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AN UNMANNED AGRICULTURAL VEHICLE FOR PRECISION PLANTER USING MECHATRONIC TECHNOLOGY

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ABSTRACT

The precision planting operation involves placing seeds in rows at the desired depth, maintaining consistent seed-to-seed spacing, covering them with soil, and ensuring proper compaction for optimal crop production. The evaluation of the mechatronic metering mechanism assessed performance parameters and the viability of using a remotely operated agricultural field vehicle. For cotton crops, the optimized combination led to the following dependent variables: average seed spacing of 44.95 cm, miss index of 3.72%, multiple indices of 7.06%, quality of feed index of 89.92%, cell fill percentage of 103.01% and seed rate of 1.5 kg/ha. The centre of gravity of unmanned vehicle was 230 mm forward from the rear axle on flat ground and 199 mm forward when lifted 21° from the ground surface. The turning radius was 1490 mm. economically, the average operating cost was ` 156 per hour, with a payback period of 1.77 years and a B-C ratio of 5.63.

Key words : Cotton, Mechatronics, Planting, Precision, Unmanned

Introduction

Farm mechanization has long been known to provide a number of economic and social advantages to farmers. The most important of the economic benefits is the enhanced yield that comes as a result of increased mechanization. Combination of mechanical linkage or systems replacing by some electronic components it's become mechanical + Electronics = Mechatronics. Linear actuator is best example of mechatronics in term of combination of electronic and mechanical. In linear actuator no need to any hydraulic link, distributor, oil tank, hydraulic pump. In some cases, it's given better than the hydraulic control actuating devices. If we use mechatronics technologies into agriculture sector there have helpful in controlling system and compactness in whole mechanism. Precision seeding is a seeding technique being used agriculture that involves sowing seeds at precise spacing and depth. This differs from broadcast seeding, in which the seed is dispersed over a large region. Although accurate hand placement qualifies, precision seeding is more commonly associated with a mechanized procedure. For modest to large-scale projects, a variety of hand-push and motorized precision seeders are available. They all open the soil, deposit the seed, and then cover it to form rows, using a variety of methods. Precision seeders are also available for planting flats of seeds for indoor seed beginning. The depth and spacing can be adjusted to meet a variety of crops and plant densities; the degree of flexibility varies depending on the seeder used.

Material and Methods

Concept of Electronic Seed Metering Mechanism with Vehicle

This system is divided into mainly two sections (i) electronic seed metering system and (ii) vehicle control system. The electronic seed metering system consists Arduino Mega 2560 microcontroller board, 360 PPR Incremental optical rotary encoder, NEMA17 4.4 kg-cm stepper motor and A3967 Stepper Motor Driver. For vehicle, MY1016Z3 24 volt, 350 W DC geared motor, 100 mm stroke length DC linear actuator with 1500 N static load, MDDS30 Cytron smart drive 2-channel, MDDSRC-10 Cytron smart drive with 2- channel, fly-sky fs-I6-M2 2.4 GHz 6-channel receiver and transmitter and voltage regulator. A rotary encoder is mounted with a sensing wheel shaft and transmitted a signal to the microcontroller system. The rotary encoder has a 360 PPR (pulse per revolution) and a stepper motor of 400 steps/revolution (0.9°). Rotary encoder direction and step pin connected digital pins 2 and 3 of Arduino Mega 2560. A3967 stepper motor driver connected through direction and step pin to digital pins 4 and 5 respectively. The rotary encoder gave a continuous signal to a stepper motor. When rotary encoder completes 360 pulses at the same time stepper motor also completes its 400 steps. The sensing wheel was fabricated in such a way that a complete revolution of the sensing wheel gives 360 steps of a rotary encoder. Arduino IDE was a programming environment that allows the user to draft different kinds of programs and load them into the Arduino microcontroller. Arduino uses a user-friendly programming language, which was based on a programming language called processing. After the user has written his code, IDE compiles and translates the code to the assembler language. After translating the code, the IDE uploads the program to the Arduino microcontroller. After testing the program, it was uploaded to the Arduino by USB cable. This electronic seed metering system is fabricated in one frame and mounted with a vehicle frame with telescopic motion with help of a DC linear actuator. When DC linear actuator opens metering unit goes upward direction and DC linear closes. Two MY1016Z3 geared dc motors gave rotational power to the driving wheel through chain and sprocket mechanism. For turning, Ackerman steering was selected. For actuating process of link rod steering, DC linear actuator is used.

The ultimate aim of planting was to maintain the singularity of seeds while placing them precisely at recommended spacing and depth without any missing or seed damage. The seed metering performance of the planter depends on peripheral velocity, inclination of seed metering disc, cell size, number of cells and height of seed dropping (Hunt, 2001; Singh *et al*., 2005; Findura *et al.,* 2008; Sharma and Kumar, 2014; Sahu and Verma, 2016). Forward speed (S), Inclination angle of seed metering plate (A) and Geometry of seed hole on metering plate (P) variables were selected as testing parameters for precision seeding because they play comparatively more significant role in seed placement among the above mentioned.

The experimental setup was prepared in such a way that 9750 mm log and 240 mm wide wooden board with an adhesive strip. Wooden board was fixed and developed planter travel over the wooden board as per shown in Fig. 2. This was also called the mobile test. In which, the sowing/ planting unit should be fixed to a mobile trolley at a constant speed and without jolting over a stationary adhesive strip (ISO 7256/1 -1984).

The sowing uniformity of seed distribution along the length of the row was analyzed using the methods described by Kachman and Smith. Average seed spacing indicates average value of spacing measured between two consecutive seeds in a row. Miss index (MI) is the percentage of seed spacing that are greater than 1.5 times the nominal seed spacing and indicates the percentage of missed seed locations or skips. Multiple index (DI) indicates more than one seed dropped within a desired spacing. It represents the percentage of spacing that are less than or equal to 0.5 times the theoretical spacing. Quality of feeding index (QFI) is the percentage of seed spacing that are more than half but no more than 1.5 times the nominal spacing and indicates the percentages of single seed drops. The calculation formulas for Average seed Spacing, MI, DI, QFI and Seed rate (Gautam, 2017) are as follows:

$$S = \frac{\Sigma S_a}{N} \quad (01)$$

$$MI = \frac{N_M}{N} \quad (02)$$

$$DI = \frac{N_D}{N} \quad (03)$$

$$QFI = \frac{N_Q}{N} \quad (04)$$

$$SR = \frac{N_C \times W}{l \times b} \times 10 \quad (05)$$

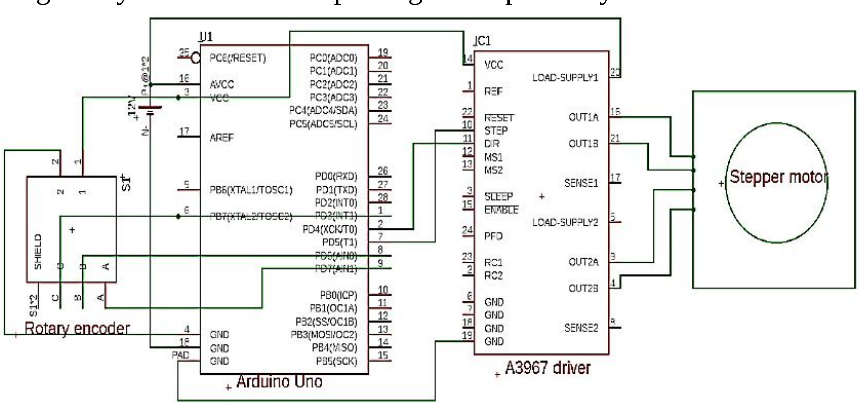

Fig. 1 : Circuit diagram of mechatronic system.

Fig. 2 : Experimental setup for laboratory evaluation of developed planter.

For evaluation of remote-control mechatronic precision planter, speed of operation (S1= 1.5 km/h, S2= 2 km/h and S3 = 2.5 km/h), inclination angle (A1 = 50°, A2 = 55 and A3 = 60) and geometry of seed hole on metering plate (P1 = 100% maximum size seed, P2 = 110% maximum size seed and P3 = 120% maximum size seed) were decided on three level.

Results and Discussion

The maximum length, width and thickness of cotton seeds were observed 9.31, 5.13 and 4.81 mm. The maximum dimensions were considered for designing cells of seed metering plates to obtain a good cell fill percentage. The centre of gravity test was measured using standard procedure using standard code (IS 11859:2004). A weighing scale was used to measure the total weight of the developed planter and the reactions acting on the two wheels. The total weight was 131 kg for the developed planter and reaction force on front wheel was found 34.5 kg on the flat surface. Reaction forces on the front wheel were 31 kg while the developed planter lifted 320 mm from the front axle. Centre of gravity of remote-control mechatronic precision planter was found 230 mm forward from rear axle while planter was on flat ground and 199 mm forward from rear axle while planter was lifted 21° from ground surface. Turning radius of developed planter was determined using a standard procedure. Turing diameter for the developed planter was 1490 mm.

An unmanned agricultural vehicle for precision planter was tested in laboratory as well as in the field. Best results were obtained with 0.55 m/s of forward speed (S2), 50° of inclination angle (A1), and 110 % of the geometry of the seed hole (P2). Average seed spacing and seed rate obtained from laboratory were 44.95 cm and 1.50 kg/ha. Miss index, multiple indices, quality of feed index and cell fill percentage were found 3.72, 7.06, 89.92 and 103.01%, respectively. Recommended spacing for cotton seed was 45 cm and from results of remote-control mechatronic precision planter gave quite satisfactory in terms of average spacing. Graphical representation of different parameters was shown in Fig 3. These findings were in close agreement with the result reported by Kachman and Smith (1995), Singh *et al.* (2016). For the precision planter CV value of seed spacing was less than 10 % was finding by Kachman and Smith (1995).

Field evaluation was carried out in the same manner as laboratory, in terms of the number of treatments and parameters. Different parameters influence field evaluation, such as field condition, planting depth, and germination rate and planter vibration. Combination of 0.55 m/s of forward speed (S2), 55° of inclination angle (A2) and 110% of geometry of seed hole (P2) gave best results. Average seed spacing and seed rate were found 44.92 cm and 1.43 kg/ha respectively. Miss index, multiple indices, quality of feed index and cell fill percentage were found 5.15, 6.10, 88.75 and 100.95%, respectively.

The missing index was increased, whereas multiple index and seed rate were decreased with an increase in forward speed for all inclination angle. Inclination angle of metering plate, 55° with horizontal was observed optimum. Above findings were similar to those published by Kachman and Smith (1995) and Singh *et al*. (2016). It was found that the developed planter performed satisfactorily and its speed and field condition did not affect the performance of the metering system in the laboratory as compared to field evaluation.

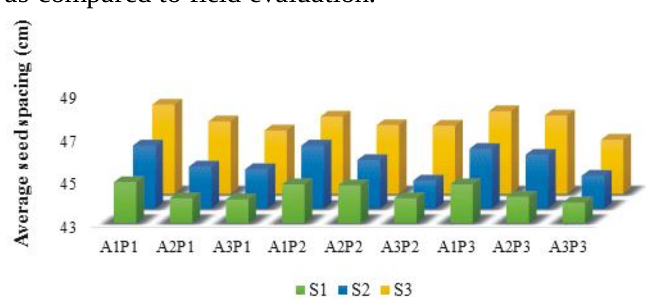

Fig. 3 : Effect of inclination angle, geometry of seed hole and forward speed on the average spacing of cotton seed.

Conclusion

Total power requirement for planter is 525.71-watt, battery run time for remote control mechatronic precision planter is 2.16 hr at full load and turning radius was found 1490 mm when planter moving at a speed of 2 km/h. Centre of gravity of remote-control mechatronics precision planter was found 230 mm forward from rear axle while planter was on a flat ground and 199 mm forward from rear axle while planter was lifted at 21° from ground surface. average seed spacing, miss index, multiple indices, quality of feed index, cell fill percentage and seed rate found for cotton crop were 44.95 cm, 3.72%, 7.06%, 89.92%, 103.01% and 1.5 kg/ha respectively in laboratory evaluation. Theoretical capacity, effective capacity, field efficiency and metering efficiency were obtained 0.25 ha/h, 0.19 ha/h, 76.80% and 97.62% respectively and average operating cost, payback period and B-C ratio of remote-control mechatronics precision planter were obtained ` 156 per hour, 1.77 year and 5.63 respectively.

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