

Intelligent Farm Machine

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(一) Introduction

The decreasing agriculture labor population and declining birth rate in Taiwan have increased the amount of fallow or abandoned farmlands. There are fewer farm workers with open markets and horizontal competition, which increases the need for an autonomous excavator to automate field work in farming-specific fields. The advanced farming instrument in this study used a microelectromechanical sensing element to integrate a two-tier dynamic control system and complete dead-locking angular correction and speed control. The complete system has already been implemented in a farming field.

The results showed that the instrument can move and complete excavation tasks according to the programmed routes, with a straight line moving error of 4.5 cm. The instrument reduced labor by 100% and reduced work time by 90% (as compared with manual shoveling). The instrument needed 20% more time than a boring machine.

(二) Design Concept

The core concept of the product design was the use of a microchip system. Four DC motors driven by pulse-width modulation (PWM) circuits were applied and a navigation path planner with accurate positioning was developed. Finally, the navigation system, decision algorithm, and human-machine interface were integrated to develop a human-machine interaction environment with high-precision positioning. A highly stable intelligent agricultural instrument for navigation and excavation was developed. The controller in the developed product used PWM signals to drive DC motors and control rotational speed and rotational position. The programming interface can provide a fully automatized excavation function where excavation tasks can be performed at different intervals, depths, and number of rows. The key point of this innovation was to improve the positioning accuracy and programming of the excavation machine. Motor circuits are independently controlled and the machine can move in a straight line according to default paths or dead-reckoning navigation mode. In order to increase safety in machine utilization, safety circuits were added to protect the machine and prevent it from collisions and unintended acceleration.

(三) Technical Development

This product is a four-wheel machine with a dead-reckoning control module. It relies only on an electronic compass to obtain machine azimuth angle data. Readjustments are made to solve the issue of external electromagnetic interference influencing the angle identification by the compass. This product used a laser ranging device to measure distance between the machine and a fixed object. When the distance equals the preset critical value, the machine makes a rotational movement. A coder was used by the system to perform a straight navigation function. The navigation control module included a one- or two-stage dynamic control device that ensured straight movement of the machine.

The programming platform used two AVR microcontrollers as the processing core. The sensing unit included an electronic compass, coder, and laser rangefinder. The controlled bodies were 12V DC motors. The current situation of the sensing unit turning device includes rotational speed, azimuth, and distance to the turning point. Output volume and controlled bodies were determined via decision core operations, completing the development of the device navigation system. The system platform was equipped with an attitude sensor that could read data from the accelerometer and gyroscope and calculate the current angle of machine inclination. A software program was used to adjust a compensating pitch angle and roll. The loose coupling method was used to ensure that no dead-reckoning error occurs in the machine attitude due to topographic influence.

With regard to the circuit design, PROTEL software was used in the layout of the machine control circuit. Related modules were all integrated into one control circuit to enhance its user-friendliness. These modules included microcontrollers, motor drive circuits, power module, and sensing unit.

The product was designed as a four-wheel vehicle. Four wheels were used as the mainspring. A coupling can be installed on the back of the machine to add a tractor if required by the user. The main vehicle is 85.1 cm long, 58.5 cm wide, and 23.6 cm high. Its bearing capacity is 80 Kg. The vehicle has an aluminum extrusion support and uses 12V NiMh batteries, 13 AH. The external diameter of the tires is 310 mm. A rectangular space was designed in the main vehicle body, in which a controller, sensor, driver, and batteries can be installed. This ensures the machine safety and allows to use the vehicle during rain.

(四) Technological Competitiveness

The market segment for the developed product is differentiated from that for large field machines (e.g. tractors, combine harvesters, seed planting machines, etc.) that focus on producing crops. With regard to the product price, among boring machines commonly used in gardening, manually controlled wheeled boring machines cost NT\$28,500 (excluding the drill bit) and the cheapest boring machines costs approximately NT\$12,000. The development costs of the electric machine designed in this study was NT\$40,000. However, once it is mass produced, the processing costs can be reduced by NT\$10,000. The machine's total price, including the managing and marketing costs, will be NT\$35,000.

Moreover, the machine uses a DC power supply and has an environmental pollution-free value. The machine relieves farmers from the necessity to do outdoor field works for long periods of time under the sun. Initial assessment showed that the machine could move 30 meters straight in loam, silty loam, and sandy loam (movement speed: 8 cm/sec; error: <10 cm). After every two meters, the machine performed excavation (a total of 14 holes). The excavation procedure took approximately 40 seconds. Movement and excavation together took 6 minutes. When excavation was performed manually, approximately 15 minutes were required to make one hole (in total, excavation took 3.5 hours). When a gasoline-powered excavator was used (which also required manpower), excavation of a 30 cm deep hole took 25 seconds (excluding time needed to shovel aside earth). The manual excavation method also required an excavation instrument.

(五) R&D Result



Figure 1.
Appearance of intelligent farm machine.

The appearance of the intelligent farm machine is illustrated in Figure 1. Product specifications are as follows:

- A) User-friendly touch panel interface.
- B) High-torque motor independent four-wheel drive:
Torque force – 30 Kg-cm (reduction ratio of 1/516)
- C) Overcurrent detector module used for detection of hard objects during excavation works.
- D) Power capacity: endurance of 4.5 hours (120 excavation actions under 8 cm/sec)
- E) Emergency stopping device and 360 degree obstacle detector (detection distance: 5-20 cm)
- F) Herringbone tread, waterproof and shoveling/casting case design.
- G) 5-8 cm slope spanning capability.
- H) Grade ability of <45 degrees.
- I) Speed 0-15 rpm.
- J) Linear positioning error of 4.5 cm (measurement distance: 100 m).
- K) Excavation depth 0-30 cm (can be adjusted; excavation of one hole takes 40-90 sec)
- L) Vehicle bearing capacity 80 Kg.

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Reference

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