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Development of Electronically Meterized Maize Planter

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A B S T R A C T

A seed metering mechanism of conventional precision planters are usually driven by ground wheel with chain and sprocket system and these mechanisms are of mechanical type. They are less efficient as there is a number of losses while transmitting the power. Due to continuous friction between moving parts, these devices are subjected to wear and tear; hence they require frequent maintenance. To improve the planting performance of precision planters, the best substitute is to develop an electronic meterized planter for maize. The design and development of electronic meterized planter includes main frame, hopper, metering unit, furrow opener etc. The speed synchronization between ground wheel and metering unit is vital at it has been taken care by electronically.

Introduction

Modernization of agriculture necessitates appropriate machinery for enhancing resource use efficiency and productivity in agriculture. The more precise the planting operation, the better the quality and quantity of crop harvested (Ebrahim, 2008). The objective of planter in agriculture is to place the seeds at a desired depth, rate and spacing within the row. Precision planting reduces seed scattering and excessive use of seeds due to uniform distribution of seeds and by preventing seed from bouncing in the furrow (Domier, 1991).

Currently, there are various types of planters which have different types of seed metering mechanisms which are driven by attached with ground wheel; these mechanisms are of mechanical type and they use drive through gears, chains or belts from the ground wheel and they are less efficient as there exist number of losses while transmitting the power. Due to continuous friction between moving parts, these devices are subjected to wear and tear; hence they require frequent maintenance. To eliminate the above challenges as well as to increase precision of seed metering mechanism for a better crop productivity, it is necessary to use identify a electronic meterized planter and attempt was made to use employ electronics for the purpose.

Singh *et al.,* (2004) developed an electronically controlled metering mechanism for okra seed. Li *et al.,* (2007) adapted stepper motor to drive seed meter and developed a control system based on Intel 8031 to control the planting process. Kocher *et al.,* (1998) and Lan *et al.,* (1999) developed an opto-electronic seed spacing evaluation systems that measure time intervals between the seeds and detect from the front to back location of seed spacing uniformity in the laboratory condition. The data obtained based on time intervals between seed drop were strongly correlated with the measurements obtained using greased belt test rig. Raheman and Singh (2003) developed a sensor based light interference technique for sensing the seed flow from the metering mechanism of seed drill and planter.

Materials and Methods

Development of the prototype of electronic meterized planter for maize

Construction details of electronic meterized planter for maize

A tractor drawn electronic meterized planter for maize was developed based on the optimized levels of variables for selected maize variety. The schematic drawing of the prototype of electronic meterized planter for maize using solid works software is depicted in figure 1. It consisted of main frame, seed hopper, electronic seed metering unit, furrow opener and ground wheel (Fig. 2).

Main frame

The main frame of (800 x 450 x 40 mm) was fabricated using mild steel square sections of 80 x 40 x 2.5 mm. The seed hopper with metering roll and seed delivery box was mounted on the main frame. Three point hitch assembly was provided in the front of the main frame so as to hitch the unit with the tractor. Ground wheel is mounted in front of the main frame. Two mild steel hollow square sections of 20 x 20 with bushes are provided on the main frame to mount the rotary encoder for speed synchronization.

Hopper

The seed hopper is design with volume of 3825.8 cm^3 and enough capacity to carry the sufficient quantity of seed during field operation of area 0.63 ha. The slope of the hopper was fixed at 30^o, which is higher than the average angle of repose of the maize seed. The inverted pyramid shape seed hopper was fabricated by using 2.5 mm mild steel sheet. The top length and height of hopper was 250 x 270 mm and bottom width was 30 mm.

Metering unit and components

The metering unit consists of metering roll, seed delivery box, proximity sensor which is used to detect the seed flow from the hopper, solenoid valve which is used to actuate the metering plate, 12 V DC stepper motor which is used to drive the metering roll, and encoder which is used to synchronize the speed between ground wheel and metering shaft. A metering roll was punched to make a hole with 12 mm cell size on nylon rod. Seed delivery box is fabricated with acrylic sheet with dimension of 100 x 30 x 70 mm to avoid friction during operation (Fig. 3, 4, 7 and 8).

Furrow opener and covering device

A shoe type furrow opener fitted on the main frame in the front portion of the seed metering unit opens the furrow. The seeds dropped from the seed delivery plate fall freely due to gravity through seed tube behind on the furrow opened by the furrow opener.

Ground wheel

A 50 mm wide mild steel rod was rolled to a circle of diameter 450 mm to make a ground wheel. 12 numbers of lugs (60 x 50 x 5 mm) were welded at equidistant on the circumference of ground wheel to prevent from slippage during the operation.

Design of the electronic metering unit

The planters which have different types of seed metering mechanisms transmit the power from ground wheel to metering mechanism mechanically. It is difficult to achieve 100 % precision and efficiency of mechanical system of transmission which overcome the above problem; the electronic sensors are employed to correlate the singulation of seed with electronic metering mechanism.

Control system

The control system for the electronic metering mechanism consisted of six components: Stepper motor and its driver module, encoder (forward speed sensor), proximity sensor, solenoid and microcontroller.

Motor and driver module

1.5 N-m stepper motor was selected based on the torque requirement for mechanism was selected from the previous researches with rotational movements of ground wheel.

The rotation of the metering roll was driven with 12 V DC stepper motor instead of driving with chain and sprocket system from the ground wheel. The electric power (12V, 150 Ah) available at tractor was utilized to operate a stepper motor.

Sensor of forward speed

A sensor of forward speed is used to correlate the rotational speed of metering roll with ground wheel an encoder(RPG-100P) and a decoder were located on the ground wheel as shown in figure 2 and 4.

Proximity sensor

A proximity sensor is an electronic sensor that can detect the presence of objects within its vicinity without any actual or physical contact. In order to sense objects, the proximity sensor radiates or emits a beam of electromagnetic radiation, in the form of infrared light and senses the reflection in order to determine the object's proximity or distance from the sensor. For the metering unit an inductive type proximity sensor was used with the nominal range of the 250 mm.

Solenoid linear actuator

The Solenoid converts electrical energy to mechanical energy. Linear solenoid consists of an electrical coil wound around a cylindrical tube with a Ferro-magnetic actuator or plunger that is free to move in and out of the coil body. A 220 V AC linear solenoid with stroke length 15 mm to punch a seed from the metering roll and after receiving the signal from the sensor, solenoid is trigger to drop a seed from the seed delivery box to furrow opener. The spring aids in return motion of the slider.

Arduino nano

Arduino Nano is a breadboard embedded with integrated USB. It has a pin layout that works well with the Mini and the Basic Stamp (TX, RX, ATN, and GND on one top, power and ground on the other). The new version 3.0 with ATMEGA328 was used in this research for a communication with other controllers and computers. The communication is carried out by the digital pins like pin 0 (Rx) and pin 1 (Tx) where Rx is used for receiving data and Tx is used for the transmission of data. The serial monitor is added on the Arduino Software which is used to transmit textual data to or from the board (Fig. 5 and 6).

Electronic seed metering mechanism

The metering seed metering mechanism consists of the hopper with metering roll, seed delivery box, proximity sensor, solenoid valve. The proximity sensor senses the seed from the hopper through an optical beam. A ray of light transmitted from source was collected by a photo transistor mounted perpendicular to the direction of seed flow from the hopper. Sensors are always in closed circuit mode, whenever seed drops, the circuit breaks and internal transistor is triggered and pulses are generated (Fig. 7). The generated pulses are amplified to desired level and fed to microcontroller Integrated Circuit through optically isolated digital I/O ports, by using relay switch the solenoid is triggered linearly to actuate the seed. An interrupted flag is generated inside the microcontroller for every generated pulse due to seed drop. A program which runs inside the microcontroller actuates the solenoid and stores in the memory.

Speed synchronization technique between ground wheel and metering roll

The speed synchronization technique was designed based on the electronic control unit. Optical driving wheel sensor (encoder) was used to measure the movement of the ground wheel. The series of pulses generated from the sensors are captured by the microcontroller (electronic controller unit).

These pulses are computed to get the total distance covered and the travel speed information. Based on the travel speed information, speed of the stepper motor which drives the metering roll is synchronized to drop the seeds. The speed synchronization can be achieved by precisely controlling the input of the high current drive circuits through PWM (Pulse Width Modulation) channel of microcontroller (Fig. 9).

Performance analysis of metering mechanism

The uniformity in sowing and seed distribution along the length of the row was analyzed using the methods described by (Kachman and Smith, 1995). The performance measure based on theoretical spacing, multiple index, miss index quality of feed index and precision in sowing seems to be a proper method of summarizing distribution of plant spacing for precision planters (Kachman and Smith, 1995). The parameters for evaluation of performance of planter include mean spacing and standard deviation of spacing between seeds (Parish and Bracy 1998).

Missing-seeding index (MI) is the percentage of seed spacings that are greater than 1.5 times the nominal seed spacing and indicates the percentage of missed seed locations or skips. Quality of feeding index (QFI) is the percentage of seed spacing that is more than half but no more than 1.5 times the nominal spacing and indicates the percentages of single seed drops. Precision is the coefficient of variation of the spacing (length) between the nearest seeds in a row that are classified as singles after omitting the outliers consisting of missing-seeding and multiples. The calculation formulas for MI, QFI are as follows

Miss index $I_{miss} = \frac{n_1}{N}$

Multiple index (I_{mult}) $I_{mult} = \frac{n_2}{N}$

Quality of feed index $I_{QFI} = 100 - (I_{miss} + I_{multi})$

Precision in spacing (I_p) $I_p = \frac{S_d}{S}$

Where

n_1 is number of spacing >1.5S,
n_2 is number of spacing $\leq$ 0.5S

N is total number of measured spacing
I_{QFI} is percentage of quality of feed index
S_d is standard deviation of the spacing more than half but not more than 1.5 times the set spacing S in mm

Results and Discussion

Uniformity of plant spacing

Plant spacing distribution in the field, is shown in figures 10. A 94.75 percentage was observed during evaluation which is within acceptable plant spacing (quality feed index). There was no variation between row to row spacing recorded in the field test and very closer result for recommended plant to plant spacing was obtained. There was no significant difference in average plant to plant spacing between row and is shown in Table 1. The seed spacing observed under field conditions varied from 24.6 to 27 cm for maize.

Table.1 Analysis of Variance for seed spacing of maize crop at 1.5km h^{-1} forward speed of operation in the field

Source of variation	df	MS	F-Value
Row	3	1.89	0.94(NS)
Error	17	3.17	
Total	20		
CV %	0.80		

NS: Not significant at 5% probability level

Fig.1 Schematic drawing of electronic meterized planter

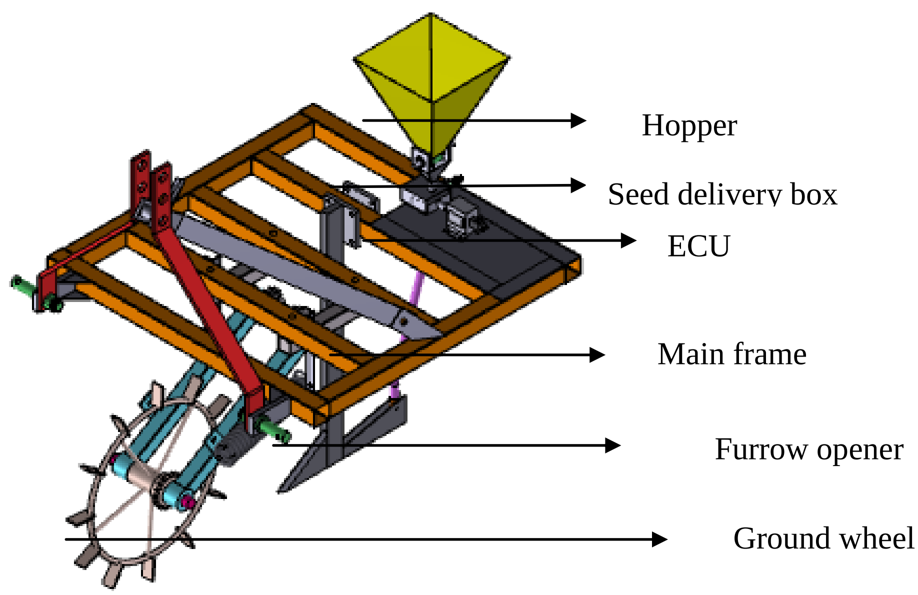
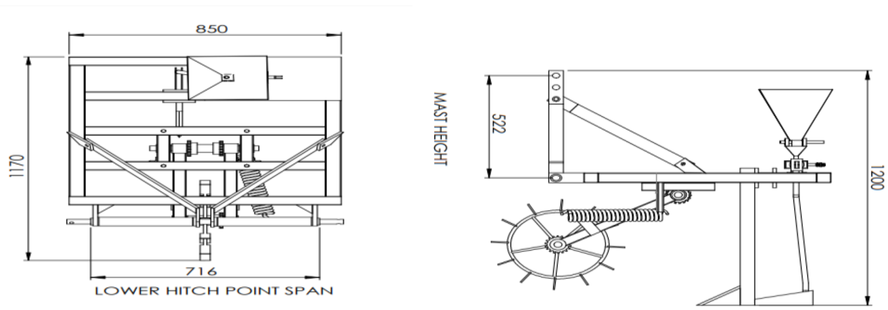


Fig.2 Top and side view of electronic planter



All dimensions in mm

Fig.3 Stepper motor and its driver module

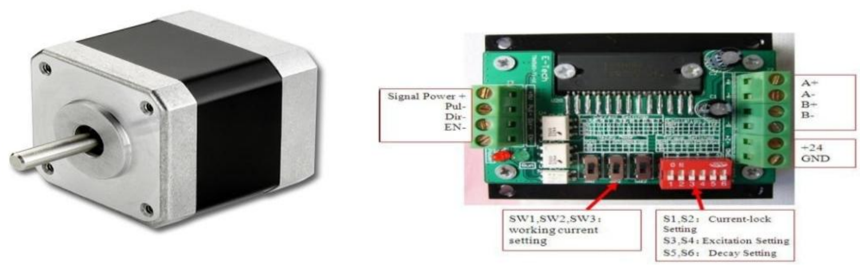


Fig.4 Encoder fitted on ground wheel

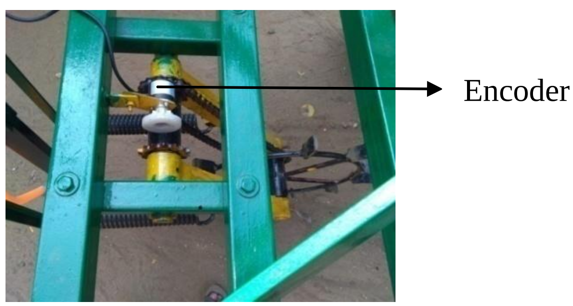


Fig.5 Aurdino nano

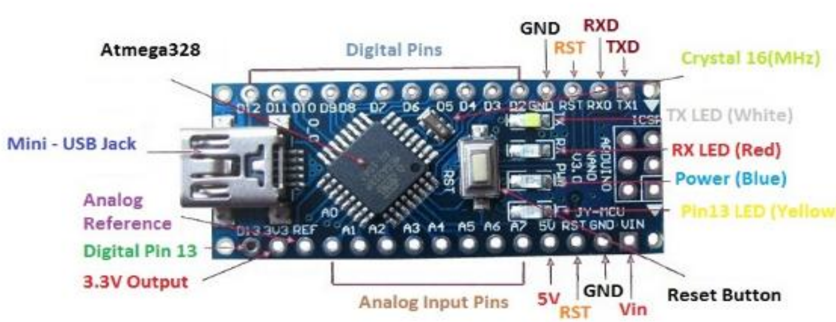


Fig.6 Aurdino nano connection with USB

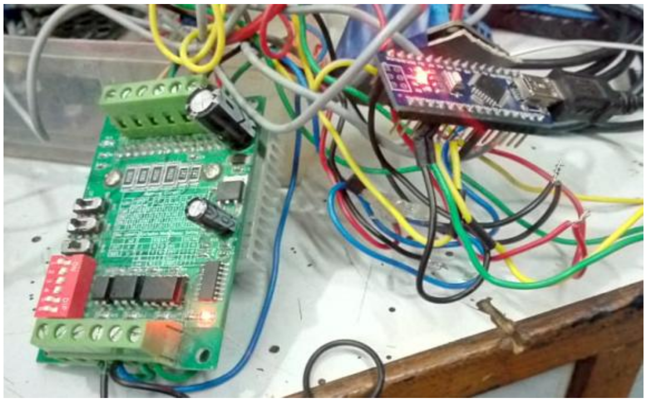


Fig.7 Electronic metering unit

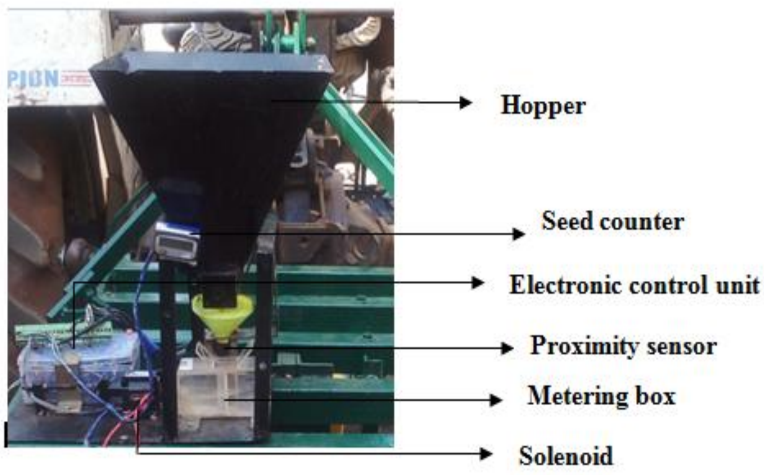


Fig.8 Flow diagram of electronic metering unit

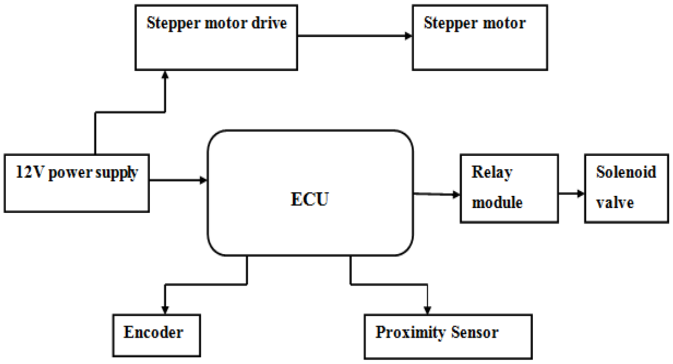


Fig.9 Controlling stepper motor using rotary encoder: circuit connection

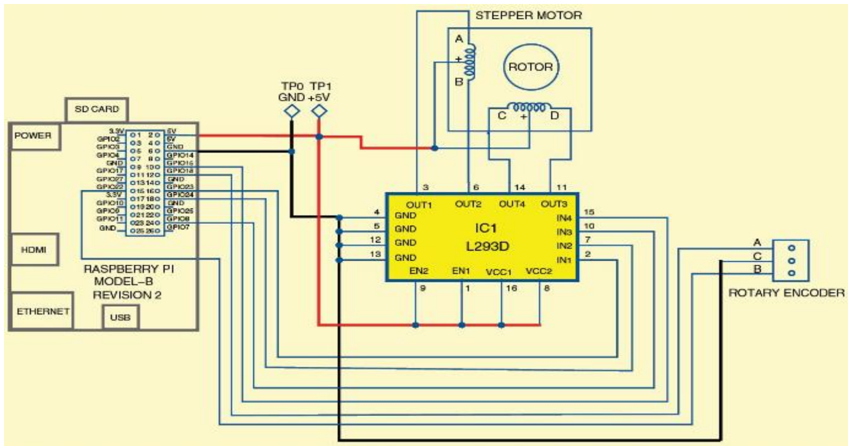
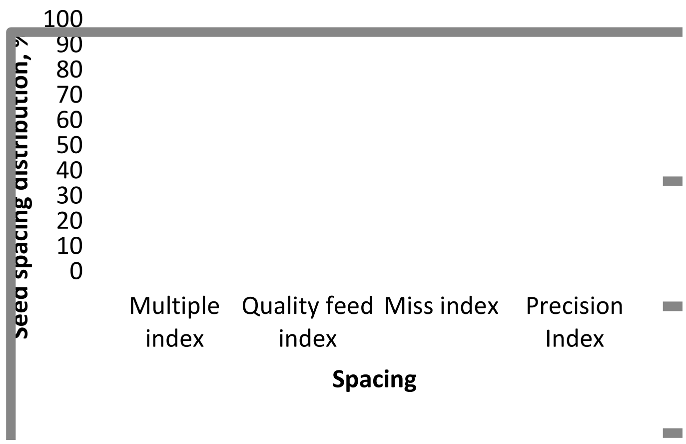


Fig.10 Performance indices for sowing maize crop at a speed of operation of 1.5 km/ hr during the field test



In conclusion, a practical solution to improve the performance of precision maize planter by using electronic metering system for seed meter instead of using ground wheel and chain sprocket driving system was outlined.

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