A CONTROL SYSTEM FOR BALANCING A BOOM OF SELF-PROPELLED BOOM SPRAYER

Chang Joo Chung — Professor
Hyun Kwon Noh — Research Assistant
Seong In Cho — Associate Professor
Yeong Soo Choi — Research Associate
Young Chang Chang — Research Associate

Department of Agricultural Engineering
Seoul National University, KOREA

ABSTRACT

Chemical application is one of the most important field operation in rice production. Rolling of a boom due to local unevenness and softness in fields causes a local under/over-application of spray. This study was conducted to develop a control system for balancing a boom. A boom mounting mechanism was modified and a control algorithm was developed in the study. The results for testing the performance of the control system showed that the system could balance the boom in flat and inclined fields. This research can contribute to improve spraying uniformity in applying agricultural chemicals with a boom sprayer.

Key words : boom sprayer, control, boom balancing

INTRODUCTION

In recent years, power sprayers are mainly used for spraying agricultural chemicals in Korea. Spraying with a power sprayer is a labor-consuming, arduous work for operators in terms of carrying and controlling long, heavy spray hoses from sprayers to application sites on levees. Thus the demand for boom sprayers increases to reduce the difficulties related to conventional power sprayers. Chemical application with a boom sprayer has many advantages such as reduction of labor and spray drift, precise application of chemicals on necessary spraying sites.

One of problems in spraying with a boom sprayer is to balance the boom rigidly mounted to the frame of sprayer. When the sprayer is inclined to the ground due to local unevenness of ground in fields, the boom is also inclined causing to lower the efficiency and uniformity of spraying and even to damage the crop by the inclined boom. Therefore, balancing a boom to the ground at a specific spraying height is very important in spraying chemicals with a boom sprayer in order to achieve satisfactory spraying performance.

There have been few studies related to control the height or the position of a boom. In this study, the vertical movement of boom tips due to unevenness of ground in paddy fields was investigated, and a control system was designed and tested for compensating the movement and balancing the boom to the ground.

MATERIALS AND METHODS

Boom sprayer

The boom sprayer used in the study was a 4 wheel drive, self-propelled boom sprayer(DSA-410, Maruyama Co.). A boom was rigidly fixed in the front of the frame of sprayer. Table 1 shows the specification of the boom sprayer.

Modification of boom mounting mechanism

In this study, the boom mounting mechanism of the sprayer was modified to smoothly balance the boom to the ground, based on a scheme suggested for compensating the rolling of a boom. The boom was pivoted on the center of boom mounting frame, allowing the boom smoothly rotate in the plane perpendicular to the forward direction of sprayer. Figure 1 shows the mounting mechanism modified in the study. As shown in the figure, a power cylinder(LPA-010M1.5, Tsubaki Co.) was installed near the middle of the boom connecting the mounting frame and the boom. The power cylinder could push or pull the boom to balance its rotation associated with rolling of sprayer.

Table 2 shows the relationship between the stroke of cylinder and the vertical movement of boom tip. The maximum vertical amplitude in the movement of boom tip was 156cm(±78cm to a horizontal line) to a full stroke of the cylinder.

Measurement of the vertical movement of boom tip

This measurement was performed to observe the rolling of boom due to local nonuniformity or softness of ground in the field, so that the input data necessary for simulating the performance and efficiency of a control system could be obtained in this study.

The measuring system consisted of a rotary potentiometer directly attached to the boom tip at a side of the boom, a PC computer with PC Lab card, a horizontal rail on the ground, a stick connected to the rotary potentiometer. Figure 2 shows the measurement system of the vertical movement of boom tip. As the boom sprayer traveled in a test field, the boom tip rolled according to the unevenness of the ground. The evenness of the ground was transferred to the potentiometer through a rotation of the stick on the horizontal rail. Thus the variation in the output voltage of potentiometer was converted to the vertical movement of boom tip. In this measurement, the travel speed of sprayer was at a normal spraying speed, 1.7 km/h.

Control system of balancing a boom

An angle sensor(PMP-S10T, Midori Co.) was selected to detect a rotation angle of boom in the control system designed in the study. The sensor was a high precision pick-up device consisted of a magnet, a magnetic-resistance element and a spring-suspension pendulum. As the device filled with damper oil is inclined at a certain slope angle, the sensor generates a linear output within the angle range, $\pm 10^\circ$. Figure 4 shows the angle sensor attached to the mid-position of the boom.

Figure 3 shows the output characteristic of the angle sensor at the input voltage 5V. The associated output was 2.6V when the angle was at 0° , 2.2V at $+10^\circ$ and 3.0V at -10° . As shown in the figure, the sensor had a excellent linear characteristic.

As an actuator to balance the boom, a direct current motor was selected in the control system because there was no hydraulic system in the boom sprayer used in this study. The nominal input voltage of the actuator was DC 12V, the stroke and speed were 150mm and 50mm/sec, respectively. Figure 5 shows the power cylinder and its attachment in the boom sprayer.

Figure 6 shows the flow chart of the balancing algorithm used in the control system. PC computer acquired a signal from the angle sensor through the PC Lab card and compared it to a reference signal. Then the computer generated a digital signal driving a relay based on the comparison. The relay between the power source(battery on the sprayer) and the cylinder switched the input DC voltage into the power cylinder to a pull/push direction.

Performance test

The performance of the control system was tested in laboratory and in fields. In laboratory tests, the performance of the system and its adaptability at various testing conditions were evaluated by investigating the output signals corresponding to the vertical movements of boom tip. Based upon the results for laboratory tests, the algorithm was refined to be applied to various operating conditions in fields. Two comprehensive experiments with and without the control system were performed in field tests. The performance of the control system was evaluated by comparing the slope of boom at two conditions.

RESULTS AND DISCUSSION

The vertical movement of boom tip

The vertical movement of boom tip measured in A/D signal by PC Lab card was converted to and evaluated in the height of boom tip from the reference level. The frequency of movement was between 0.1 Hz and 0.3 Hz. The height of boom tip to the reference level changed within the range of 15~90cm. Figure 7 shows an example for the vertical movement of boom tip at the sprayer speed, 1.7km/hr.

Laboratory tests

Figure 8 and Figure 9 show the response of the power cylinder for lowering and raising the boom in order to compensate the slope of boom. The results were represented by a rotating degree per unit time. As shown in the figures, the response of the power cylinder was 0.0163° /sec for lowering and 0.0123° /sec for raising, equivalent to 85cm/sec and 65.5cm/sec in the vertical movement of boom tip, respectively.

The performance of the control system was tested by evaluating its response in the frequency range of 0.1~0.5Hz at the fixed rotation angle of boom ±9° (±65cm for the vertical movement of boom tip). Figure 10, 11 and 12 show the response of the control system at input frequency of 0.1Hz, 0.3Hz and 0.4Hz, respectively. The control system followed well the input signals at the input frequency of 0.1~0.3Hz but, over the input frequency of 0.4Hz, showed some phase lags.

Field test

Figure 13 shows the output signal of angle sensor without the control system in fields. The figure reflected the fact that the boom was inclined according to the unevenness of test ground. Figure 14 and 15 show the output signals of the angle sensor with the control system. The reference level in figure 14 was approximately 0° . The result showed that the control system balanced the boom well with a slight wiggle but the high frequency fluctuation with a low amplitude would be acceptable in terms of overall spraying uniformity. The reference level in figure 15 was set to -3.74° in order to test the performance of the control system at a sloped field. Figure 15 also showed that the control system in the study was very effective at slope fields in balancing the boom to the ground.

CONCLUSIONS

One of problems in spraying with a boom sprayer is to balance the boom rigidly mounted to the frame of sprayer. The objective of this study was to develop a control system for balancing a boom to the ground in order to compensate a rotation of the boom due to unevenness in fields. The results for testing the performance of the control system designed in the study showed that the system could be balance the boom well in flat and inclined fields. Based on the results, this research can contribute to improve spraying uniformity in applying agricultural chemicals with a boom sprayer.

REFERENCES

1. Chung, C. J. 1990. Revised agricultural machinery. Hyang mun sa.
2. Cha, Y. B. 1996. IBM PC interface application. Doing il publishing co.
3. Whang, H. Y. 1995. Computer control. Do se san up sa.
4. Im, I. G. 1991. Turbo C jung bock. Ga nam sa.
5. Lee, K. K. 1996. Experimental Study on Coverage Coverage Characteristics of Self-Propelled Boom Sprayer. Seoul national university MS thesis.
6. O'Sullivan, J. A. 1986. Simulation of the Behaviour of a Spray Boom with an Active and Passive Pendulum Suspension. Journal of Agricultural Engineering Research 35, 157-173.
7. Marchant, J. A., Frost, A. R. 1989. Simulation of the Performance of State Feedback Controllers for an Active Spray Boom Suspension. Journal of Agricultural Engineering Research 43, 77-91.

Table 1. The specification of the self-propelled boom sprayer used in the study

Machine name	M co. boom sprayer
Size, mm	3015 × 1750 × 1890
Boom length, mm	8900 (unfold)
Ground clearance, mm	650
Weight, kg	556
Rated Output, ps/rpm	6.6 / 1800
Driving mechanism	4WD
Turning mechanism	Front wheel steering
Transmission	Forward, 6; Backward, 2;
Traveling speed, km/h	1.0 - 9.0
Tire size, mm	900 × 95
Minimum turning radius, m	2.8

Table 2. The relationship between the length of power cylinder and the height of boom tip

length of power cylinder (cm)	Boom tip height (cm)	Boom angle (°)
30	163	10
37.5	85	0
45	7	-10

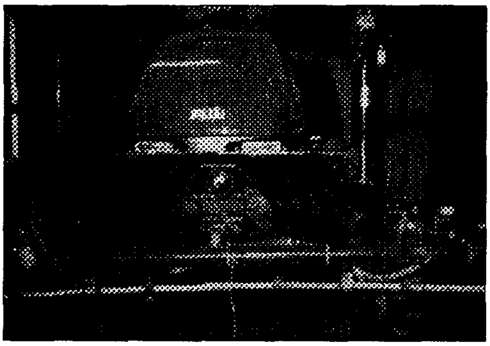

Fig. 1. Modification of a boom mounting mechanism

Fig 2. A measurement system for the vertical movement of boom tip

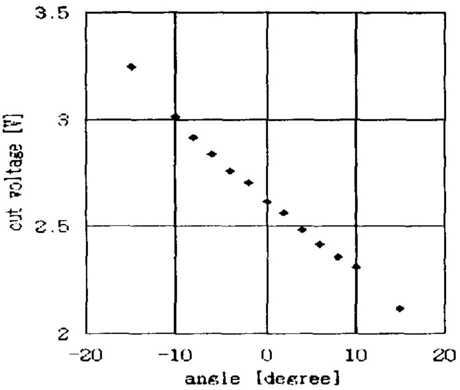

Fig. 3. The output characteristic of angle sensor

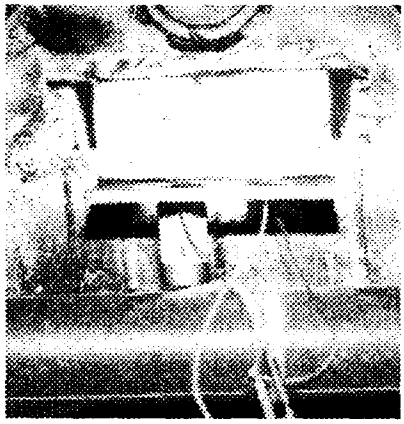

Fig. 4. The angle sensor attached in the boom

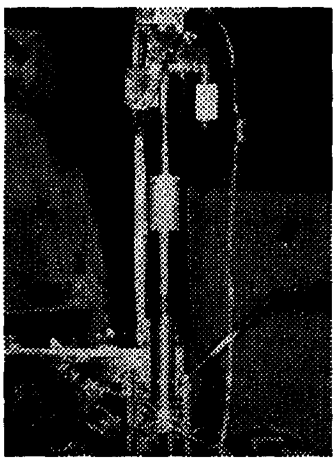

Fig. 5. The power cylinder attached in the boom sprayer

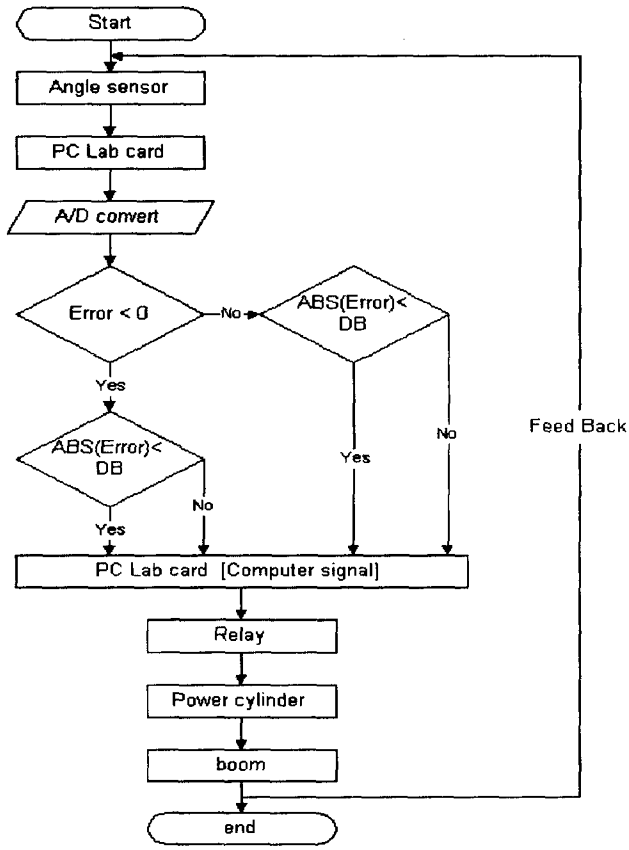

Fig. 6. The flow chart of balancing algorithm used in the control system

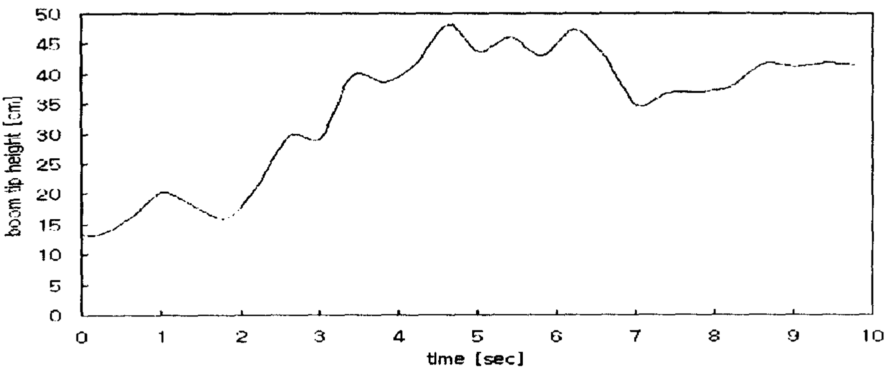

Fig. 7. Vertical movements of boom tip at the sprayer speed, 1.7km/hr

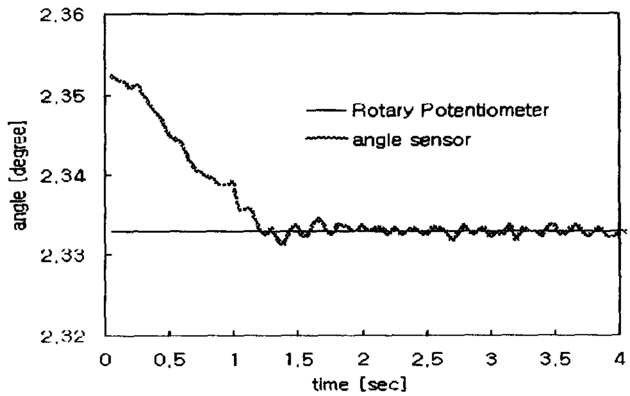

Fig. 8. The response of power cylinder (lowering)

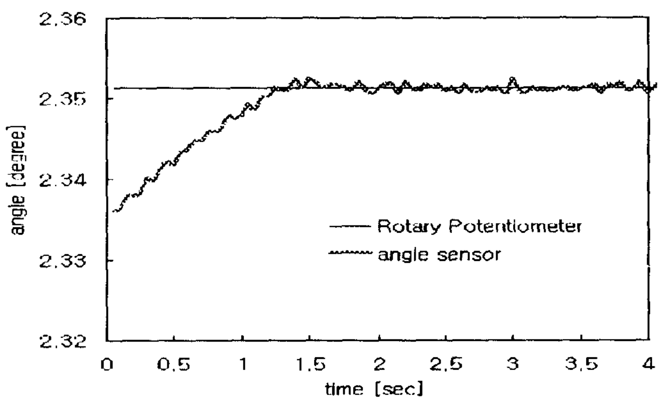

Fig. 9. The response of power cylinder (raising)

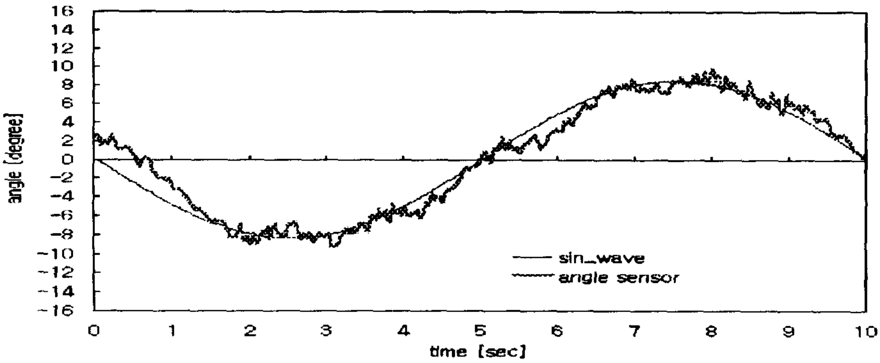

Fig. 10. The response of the control system at simulated input for unevenness of ground(sin_wave, sampling time 30ms, 0.1Hz)

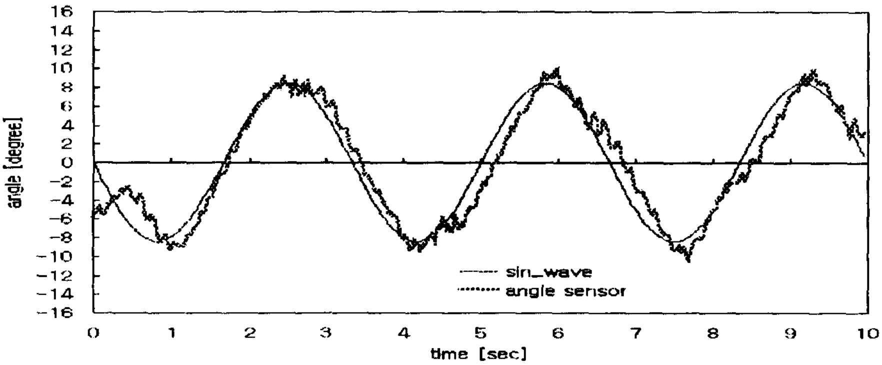

Fig. 11. The response of the control system at simulated input for unevenness of ground(sin_wave, sampling time 30ms, 0.3Hz)

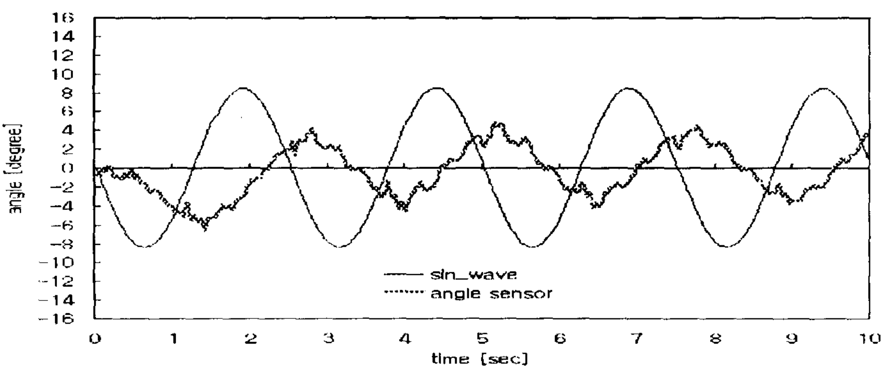

Fig. 12. The response of the control system at simulated input for unevenness of ground(sin_wave, sampling time 30ms, 0.4Hz)

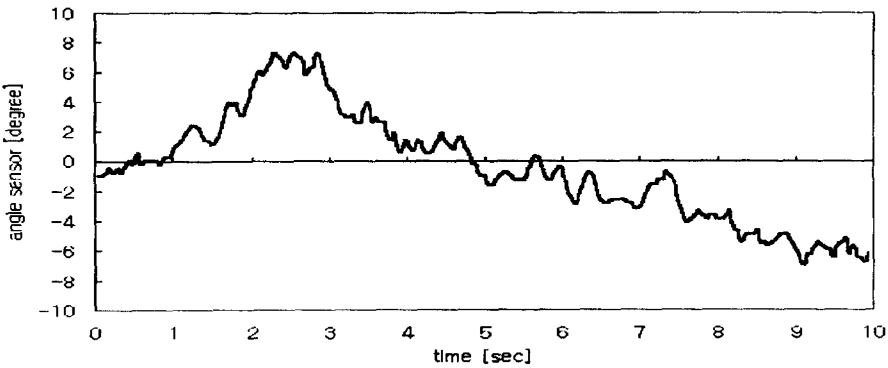

Fig. 13. The output signal of angle sensor without control system in field test

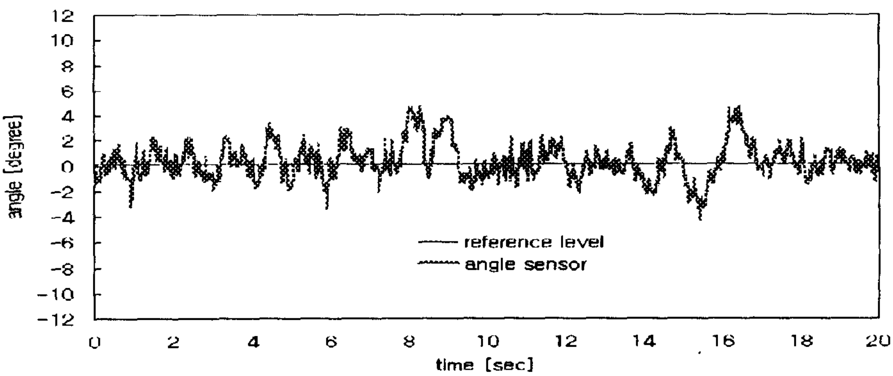

Fig. 14. The output signals of the angle sensor with the control system in field test (reference level = 0°)

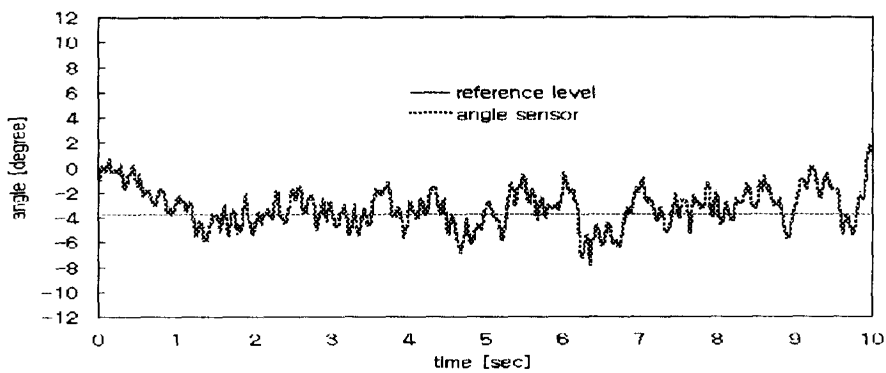

Fig. 15. The output signals of the angle sensor with the control system in field test (reference level = -3.74°)