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Development of Mock Control Devices and Data Acquisition Apparatus for Power Tiller Training Simulator

YuYong Kim[1]*, Byounggap Kim[1], Seung-yeoub Shin[1], Byoungin Kim[2], Sunjung Hong[2]

[1]Department of Agricultural Engineering, National Academy of Agricultural Science, Rural Development Administration, Jeonju, Korea
[2]Extension Service Bureau, Rural Development Administration, Jeonju, Korea

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Abstract

Training power tiller operators in safe farming is necessary to avoid farming accidents. With the continuing progress in computational technology, driving simulators have become increasingly popular for conducting such training. **Purpose:** The objective of this study is to develop mock control devices and data acquisition apparatus for a tiller simulator. **Methods:** Except for the stand and tail wheel adjusting levers, the mock control devices were developed using a tiller handle assay. The data acquisition apparatus was realized using an embedded data-logging device and LabVIEW, the system design software. **Results:** The control devices of a real handle assay were successfully mimicked by the mock operator control devices, which used sensors for the relevant measurements. The data from the mock devices were acquired and transmitted to the main computer at intervals of 10 ms via Wi-Fi. **Conclusions:** The developed mock control devices operate similar to real power tillers and can be utilized in power tiller training simulators.

Keywords: Accident prevention, Operator control device, Power tiller, Safety training, Simulator

Introduction

As agility, strength, and judgment decrease with increasing age, more farming accidents occur as farmers become older. Although the power tiller has been used by farmers for more than 60 years, it is among those agricultural machines that have the highest accident rates (RDA, 2011). It is therefore necessary to train power tiller operators in safe farming. Although empirical safety training is more effective than theoretical training, the use of a real power tiller for such training can be dangerous, especially on roads and slopes (Kim et al., 2014).

Driving simulators date back to the 1970s, when General Motors developed one of the first driving simulator models (Gruening et al., 1998). They have gained popularity as not only research tools in fields like vehicle system design and human factor studies, but also training tools. The main advantage of driving simulator education is that real driving situations can be reproduced for educational purposes in a safe and easily controllable environment (Lee et al., 1998; Kim et al., 2014). Rapid increase in the computational power and graphic capabilities of desktop computers over the last decade has enabled researchers to build high-fidelity driving simulators at reasonably low costs (Karmi et al., 2008). Although driving simulators have been used extensively in the automotive industry for many years, very few have been developed for agricultural vehicles; e.g., the tractor simulator by Kim et al. (2014). Considering that the structures of power tillers and tractors are completely different, the objective of this study was to develop an operator control device similar to a real power tiller that can be used to train agricultural power tiller operators.

***Corresponding author:** YuYong Kim
Tel: +82-63-238-4153; **Fax:** +82-63-238-4145
E-mail: kimkyu12@korea.kr

Materials and Methods

A simulator consists of five principal components: mock control devices, computer dynamic model, visual system, motion platform, and virtual environment (Kim et al., 2014). As shown in Figure 1, the structure of a power tiller is different from that of other vehicles, such as tractors and cars. In this study, a power tiller handle assay (DT10DE, Daedong, Korea) was used to develop the mock control devices of the simulator, except for the stand and tail wheel adjusting levers.

A total of 15 proximity sensors (PR08-2DN, Autonics Corporation, Busan in Korea) were used to detect the positions of various parts of the power tiller: three for the main clutch, four for the main gearshift lever, four for the sub-rotary gearshift lever, two for the two steering clutches, one for the stand lever, and one for the decompression lever. An absolute encoder (EPM50S8-1013-B-DN-24, Autonics, Korea); two rotary potentiometers (ST-350, Sensor Systems, Italy), which generate 0 to 10 V when they rotate from 0° to 360°; and a linear potentiometer (LPS-30, Dacell, Korea), which detects lengths of up to 30 mm; were employed to record the control inputs of the steering angle, pitch angle, brake pedal position, and engine speed control lever position, respectively. If the engine speed control lever was rotated maximum degree, the wire was pulled 20 mm. The contact points of the existing switches, such as the ignition key, directional signal switch, and headlamp lighting switch, were connected to a digital port, and a regulated voltage of 24 V was supplied to each switch.

To ensure that the power tiller handle of the simulator operates similarly to a real power tiller handle, it should be able to rotate about three axes (pitch, roll, and yaw). Moreover, the power tiller operator should be able to rotate in two directions (pitch and yaw) with a force that is greater than the reaction force from the power tiller. The pitch reaction force is the weight in the front of the wheel, and the yaw reaction force (steering reaction force) depends on the steering clutch condition, the power tiller speed, and whether the road runs uphill or downhill. As shown in Figure 2, each electronic clutch was installed between a servomotor and a reducer, and it was used to control the torque without affecting the position control of the servomotor. The torque proportional to the supplied current is the reaction force. If an operator rotates the

Figure 1. Schematic and photographs of power tiller structure.

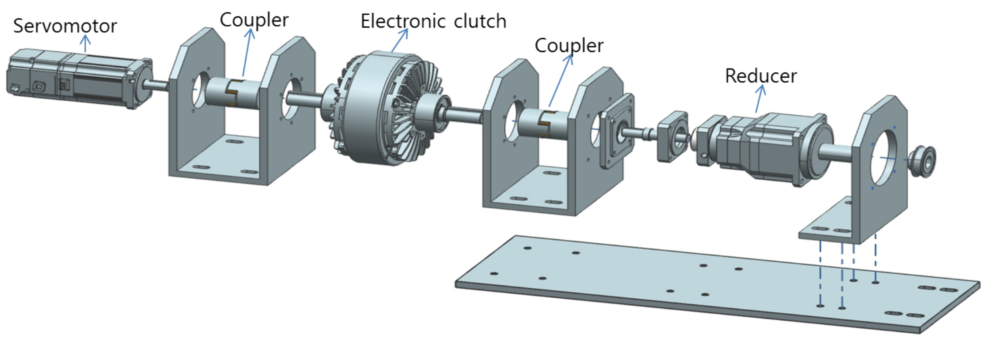

Figure 2. Pitch reaction control device of handle.

handle with a force greater than the torque, the electronic clutch slips. Because of the slip, the reduction gear does not rotate in proportion to the servomotor. It is necessary to detect the position of the reduction gear. A rotary potentiometer (ST-350, Sensor Systems, Italy) was connected to the reducer axis by using a 1:2 pulley to detect the pitch angle, and an absolute encoder was connected to the reducer axis through a 1:1 pulley to detect the yaw angle.

The operator control input data should be acquired and then transmitted via Wi-Fi to the main simulation computer that simulates the computational dynamic model and controls the motion platform. The data acquisition apparatus, which acquires the input data, consists of an embedded data-logging device (cRIO-9075, National Instrument, USA), a digital input module (NI-9425, National Instrument, USA), two analog input modules (NI-9222, National Instrument, USA), and a filter module (NI-9777, National Instrument, USA). An application for data acquisition was created using LabVIEW (National Instruments, USA), the system design software, to develop a field-programmable gate array (FPGA) hardware target using graphical structures and input/output (I/O) nodes.

Results and Discussion

Decompression, steering clutch, and engine speed control levers

As shown in Figure 3, four levers (a decompression lever, two steering clutch levers, and an engine speed control lever) were each connected to a sliding fixture that slides on a linear motion guide via a cable having a spring. Control cables with springs used in a real power tiller are utilized. When the decompression lever is not being pulled, and the two steering levers are not being held, the spring forces return them to their original positions. If the decompression lever is being pulled and two steering levers are being held, this is detected by three proximity sensors, which sense the presence of the sliding fixtures, and if released, they are returned to their original positions. A linear potentiometer was connected to the sliding fixture of the engine speed control lever to detect its manipulated variable, i.e., the length increased during the lever operation. The output of the linear potentiometer was connected to the analog module. The cable length remained constant even when released. These control levers can be operated similar to the control devices of a real power tiller.

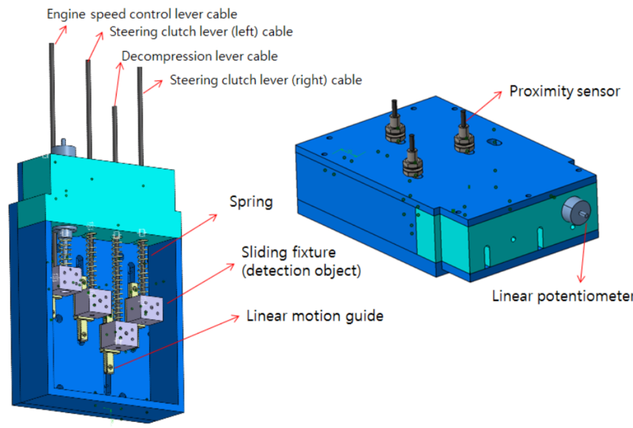

Figure 3. Decompression, steering clutch, and engine speed control levers.

Main and sub-rotary gearboxes

The fixing hole prevents the movement of the sub-rotary gearshift lever when the lever is in the central position. If the four proximity sensors of the main gear do not detect anything, then the main gear is inferred to be in a neutral position regardless of the sub-rotary gearshift lever

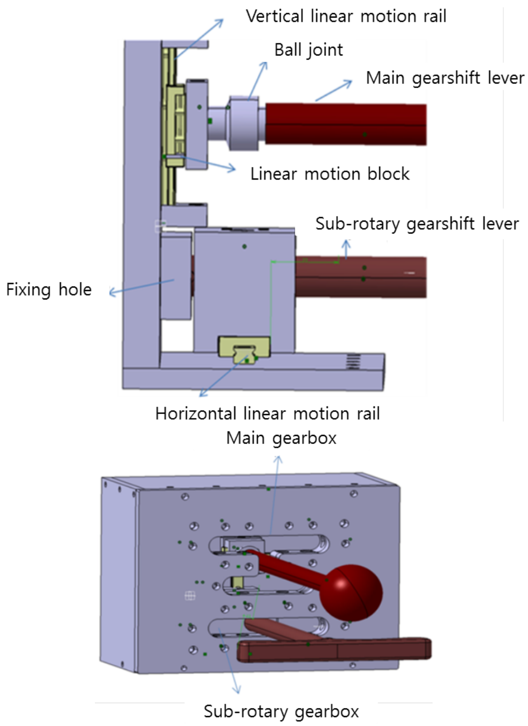

Figure 4. Main and sub-rotary gearboxes.

position. If one of the proximity sensors is triggered, the main gear is inferred to be in the detected position according to the sub-rotary gearshift lever position. If the sub-rotary gearshift lever is pressed, the sub gear sensor, which is the proximity sensor attached to the side of the fixing hole, detects that the sub gear is in the second level and the rotary gear is in neutral. Conversely, if the sub-rotary gearshift lever is pulled, the sub gear sensor detects that the sub gear is in the first level and the rotary gear is in one of three levels (fine, neutral, or bold) according to its position (left, center, or right, respectively). If the main gearshift was detected in 1, 2, or 3, the forward gear is in the level calculated as follows:

$$\text{Forward gear level} = \text{main gearshift lever level} + 3(\text{sub-rotary gearshift level} - 1) \quad (1)$$

If the main gearshift is in the R position, the reverse gear is in the sub gear level. Mock gear boxes are operated similar to real gear boxes.

Main clutch

Depending on whether the left, center, or right proximity sensor is triggered, the power tiller is inferred to be running, in neutral gear, or stopped, respectively, as with a real power tiller.

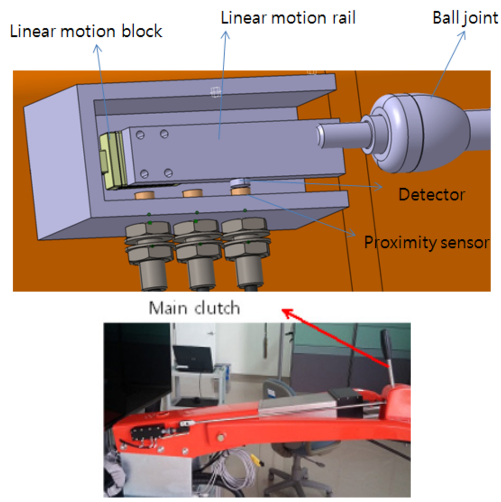

Figure 5. Schematic and photograph of main clutch.

Data acquisition and discussion

If the decompression lever is pulled and released during a predefined period when the ignition key is turned, it is programmed to start the engine. To transmit the range of analog values to the main computer, the analog data were calculated as follows. The calculated values are between zero and one.

1. Acquire minimum and maximum values of analog data.
2. Subtract each offset (minimum value) from the data.
3. Divide each value obtained in step 2 by the range (maximum value – minimum value).

$$\text{Calculated value} = \frac{\text{Acquired datum} - \text{Minimum value}}{\text{Maximum value} - \text{Minimum value}} \quad (2)$$

Figure 6 shows an example of a screen obtained in the monitoring program. As shown in Figure 6, the data were acquired and transmitted at 100 Hz in the following format:

#TP@00000000000100000000000000000000@0.123@0.123@.877@0.123@0.123@#.

The zeros and ones between the first and second @ symbols represent 32-bit digital data. The five analog values following the digital data reflect the engine speed, foot break, steering angle, pitch angle, and height of the tail wheel, respectively.

To reduce dizziness during operation, the screen should be updated at a rate of over 60 frames/s. With the present

Figure 6. Snapshot of monitoring program.

technology, it is difficult to display a virtual reality program with more than 100 frames/s. It is necessary to rotate the power tiller continuously in the yaw direction to the infinite to simulate the tilling operation. Data must be transmitted wirelessly or through a wire by using a slip ring. The calculated effects are transmitted to the simulation program via Wi-Fi at 100 Hz. The simulation program must receive the transmitted data every 10 ms to calculate the dynamics and update the screen.

Conclusions

This study was conducted to develop the mock control devices and data acquisition apparatus for a power tiller training simulator. The operator's data input to the mock control devices were acquired and transmitted to the simulation program at intervals of 10 ms via Wi-Fi. The developed mock control devices function similar to the operator control devices of a real power tiller and can be utilized in the power tiller training simulator.

Conflict of Interest

The authors have no conflicting financial or other interests.

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