DEVELOPMENT OF A FEED SHAFT DRIVING SYSTEM USING THE FIFTH WHEEL AS A SPEED SENSOR

J. H. Kim and K. U. Kim
Department of Agricultural Engineering
Seoul National University
Suweon 441-744, Korea

ABSTRACT

In order to maintain a constant speed ratio between the ground wheel and feed shaft of planters, a feedback control unit was designed to drive the feed shaft in proportional to the ground speed. The fifth wheel was used as a ground speed sensor for the control unit. Using this control unit a feed shaft driving system was developed and tested both in the laboratory and field to evaluate its performance. The test results showed that the system drove the feed shaft in proportional to the ground speed in the normal planting speed range of 0.5-0.8m/s with an error of less than 5%.

Key Word : Seed Planter, Feed Shaft Driving System, Fifth Wheel, Feed Shaft Speed Control

INTRODUCTION

In general a feed shaft of seed planter is driven by a ground wheel attached to the planter frame. Theoretically, the ground wheel rotates in proportional to the ground speed of planter and drives the feed shaft accordingly. However, the speed of feed shaft is not proportional to the ground speed due to slip of the ground wheel. If the soil condition is not proper speed variation of the feed shaft becomes large. This causes non-uniform seed dropping or even missing of seeds when the rotation of the ground wheel is stopped by sticky soil.

Maintaing a constant speed ratio between the ground wheel and the feed shaft is very important, affecting the seeding performance of planter. The constant speed ratio may be essentially needed for high speed planting operations.

In order to design a control unit driving the feed shaft in proportional to the ground speed of the planter a ground speed must first be measured. Stuchly et al.(1978) and Sokol(1983) used a doppler radar and Tompkins et al.(1988) did the microwave doppler speed sensor to measure actual ground speed. Shin(1994) developed a unit to measure the actual ground speed of tractor using a supersonic-wave doppler sensor. He tested the unit in the speed range of 0~3m/s and obtained a measuring error of less than 20% when tested at the rotating belt device. However, the speed measurement on the soil surface was unsuccessful.

This study is intended to develope a feed shaft driving system, which rotates the feed shaft in proportional to the ground speed of planter using the fifth wheel as a speed sensor.

DEVELOPMENT OF FEED SHAFT DRIVING SYSTEM

Design of Control System

A fifth wheel was attached to the planter to pick up its ground speed. Then the feed shaft was driven by a motor in proportional to the speed of fifth wheel. it was assumed that the fifth wheel has no slip. A control system was designed to regulate the speed of the feed shaft driving motor in proportional to the speed of fifth wheel. Fig. 1 shows the block diagram of the developed control system.

As shown in Fig. 1 the control system used two input signals, one from the fifth wheel and another from the feed shaft. The signal from the fifth wheel is the output of a rotary encoder mounted on the fifth wheel shaft. The signal from the feed shaft is the output of an encoder mounted on the feed shaft. Both encoder signals were converted to voltages by passing through the F/V converters. Difference V_3 between the speeds of the fifth wheel V_1 and the feed shaft V_2 was obtained and amplified. Signal V_4 was obtained by adding V_1 to V_3. Input signal to the feed shaft driving motor V_5 was the inverse of V_4. Subtraction, addition, and inversion were made by the amplifiers having respective functions. Fig. 2 shows the circuit diagram of the speed control unit implementing the above process. Fig. 3 shows the block diagram of the F/V converter used in this circuit.

The pulse signal output from the rotary encoder was converted to 0/12V pulse signal and its noise removed by passing through the inverter and Schmitt trigger. The inverted signal passed through a monostable multivibrator has H level during only a of period, t_H. This relationship is shown in Fig. 4.

The period, t_H can be expressed as Eq. (1). Parameters C_o, R_a and R_c are designated in circuit diagram.

$$t_H = 1.1C_o(R_a + R_c) \qquad (1)$$

t_H is regulated by using a variable resistance R_a. The output pulse signal from the active filter was changed to an average voltage which is represented by the dotted line in Fig. 4. (Lee, 1992). As the output frequency increases, so does the average voltage.

Although there exists many kinds of servo-amplifiers, this circuit used a basic type, the linear voltage amplifier. A safety feature consisting of an assistant transistor(2SC1815) and a diode(1S1588) was included in the system to protect the main transistor(2SD768) from any damages due to over-current.

Driving System

A feed shaft driving system shown in Fig. 5 was developed using the speed control unit. Rotary encoders used in the driving system were those of the series ENB-600. To keep the encoders from vibrations induced during field operation, a cushioning material was added in its mounting locations.

A 12V DC motor commonly available as a wipe motor for automobiles was used to drive the feed shaft.. It is cost effective and reliable than other industrial DC motors. Since the motor has a built-in reduction gears and its output speed was appropriate to driving the feed shaft, the motor was directly coupled to the feed shaft.

Power to the motor was provided by a 12V battery. To supply power to IC chips in the control unit a DC/DC converter chip was used. Since TL084(op-amp) requires an input voltage of ±12V, battery power of 12V was amplified and divided into ±12V by the DC/DC converter chip. The chip supplied more stable voltage than the battery can do directly to IC chips.

PERFORMANCE TEST

To order to evaluate the performance of control unit and the driving system, both the indoor and field tests were carried out. The indoor test was to identify proper functioning of the entire system and the field test to evaluate its performance in actual field conditions.

Indoor Test

Let $V(m/s)$ and $d(cm)$ be a planting speed and fifth wheel diameter, respectively angular velocity of the fifth wheel $n_1(rpm)$ may be given by

$$n_1 = \frac{60V}{\pi d} \qquad (2)$$

The angular velocity of the feed shaft $n_2(rpm)$ is determined from the hill distance $x(m)$ and number of seed holes n in the metering roller as follows;.

$$n_2 = \frac{60V}{nx} \qquad (3)$$

From Eqs. (2) and (3), it was known that angular velocities of the fifth wheel and feed shaft varies with changes in planting speed. For the test the fifth wheel diameter was set to d=0.39m, number of holes to n=5 and hill distance to x =0.15m. The planting speed was varied to 0.5, 0.6, 0.7, and 0.8m/s, respectively. To examine the functioning of the system, the actual speed of the feed shaft was compared with that calculated by Eq. 3.

Field Test

In the field test the hill distance was set to 0.13, 0.14, and 0.15m, respectively. The planting speed was varied by same way as done in the indoor test. The test was to verify that the driving system keeps hill distance constant irrespective of planting speed. If the feed shaft rotates in proportional to the planting speed the hill distance must be equal whatever the planting speed may be. The actual hill distance was measured and compared with the setting distance.

The hill distance was defined as a distance between the centers of two adjacent hills. Since seed distribution of the hill was not uniform a geometrical centroid of region bounded by seeds dropped first and last along the forward direction of planter was considered as center of the hill as shown in Fig. 6.

RESULTS AND DISCUSSION

Indoor Test

Table 1 shows the results of the indoor test. With a planting speed range of 0.5~0.8m/s the discrepancies between the actual and calculated speeds of feed shaft were about 0.31~0.61%. Although it was not able to derive any general trend in the discrepancies, it was understood that fluctuation in load acting on the feed shaft. may cause the speed variations.

Fig. 7 depicts a statistical correlation between the actual and calculated speed of feed shaft. The coefficient of determination was 0.9963, which indicated a good relation enough to assure a proportionality between the two speeds. It was therefore certain that the system rotates the feed shaft in proportional to the fifth wheel speed.

Field Test

Table 2 shows the measured hill distances at 4 levels of planting speeds in a range of 0.57~1.01m/s. When the hill distance was set to 13cm the error of the measured value with respect to the setting distance was 0.4~4.7%. When the setting values were 15 and 17cm respectively, corresponding errors were 1.1~9.7% and 2.1~8.3%. As the hill distance increased, so did the error. With the same distance setting the error was great at low and high speeds. It was considered that the error can be reduced by reducing the range of seed distribution at hills.

With the same hill distance setting a relation between the planting speed and measured hill distance was shown in Fig. 8. With a hill distance setting of 13cm the average of measured hill distance was 13.1cm in the range of planting speed and the error relative to the planting speed was 0.023. With the hill distance settings of 15 and 17cm respectively, the corresponding average values of the measured hill distance were 15.3 and 17.1cm. The errors in each hill distance relative to the planting speed were 0.038 and 0.040, respectively.

Results of the test showed that the error in hill distance relative to the planting speed increases as the hill distance setting and planting speed increase. Theoretically, the ratio should be zero if the feed shaft rotates in proportional to the planting speed. However, the error was in the range of 0.023~0.040. It was estimated that the error is small enough to prove a proportionality between the speeds of the fifth wheel and the feed shaft. The reason for the non-zero errors was due to the wide distribution of seeds dropped at hills. Therefore, it is necessary to reduce the range of dropped seeds at hills to improve the performance of feed shaft driving system.

CONCLUSIONS

This study was carried out to develop a feed shaft driving system which rotates the feed shaft in proportional to the ground speed of planter using the fifth wheel as a speed sensor. The results were as follows;

1. A feed back control unit of feed shaft driving system was developed by using the signals from the fifth wheel and feed shaft motor.

2. A feed shaft driving system using the feed back control unit was developed.

3. Performance of the developed control unit and driving system was evaluated by the indoor and field tests.

4. In the range of planting speed of 0.5~0.8m/s the feed shaft rotated in proportional to the speed of the fifth wheel and the coefficient of determinant between the two speeds was 0.9963. The range of error in the measured speed of the feed shaft was 0.31~1.61%.

5. In the range of planting speed of 0.5~0.8m/s the error of the measured hill distance was less than 5% and the relative error to the planting speed was 0.023~0.040. A proportionality between the speeds of the feed shaft and the planter was maintained without any significant effects of hill distance setting.

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Table 1. Discrepancy in velocities of the fifth wheel and feed shaft.

Planting velocity (m/s)	Velocity of 5th wheel (rpm)	Velocity of feed shaft(rpm)		Error (%)
		Theoretical value	Experimental value	
0.5	23.9	40	39.5	1.25
0.6	28.6	48	48.4	0.83
0.7	33.4	56	56.9	1.63
0.8	38.2	64	63.8	0.31

Table 2. Errors in measured hill distance.

Hill Distance Set (cm)		13				15				17			
Planting Speed (m/s)		0.57	0.63	0.85	1.01	0.55	0.77	0.86	1.04	0.48	0.67	0.80	1.04
Measured Hill Distance	Average (cm)	12.4	13.1	13.3	13.6	14.6	14.8	15.4	16.5	16.2	16.6	17.2	18.4
	Standard Deviation (cm)	1.23	1.32	1.46	1.79	1.76	1.85	1.93	2.48	2.06	2.16	2.39	2.58
Error (%)		4.5	0.4	2.5	4.7	2.7	1.1	2.7	9.7	4.5	2.1	1.4	8.3

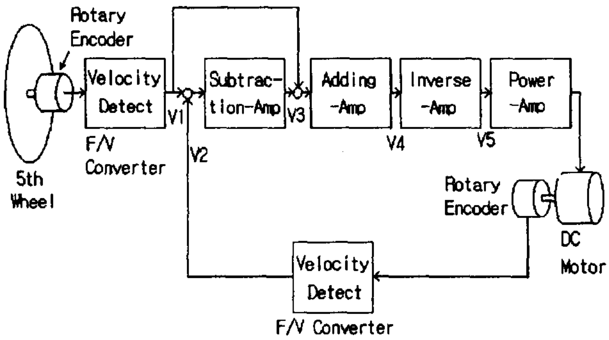

Fig. 1. Block diagram of a motor speed control system.

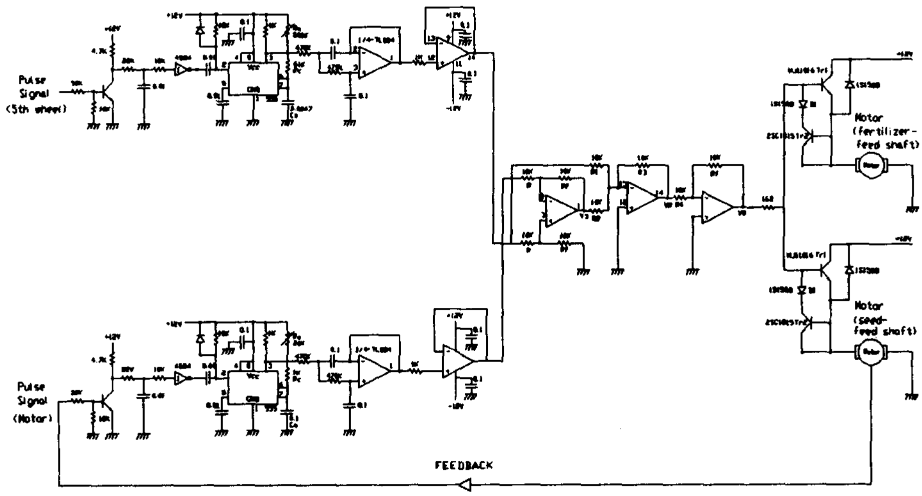

Fig. 2. Circuit diagram of the control unit.

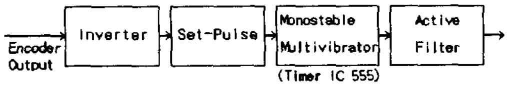

Fig. 3. Block diagram of the F/V converter.

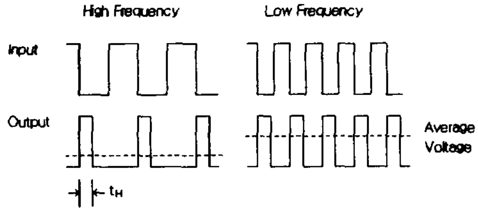

Fig. 4. Relation of input and output in monostable multivibrator.

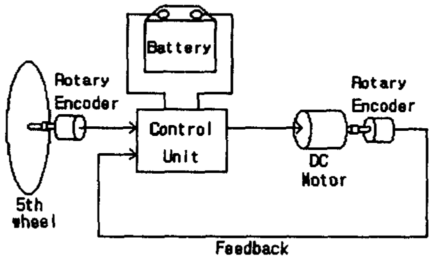

Fig. 5. Schematic diagram of the feed shaft driving system.

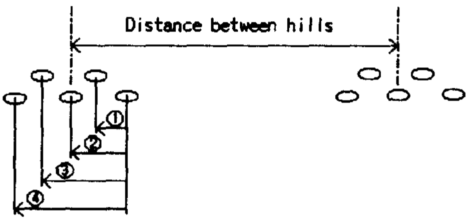

Fig. 6. Measurement of hill distance.

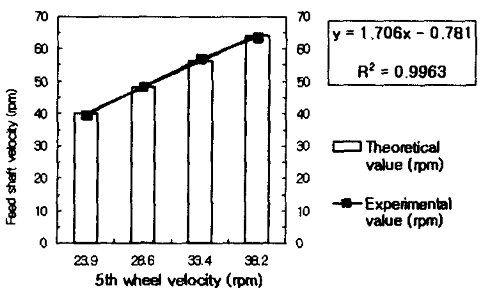

Fig. 7. Relation between the fifth wheel and feed shaft velocities.

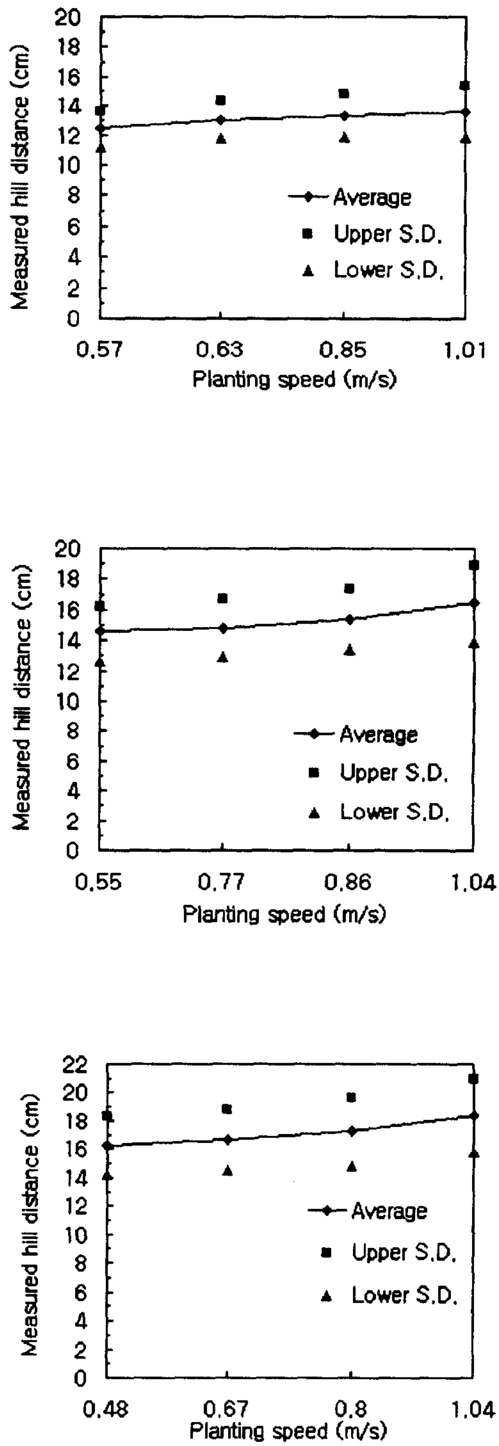

Fig. 8. Relation between the measured hill distance and planting speed.