect the down force for the three different spring diameters relative to the spring displacement. Fig. (4) is illustrated the spring displacements at different down force. Mostly, the load data from figure is directly proportional with spring displacement at elastic spring stage. The general trend equations identified using excel program as the follow:

$$L_1 = (S_1 - 1.3364)/0.0548 \text{ for wire spring diameter of 3.5mm}$$

$$L_2 = (S_2 - 1.0455)/0.0263 \text{ for wire spring diameter of 4.5mm}$$

$$L_3 = (S_3 - 0.2891)/0.0136 \text{ for wire spring diameter of 5.5mm}$$

Where "L" is the load and "S" is the spring displacement. The above equations were used to identify the actual load from the different spring displacements due to load.

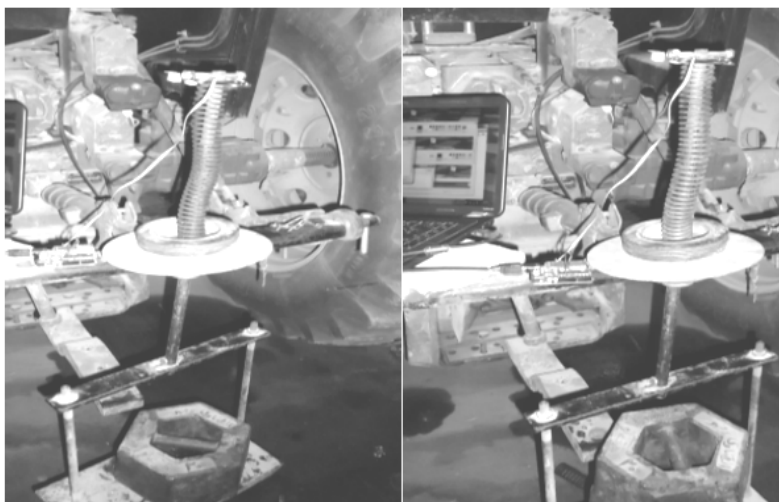


Fig. 3. Calibration of the up-down spring displacement to load

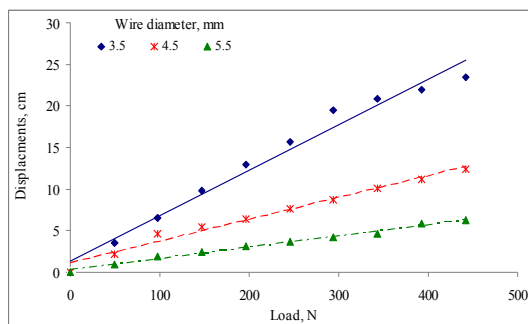


Fig. 4. The spring displacements at different down force.

Three replicates of each variable of study were testes. The variables of the study are two soil moisture contents 18 and 28 %, three wire diameters of spring 3.5, 4.5, and 5.5 mm and two forward speeds 3.0 and 4.0 km/h.

RESULTS AND DISCUSSION

Currently there are three kinds of helical spring under open field were conducted with the seeder to supply up-down forces on furrow opener. Fig. (5) is illustrated the distribution of up-download per operating time for soil MC of 18% (wet bases) under three different spring wires diameter of 3.5; 4.5 and 5.5mm.

Data in Fig. (5-A) indicated that, the values of up-download relative to operating time recorded diverse absolute values ranged in-between 7.07 to 15.77 N with an average of -6.70; -0.34 and -7.30 N for track one, two and three respectively. Also, Fig. (5-A) indicated that the change in relation had no clear trend. For example, at track 1, the values of up-download increasing until operating time of 22 sec after that it trend to decrement until 75sec and then increment with low rate. This phenomenon may be regarding to the soil particle is irregular in shape. On

other side the track, two indicated the homogenies of relation and vice versa for track three.

Regarding to data in Fig. (5-B), the values of up-download relative to operating time recorded values ranged in-between 21.57 ± 5.08 N with an average of 25.12 (SD = ± 5.51); 19.40 (SD = ± 3.94) and 20.21 N (SD = ± 3.79) for track one, two and three respectively for spring diameter of 4.5mm. Data in Fig. (5-C) indicated that the values of up-download relative to operating time ranged in-between -12.43 to 381.24 N with an average of 196.16 (SD = ± 20.61); 201.38 (SD = ± 71.82) and 142.47 N (SD = ± 85.13) for track one, two and three respectively and spring diameters of 5.5mm. The data from Fig. (6) reversed that the alternative direction from the relationship between operating time as independent variable and each of

residuals of calibration spring equation and load. At zero level for calibration of spring equation, the loads acting upon spring recorded -5; 20 and 100N for springs with wire diameter of 3.5; 4.5 and 5.5mm respectively. The negative sign for the spring with 3.5mm diameter indicated that the helical spring loaded under compression state i.e. the seeder push spring to up and vice versa for helical spring with 4.5 and 5.5mm. In addition, the largest number of data lies under zero line of spring calibration for 3.5mm diameter and vice versa for 5.5mm wire spring diameter. At 4.5mm wire of spring diameter, the data of load acting upon the seeder were distributed around the zero equation level. Then under operating speed of 3.0 km/h, it may be recommended using the spring with wire diameter of 4.5mm.

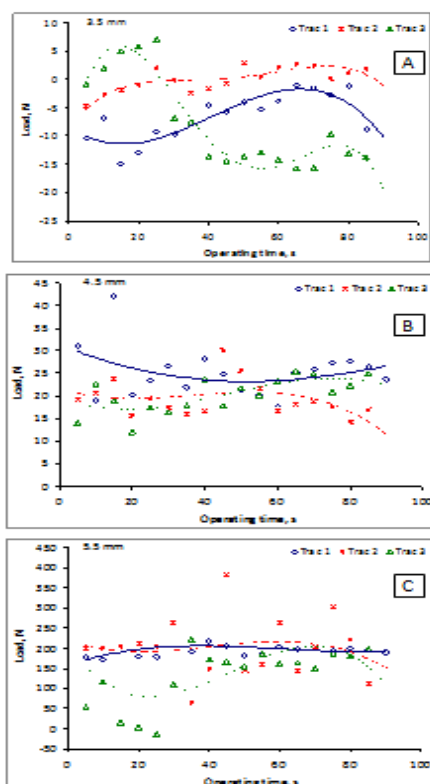


Fig. 5. The up-download values per operating time during traveling speed of 3.0 km/h and different helical spring diameters.

At furrow seeder operating speed of 4.0 km/h, data in Fig. (7-A) indicated that, the values of up-download relative to operating time recorded different values of up-download. These values ranged in-between from 17.87 ± 5.36 N with an average of -17.87 (SD = ± 5.4); -18.15 (SD = ± 8.95) and -8.62 (SD = ± 9.01) N for track one, two and three respectively.

Also, Data indicated that, the change in relation for the spring slowly increased with increases operating time for wire diameter of 3.5mm (Fig. 7-A) and vice versa for wire diameter of 4.5mm (Fig. 7-B) but for 5.5mm wire diameter (Fig. 7-C) the change may be in liner relation with operating time. This phenomenon may be regarding to the helical spring with 5.5mm have ability to keep up-down force in nearly to constant values with operating time.

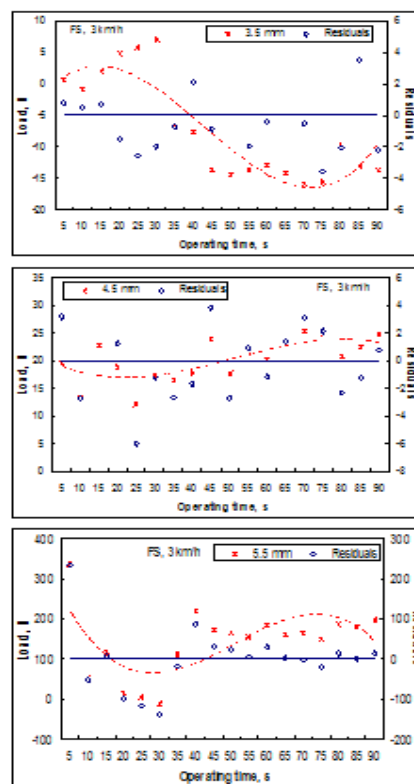


Fig. 6. The up-download values and their residuals of analysis per operating time during traveling speed of 3.0 km/h and different wire diameters

Regarding to data in Fig. (7-B), the values of up-download relative to operating time recorded values ranged in-between 25.12 with SD of ± 5.5 N for an average of 19.01 (SD = ± 5.12); 17.32 (SD = ± 3.94) and 19.11 (SD = ± 11.4) N for track one, two and three respectively at spring diameter of 4.5mm. Also, Data in Fig. (7-C) indicated that the values of up-download relative to operating time ranged in-between -12.43 to 381.24 N with an average of 192.34 (SD = ± 17.23); 174.21 (SD = ± 71.82) and 173.99 (SD = ± 85.13) N for track one, two and three respectively for spring diameters of 5.5mm.

The data from Fig. (8) reversed that the alternative direction from the relationship between operating time as independent variable and each of residuals of celebration spring equation and load. At zero level for celebration of

spring equation, the loads acting upon spring recorded -5; 20 and 170N for springs with wire diameter of 3.5; 4.5 and 5.5mm respectively. The negative sign for the spring with 3.5mm diameter indicated that the helical spring loaded under compression state i.e. the seeder push spring to up and vice versa for helical spring with 4.5 and 5.5mm. In addition, the largest number of data lies under zero line of spring

celebration for 3.5mm diameter and vice versa for 5.5mm wire spring diameter. At 5.5mm wire of spring diameter, the data of load acting upon the seeder were distributed around the zero equation level. Then under operating speed of 4.0 km/h, it may be recommended using the spring with wire diameter of 5.5mm.

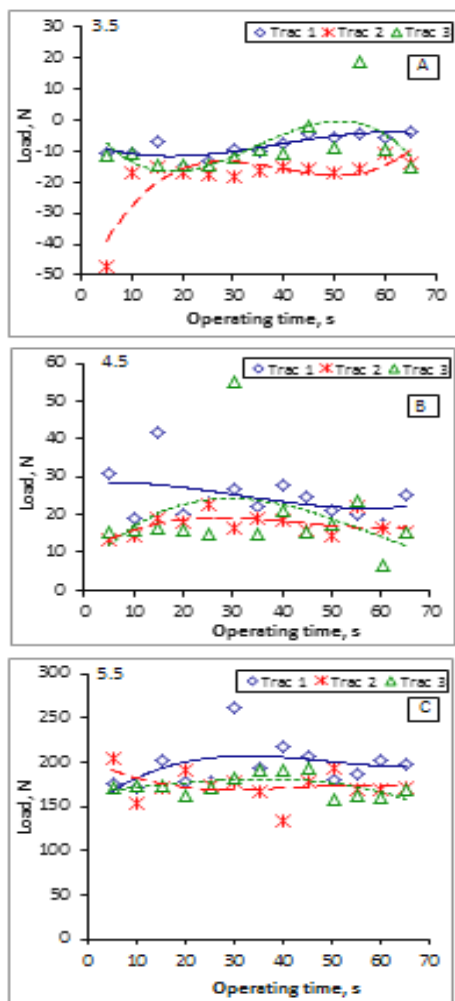


Fig. 7. The up-download values per operating time during traveling speed of 4.0 km/h and different helical spring diameters.

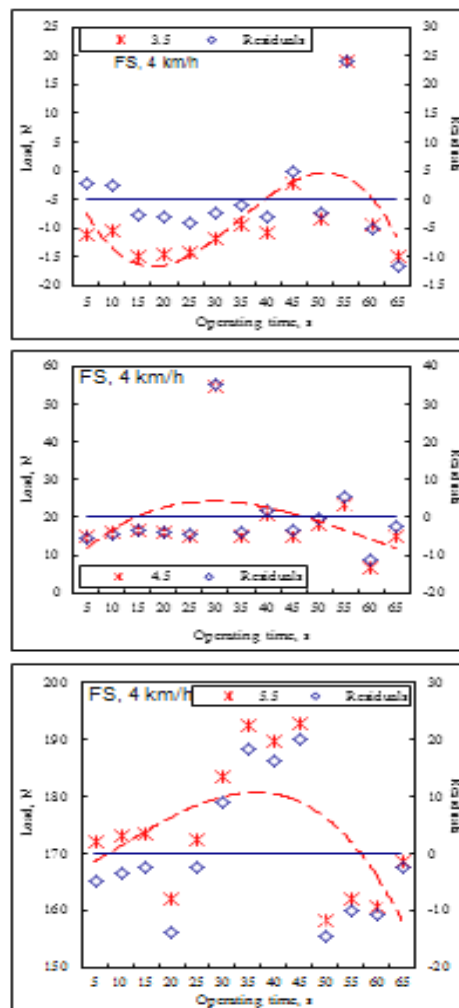


Fig. 8. The up-download values and their residuals of analysis per operating time during traveling speed of 4.0 km/h and different wire diameters.

CONCLUSION

From the experiments, it can be concluded that the strongest effect of the spring pressure was at use 5.5 mm wire diameter for different forward speeds and soil moisture contents under study. The results indicated that the electronic device is suitable for estimating the change in spring deflection related to pressure upon seeder furrow opener during acting. Therefore, it is recommended to apply this device in different agricultural machines to measure the extent of change in spring deflection during movement.

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محاكاة القوة الضاغطة للسطارة عند اللاحرث باستخدام الموجات فوق الصوتية والأردوينو "Arduino"

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تم تصميم جهاز إلكتروني بسيط باستخدام دائرة أردوينو "Arduino" والموجات فوق الصوتية لقياس وتقييم الحركة الضاغطة لفاتح الخط لآلة التسطير التقليدية عند اللاحرث. تم توصيل الجهاز بنموذج الأولي لضاغط يابى آلة الزراعة بتجهيزة خاصة. ولتقييم أداء النموذج الأولي تم معايرته معملياً لتحديد التغير فى طول الياى عند الأحمال المختلفة. ثم تجربة جهاز القياس بعد تركيبه على آلة الزراعة حقلياً عند متغيرات رطوبة التربة ١٨، ٢٨% وقطر سلك الياى ٣,٥، ٤,٥، ٥,٥ مم وسرعة التقدم ٣,٠، ٤,٠، ٥,٠ كم/ساعة فى أرض رملية طميية بمحطة بحوث إختبار الجرارات والآلات الزراعية بالصباحية، محافظة الأسكندرية. نتج من التجارب أن التأثير الأقوى لضغط الياى ظهر مع استخدام الياى نو قطر سلك ٥,٥ مم عند سرعات التقدم ونسب رطوبة التربة تحت الدراسة. وقد أشارت النتائج إلى أن الجهاز الإلكتروني المستخدم مناسب لتقدير التغير فى طول الياى كمدلول للقوة الضاغطة على فاتح الخط خلال فترات التشغيل. لذا وينصح بتطبيقها فى الآلات الزراعية المختلفة لقياس مدى التغير فى الإرتفاع أثناء الحركة.