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COMPUTER CONTROLLED PLANTING SYSTEM FOR MULCHING CULTIVATION USING POLYETHYLENE FILM

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ABSTRACT

A precision planting system using computer controlled technology for mulching cultivation was developed and tested. The system consisting of a micro-computer, several optical fiber sensors and control actuators realized the mechanization of the precision planting operation. The film hole positions, existences of a seed on shutter were detected and the planting speed was measured. The shutter opening mechanism and a seed metering device driven by a stepping motor were controlled, automatically. The planting timing of the shutter opening mechanism were analyzed from a video camera motion analysis, theoretically. The results showed a sufficient accuracy of a seed planted into the center of a film hole with a variety of planting speeds. The gravity point positions in film hole of seeds planted by the system just were within the area of +-5 mm of the hole center when the hole diameter was 40 mm.

Key words. mulching cultivation, precision planting, mulch seeder.

INTRODUCTION

Mulching cultivation using polyethylene film is very popular in Japan. This is because the mulching cultivation can hasten agricultural products growth quickly and earlier than the normal cultivation to catch the grocery market. Mulching cultivation have many advantages in vegetables production indicated by Hiraoka (1974) as increasing and holding soil temperatures, controlling soil moisture from heat evaporation, restraining weed growth especially suing opaque mulch film, holding soil surface at a good condition and preventing soil loosing away at raining, etc.

'Although many kinds of vegetables such as sweet-corn, peanut, radish, carrot etc. as many as passible are produced by this system in Japan and the utilizations of mulching cultivation increase year by year, but the mechanization of mulching cultivation especially the precision planting operation is difficult to realize because it couldn't be accomplished to plant a seed into the center of a film hole accurately by using the normal planting system.

Main reasons of undevelopment of a planter on mulching cultivation until now were that hole positions for planting on mulching film is fixed, the planting area is limited to the diameter of a film hole which usually is 40 to 60 mm; and the planting speed has to depend on the hole interval distances of mulching film, etc. That means the planting accuracy is the most importance in development of a new planting system for using on mulching cultivation. Therefore, in order to mechanize the planting operation on mulching cultivation, a precision mulch planting system using high technologies would be needed to develop and it have to be different from planting system used on naked field because the hole position have to be detected by a sensitive sensor. At this meaning, it is useful to develop a new planting system applying mechanical and electrical control devices and computer technologies.

PREVIOUS WORK

A good timing was requested for planting a seed precisely into the hole center with continuous holes at regular intervals. In the normal planter, the planting timing usually used to be controlled by mechanical transmission gears and sprockets chains driven from the gauge wheel. In the mulch planter case, the precision planting timing is difficult to get because the timing could not be synchronized with a coming film hole. Thus it is importance to detect the hole position on mulch film and to control the seed drop timing accurately.

Nagata et al (1988) developed a sequential controlled planting system for mulching cultivation which consisting of two optical fiber sensors, a stepping motor, a rod-type shutter opening mechanism and a rotary solenoid. Even if the precision planting timing could be obtained when a film hole was coming at a constant planting speed by using the system. The results of preliminary test indoor and field test showed that the sequential controlled planting system were reported by Nagata and Furuchi (1991). However, the system could not realize the precision planting timing when the planting speed changed with a variety because the shutter opening mechanism only worked depending on the sequential control procedures and the timing previous set early in the design and development of the machine. Another defect of the sequential control planting system was that planting a seed just into the center of a film hole could not be guaranteed because the sequential control algorithm could not be calculated accurately at the real time and the shutter opening mechanism with a rod-type was not the optimum one.

Therefore, a continue study on the planting system using computer controlled technology with a precision shutter opening mechanism of gear-type for mulching cultivation was conducted and reported here.

DEVELOPMENT OF COMPUTER CONTROLLED PLANTING SYSTEM

1. System Design

The computer controlled planting system was composed of four main partial devices that such as a detecting unit, a calculating unit, a controlling unit and a actuating unit which is shown in Fig. 1.

The detecting unit consisted of two optical fiber sensors for detecting the existences of a seed on the shutter and film hole positions, and a rotary encoder for measuring the planting speed. The calculating unit consisted of a micro-computer with several I/O interface and driving circuits. The controlling unit consisted of two relay circuits for driving the rotary solenoid on/off switch and turning the stepping motor. The actuating unit consisted of a shutter opening mechanism of a gear type with a rotary solenoid driving device for planting a seed into the center of a film hole and a compensation mechanism with a stepping motor for preventing miss seed metering.

The trial planting system using computer controlled technology for preliminary test indoor is shown in Fig. 2. The personal computer was used to analyze the planting timing accurately and really.

2. Planting Timing Analysis

Three input signals from detecting unit to the micro-computer are a coming hole edging, whether a seed on shutter and planting speed. Two output signals from the micro-computer to controlling unit are used for controlling the shutter opening mechanism with a rotary solenoid device and the seed metering plate with a stepping motor.

The main purpose using computer control technology was to achieve the synchronized timing with the shutter opening and the hole edging coming based on a variety of planting speed. Because in the sequential controlled planting system, the time which from the hole edging was detected by the sensor to the shutter opened was fixed usually by the sequential control methodology early, so when planting speed varied according to field conditions or some other incredible reasons, the precision planting operation could not be obtained, and the seed could not be planted into the center of a film hole accurately.

Therefore, the planting timing have to be calculated accurately by the micro-computer system based on planting speed.

Figure 3 shows the analytical method and the related parameters. The time from a film hole edging detected by the sensor to the center line of the shutter opening mechanism moving over the center of a film hole was defined as sensor time (ts) and it can be calculated by the following equation.

$$ts = (d/2+Ls)/V \qquad [1]$$

Where

Ls = the distance from the center line of the film hole sensor to the center line of the shutter opening mechanism, here Ls=50 mm according to the dimensional construction of the machine.

d = diameter of a film hole, here d=40 mm.

V = planting speed measured by the rotary encoder.(mm/sec)

As Fig. 3 showed, at the wink of a film hole edging detected by the optical fiber sensor, the time ts would be accounted and the center line of the shutter opening mechanism would be moved to the center line of the film hole within the time ts. That means the shutter would be just over the center of the film hole after the time ts passing.

On the other hand, if the shutter opened just at the over center of the film hole, the seed could not be dropped down to the center of a hole, because there was a time gap while the seed dropped from the shutter to seed bed.

The gap time (tg) could be defined by the following equation.

$$tg = \sqrt{2h/g} \qquad [2]$$

Where

h = the height of the gravity point of a seed on shutter to seed bed in a film hole.

So, the planting timing could be expressed as the executive time (te) that from the film hole edging was detected to the shutter opened for dropping a seed just into the center of a film hole.

$$te = ts - tg \qquad [3]$$

This planting timing could be adjusted by the dip switch in micro-computer system.

3. Control Procedures

Planting a seed into the center of a film hole with a variety of planting speed was the main target of this system. Thus the planting operation timing have to be controlled as a function of the diameter of a film hole and the distance from shutter center line to hole center line based on planting speed accounted by the rotary encoder. For preventing miss seed metering, a called compensation mechanism was also developed.

In the computer control software, two operation modes were designed to achieve the practical use of the machine in a mulching field. One was a hole diameter measuring mode, and another was a practical planting mode. The hole diameter measuring mode was utilized using the rotary encoder to account the hole size for measuring the diameter of a film hole while the film hole sensor was moving across over the hole. The flow chart of this procedures is shown in Fig. 4.

The hole diameter has to be measured before practical planting operation. While the diameter of a film hole was measured, the value of the hole size would be memorized into micro-computer automatically.

When the mode switch was shifted to the planting operation mode, the micro-computer and all of the devices would do the planting works according to the programs. The flow chart of the control procedures is shown in Fig. 5.

As shown in the figure, firstly the seed metering plate would be turned by stepping motor to delivery a seed down onto the shutter plate from a cell of the seed plate, here the existence of a seed on the shutter plate was detected by the optical fiber sensor. If there was a seed on the shutter, the stepping motor would be stopped. On the reversed way, if there was no any seed on the shutter, the stepping motor would be turned again until a seed delivered down onto the shutter plate from a cell of the seed plate continuously. This was the compensation mechanism for preventing miss seeding.

Then, the planting speed would be calculated by the rotary encoder accounter. The planting timing of a seed would be calculated and adjusted by the micro-computer system with the dip switch at a film hole edging was detected by the optical fiber sensor. When the upcoming center of a film hole was predicted by the planting timing, the shutter would open and drop a seed down into the hole center of seed bed at the good timing. This was the key point of this system. This operation would be continued as long crop row until the operation stopped the planting work.

ANALYSIS OF TEST RESULTS

A planting test was carried out in the indoor experiment system to investigate and evaluate the planting accuracy and utilizations of this system. Peanut seeds sized 20.8 mm of length, 11.5 mm of width 'and 8.4 mm of thickness in averages were used. In the test, planted seed positions in film hole were measured and analyzed depending on different planting speed. A video camera motion analyzer, which shown in Fig. 6, was used to analyze the seed dropping path and the position in a film hole.

As the measuring method, a side view and a view in front of the system were recorded into a video camera tape. Then the position of a seed gravity point in a film hole of seed bed were scaled on the monitor screen of the video camera motion analyzer using the light pen. The scaling method on the screen is shown in Fig. 7.

Test results of the side view along the planting direction are shown in Fig. 8. From the figure, even if the planting speed changed as 150, 200, 250, 300 (mm/s), seed positions were always in the center of a film hole just within +-5 mm scattered only.

The view in front of the machine expressed seed positions in a film hole with width way. According to the results which shown in Fig. 9, a sufficient accuracy of planting positions were performed perfectly.

The planting timing were adjusted by the dip switch at 4&6 on.

CONCLUSIONS

The computer controlled planting system for mulching cultivation using polyethylene film was developed and tested. The system consisted of a detecting unit with two optical fiber sensors and a rotary encoder, a calculating unit with a micro-computer and several I/O interface circuits, a controlling unit with relay driving circuits and an actuating unit for controlling the seed shutter opening mechanism and the metering device driven by a stepping motor. According to the results of the test indoor experimental system, sufficient results of a seed planted into the center of a film hole was realized.

By using this system, the planting operation on mulching cultivation would becomes to easier and quickly.

It was cleared that the main advantage of this system was accurately planting a seed into the center of a film hole based on a variety of the planting speed.

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FIGURES

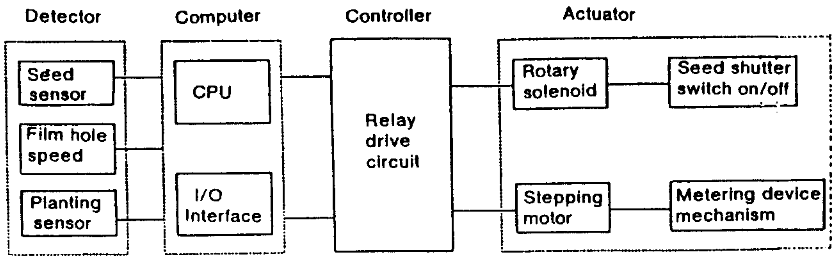

Fig. 1 Computer control diagram.

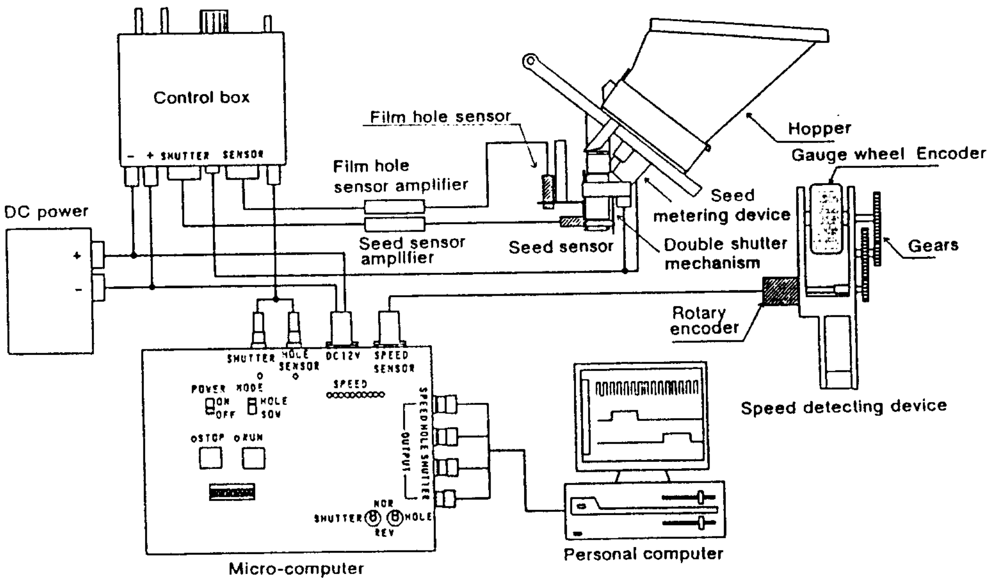

Fig. 2 Computer controlled planting system.

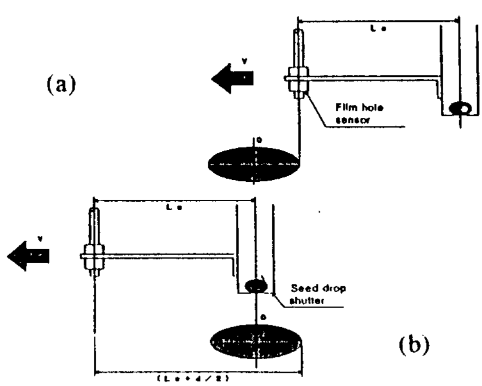

Fig. 3 Analytical method of planting timing.
(a) The wink of hole edging detected by the film hole sensor.
(b) The shutter position after time ts passing.

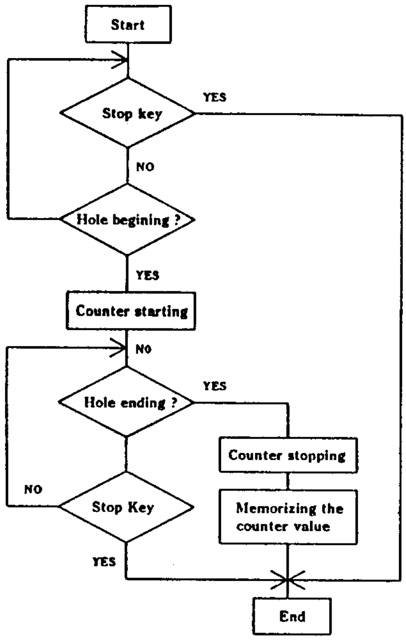

Fig. 4 The flow chart of the film hole diameter detection.

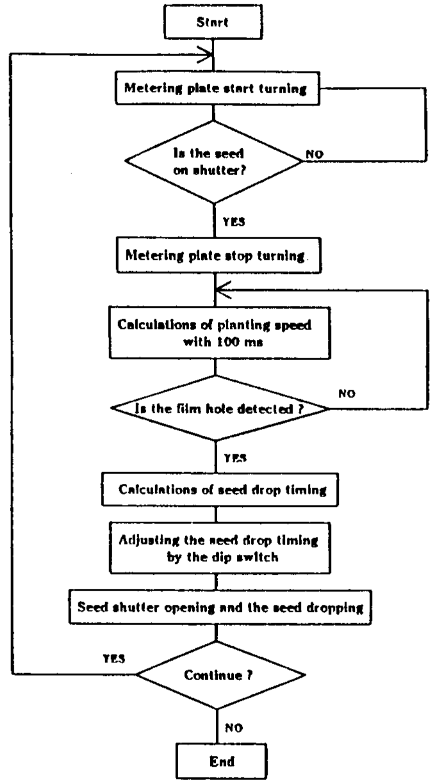

Fig. 5 The flow chart of the practical planting operation.

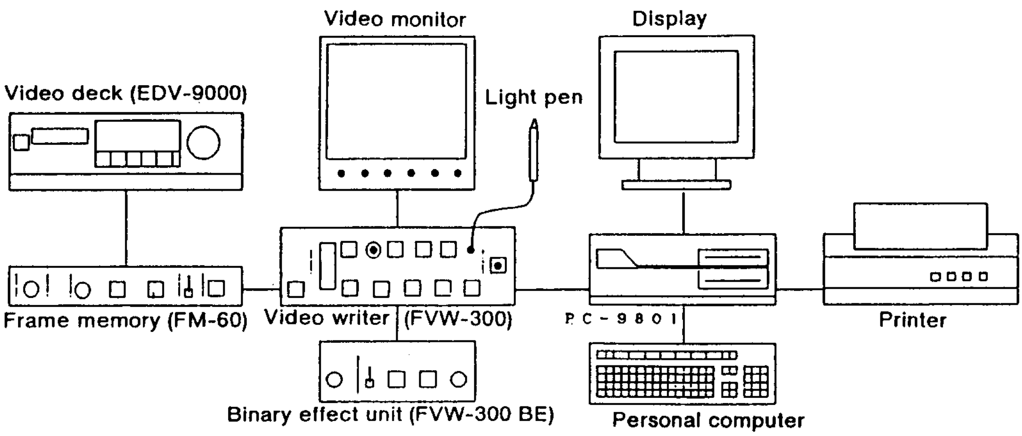

Fig. 6 Video camera motion analyzer.

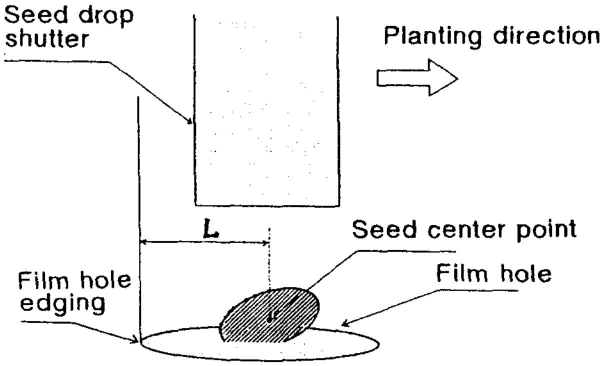

Fig. 7 The scaling method of seed position.

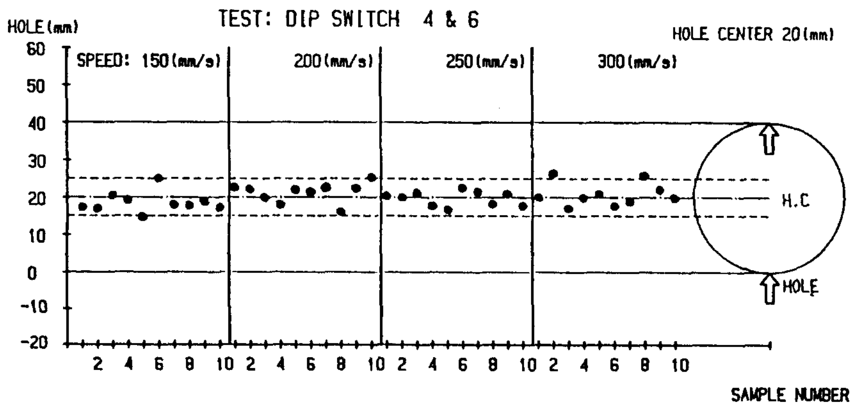

Fig. 8 Evaluations of seed positions in the side view.

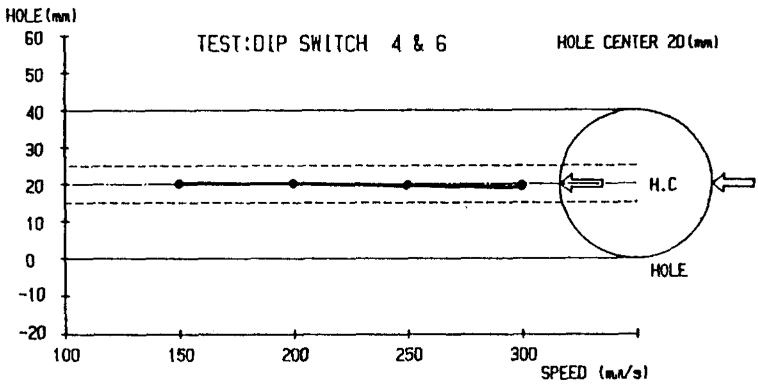

Fig. 9 Evaluations of seed positions of the view in front of the machine.