STUDY ON A CONTACT TYPE SENSOR FOR DETECTING HEIGHT FROM GROUND SURFACE

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ABSTRACT

The tillage operation by rotary implements is widely done in Korea. In the case of rotary implements, the tillage depth control system is one of important implement control systems. A contact type-sensor for measurement of the ground height was designed and fabricated to evaluate the possibility of application of the sensor on the tillage depth control system. Indoor experiments were conducted to obtain static and dynamic detection characteristics of the sensor under various conditions; 1) several moisture contents for four soil samples, 2) two soil surfaces with a designed configuration, 3) four heights of the sensor from the soil surface, 4) five traveling speeds of the carrier on which the sensor was attached, and so on. The experimental results showed the detection characteristics of the sensor sufficient as the ground height sensor of the tillage depth control system.

INTRODUCTION

The tillage operation by agricultural tractors in Korea is mainly done by plow and rotary implements. In the case of rotary implements, the implement attitude and tillage depth control systems are given special importance. The attitude control system for keeping horizontal attitude of implements even on an uneven field is widely being utilized for tillage operation in Korea. Especially, tractors sold in Japan are generally equipped with the tillage depth control system as well as the implement attitude control system. The swing angle of the leveling plate hinged on the cover of the rotary implements is used as the feedback signal for the tillage depth control. The tillage depth is well controlled by the control system under a normal operational condition. However, when an excessive pitching is given to a tractor due to uneven ground surface and sinkage of tractor wheels, a constant tillage depth cannot be attained because of the response delay of the hydraulic unit, which consists of the control system.

Studies on the tillage depth control system were mainly done in Japan, which the rotary implements are widely utilized for the tillage operation. Satow *et al.* (1985) reported a study on the plow depth control system based on the distance measured from the ground surface utilizing an ultrasonic sensor. Jiang *et al.* (1992) reported a study on the mixed control system including the tillage depth control. They detected the angle of lift arm and pitching for the tillage depth control. Lee *et al.* (1995) reported the study on the attitude and tillage depth control system based on the implement slope angle that is measured by potentiometers attached on the implement. Lee *et al.* (1996, 1998, and 2000) carried out the study on the tillage depth control system for rotary implements. They detected the angle of lift arm, pitching and ground height based on non-contact optical and ultrasonic sensors.

To realize the more accurate tillage depth control, the ground height as well as the angle of lift arm and pitching should be detected. The objective of this study are; 1) to design and fabricate the contact type - ground height sensor, 2) to investigate the detection characteristics of the sensor through indoor experiments, and 3) to evaluate the possibility of application of the sensor as the ground height sensor of the tillage depth control system.

PRINCIPLE OF SENSOR

The sensor is composed of two main units; a driving unit and a controller as shown in Fig. 1. The driving unit consists of a bar for detection of the ground surface, a DC motor (RS-755SH, Mabuchi) for driving the detection bar, a potentiometer (2 kΩ) for the displacement measurement of the detection bar. The potentiometer is linked to the detection bar by two linkages (a upper and lower link). The detection bar is linked to the pulley, which is fixed on the axle of the DC motor, by a string.

In the first, the motor lifts up the detection bar, and is turned off when the detection bar reaches to the reference position. And then, the bar goes down along a slider by a self-weight and the spring, which is fixed between the bar and the slider. The sensor outputs the output voltage of the potentiometer, when the bar reaches on the soil surface. At the same time, the motor is turned on and lifts up the detection bar. The output voltage of the sensor is proportional to the displacement of the detection bar

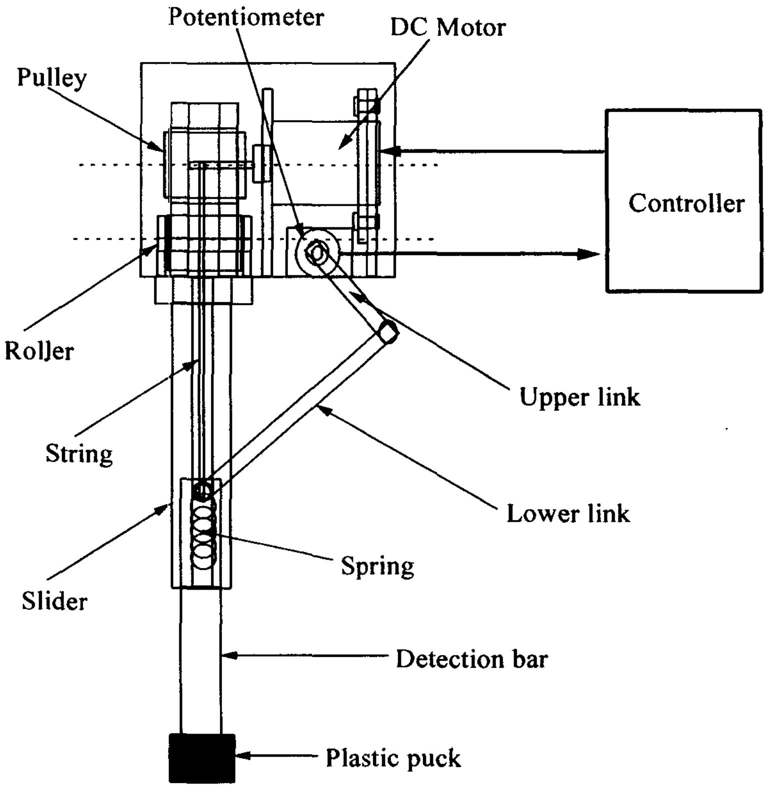

Fig. 1. Schematic diagram of sensor

MATERIALS AND METHODS

1) Static experiments

Static experiments were conducted to investigate the effect of such factors as types of soil, moisture contents and the heights of the sensor on the detection characteristics of the sensor.

Preparation of soil samples

Four kinds of soil samples were used in the experiments. The composition and classification of them are shown in Table 1.

Table 1. The composition and classification of soil samples

		Soil A	Soil B	Soil C	Soil D
Particle size dist.	Sand	70%	74%	95%	34%
	Silt	19	17	2	46
	Clay	11	9	3	20
Soil type		Sandy loam	Loamy sand	Sand	Loam

The moisture contents of soil samples were 0, 10, 20 and 30%.

Experimental procedure

The experiments were carried out at different heights (4, 9, 14 and 19 cm) of the sensor from the soil surface and moisture contents (0, 10, 20% for the soil A, C and 0, 10, 20, 30% for the soil B, D). The output voltage of the sensor was measured under the above conditions.

2) Dynamic experiments

In order to investigate the effect of an uneven ground surface and traveling speed on the detection characteristics of the sensor, dynamic experiments were conducted indoors.

Experimental apparatus

Fig. 2 and Fig. 3 showed the experimental apparatus. As shown in Fig. 2, it is composed of a soil bin, a carrier, an AC motor for traveling the carrier and a mini soil bin for constructing the configuration of soil surface. The soil bin is equipped with rails and pulleys, which are attached on both ends of it, for traveling the carrier. Both ends of the carrier is linked by the string through pulleys. The pulley is connected with the axle of the AC motor by a chain. The carrier is traveled by driving of the motor and the speed of it is adjusted by adjusting the rotation speed of the AC motor. The sensor is attached on a sensor-supporting frame fixed on the carrier. The fifth wheel with a tachogenerator is attached on the carrier for measuring the traveling speed of the carrier during the experiments.

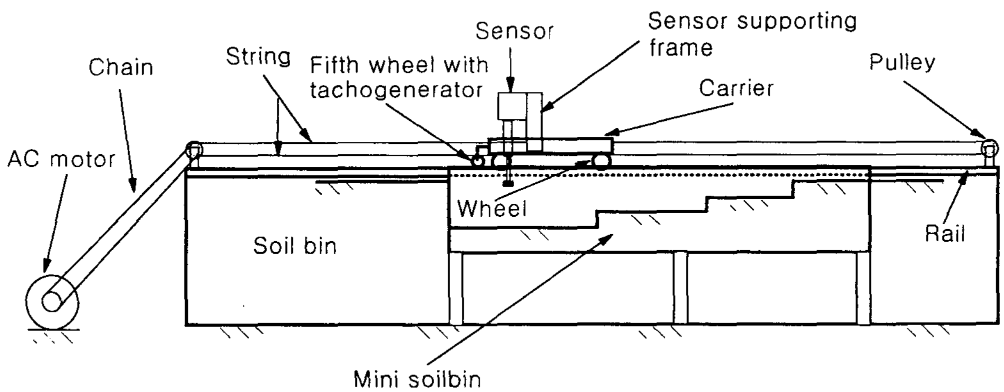

Fig. 2. Schematic diagram of the experimental apparatus

Experimental procedure

The soil sample B was typically used for the experiments. Two types (step and sine wave) of configurations of the soil surface were constructed in the mini soil bin (300cm length, 30cm width, and 26cm high) for the experiments. In the experiments of the step configuration, four steps were constructed in the mini soil bin. The heights of the sensor from each step of soil surface for the experiments were 18, 14, 11 and 6cm. In the sine wave experiments, the amplitude of the soil surface were ± 8cm and the height of the sensor from the reference surface were 11cm. Both experiments were carried out at five traveling speeds (1, 2, 3, 4 and 5km/h).

All output signals from the sensors were recorded on an analog data recorder during the experiments. The data was processed by using a computer after the experiments.

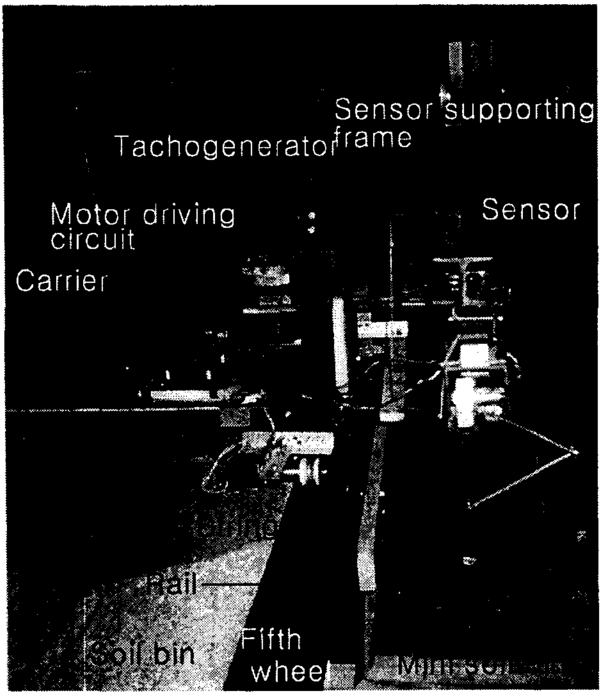

Fig. 3. Photo of the experimental apparatus

RESULTS AND DISCUSSION

1) Static experiments

The calibration result of the sensor was plotted in Fig. 4. The high linear relationship (R^2=0.9945) was observed between the height of sensor from the soil surface and the output voltage as shown in Fig. 4.

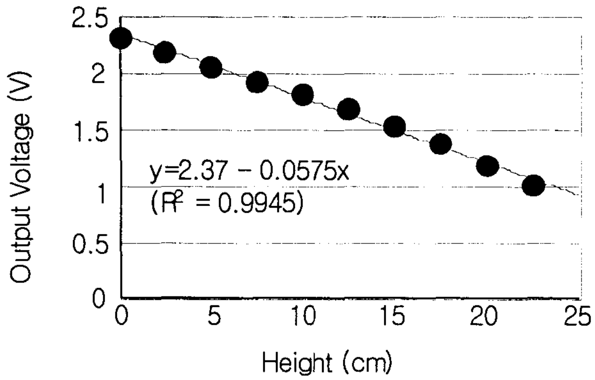

Fig. 4. The calibration results of the sensor

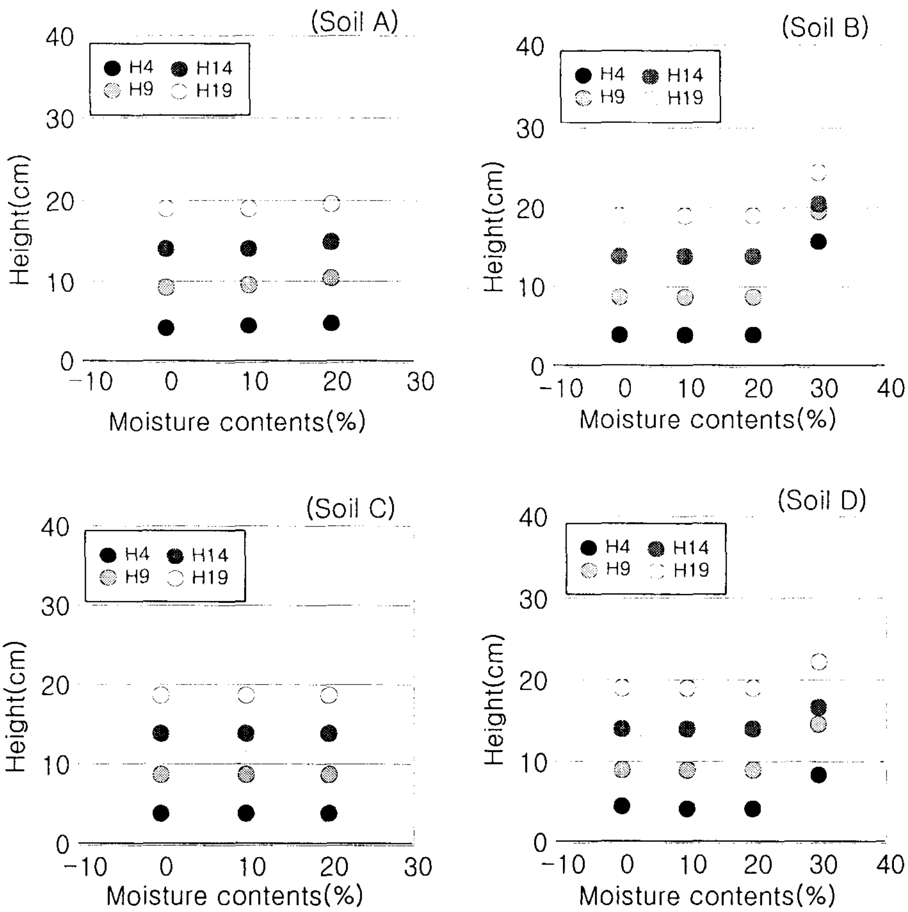

Fig. 5. Effect of soil types with different moisture contents and sensor heights on detection characteristics of the sensor

Fig. 5 showed the experimental results at different heights (4, 9, 14 and 19 cm) of the sensor and moisture contents (0, 10, 20 and 30%) for four types of soil samples. As shown in Fig. 5, the measurement errors were scarcely observed in spite of different soil types, soil moisture contents and heights of the sensor in the case of the soil A and C. However, large errors were observed at 30% of moisture content in soil B and D. The soil B and D reached to the state of saturation at 30% and the soils became the soft state. Therefore, it is considered that the errors were caused due to the penetration phenomenon of the plastic puck, which was attached on the bottom of the detection bar, on the sampled soils.

2) Dynamic experiments

Fig. 6 showed the experimental results for the step configurations of soil surface at five traveling speeds (1, 2, 3, 4 and 5km/h) of the carrier. As shown in Fig. 6, the sensor accurately detected the height from the soil surface along the configuration of soil surface that was constructed in the mini soil bin for the experiments. The standard deviation for step experiments was shown in Table 2 and was within the ranges of 0.1 - 0.5cm. The results for the sine wave experiments were showed in Fig. 7, the heights well were detected by the sensor in spite of the uneven soil surfaces and the changes of the traveling speeds.

Table 2. The standard deviation in the step configuration experiments

Speed	Standard deviation (cm)			
(km/h)	18cm	14cm	10cm	6cm
1	0.33	0.23	0.44	0.39
2	0.15	0.25	0.20	0.51
3	0.17	0.25	0.15	0.21
4	0.14	0.14	0.15	0.19
5	0.19	0.13	0.03	0.34

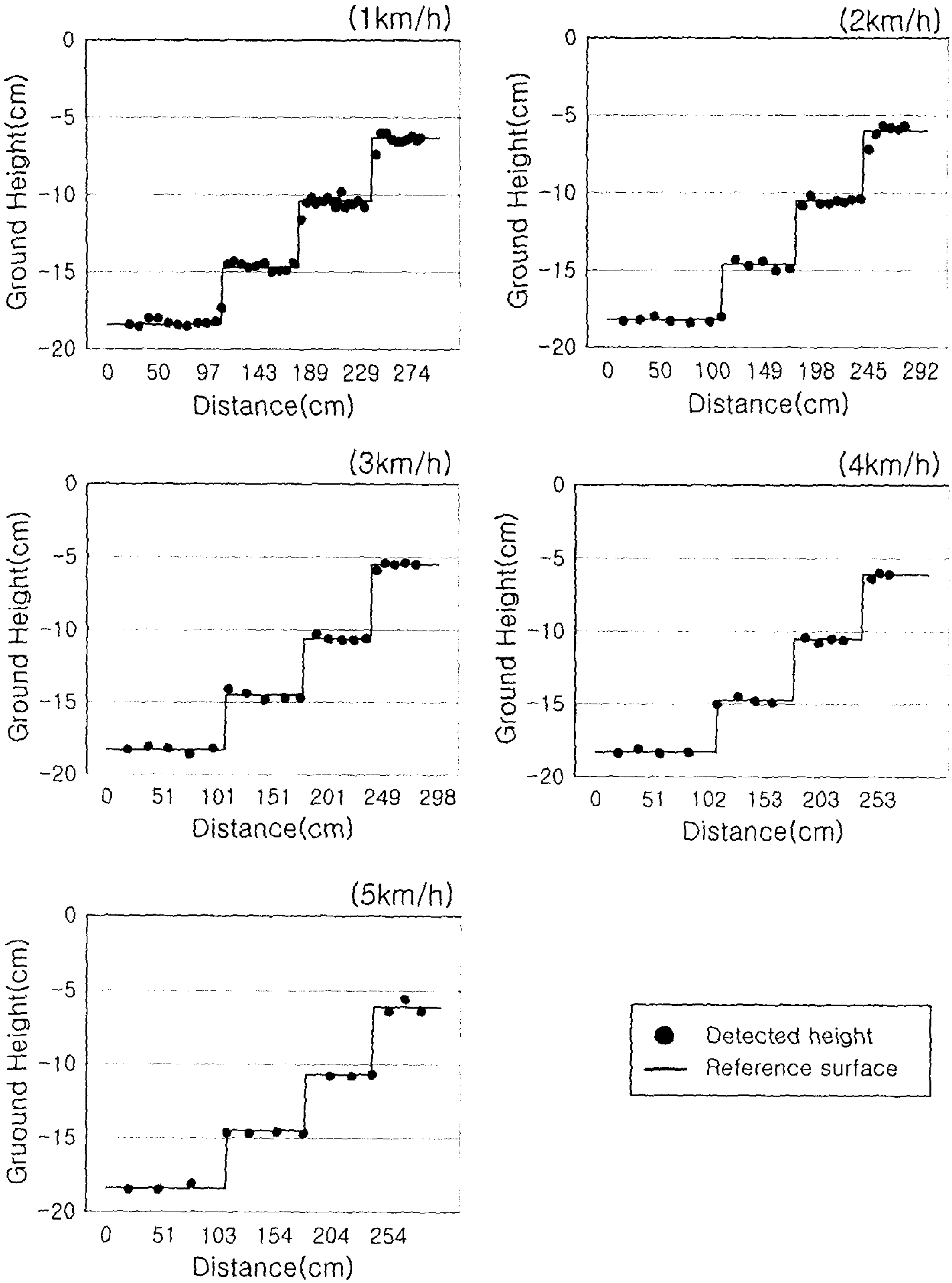

Fig. 6. Results for the the step configuration experiments

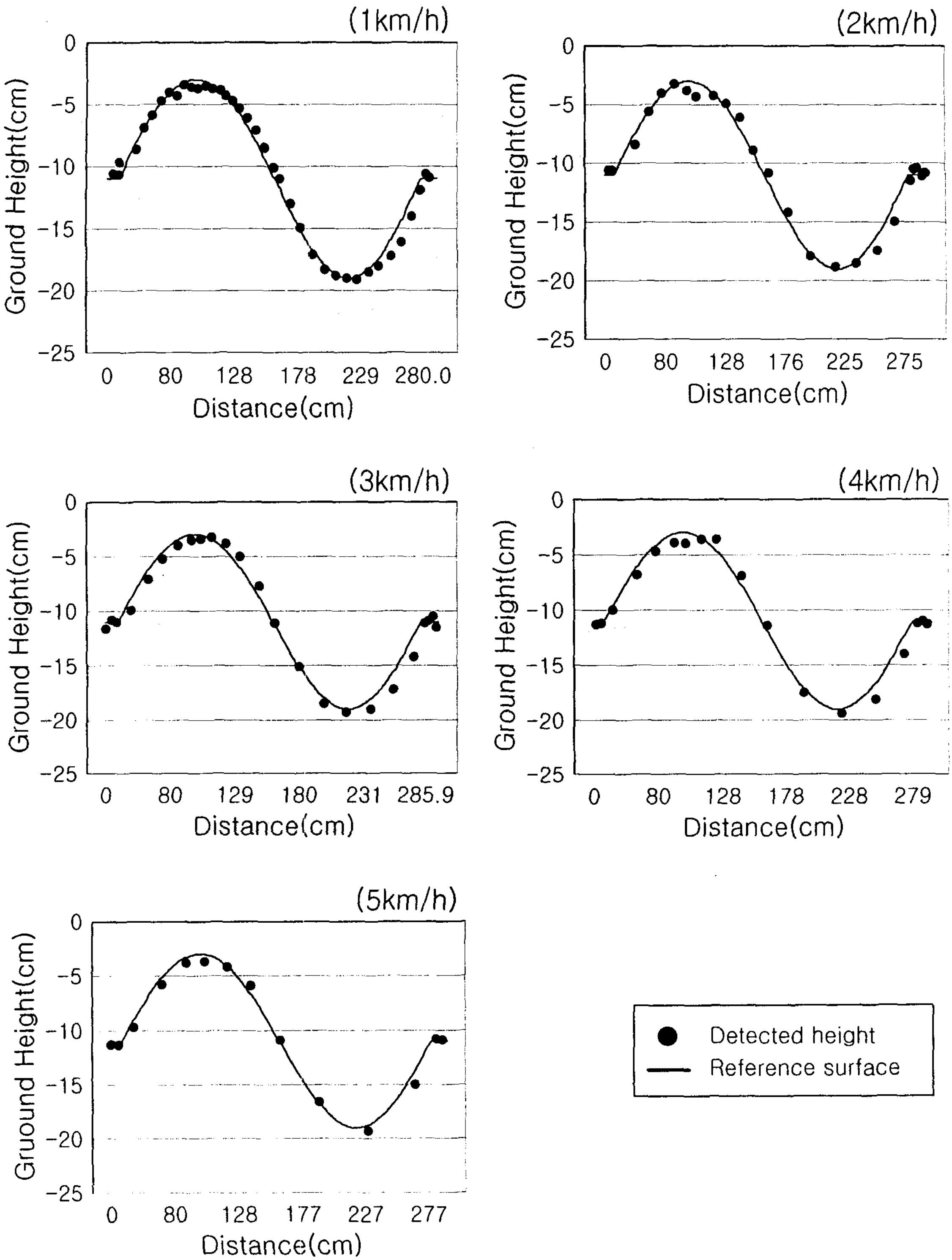

Fig. 7. Results for the sine wave configuration experiments

(reference height: 11cm, amplitude: ± 8cm)

CONCLUSION

The contact type ground height sensor was designed and fabricated, and the indoor experiments for investigating the detection characteristics of the sensor were carried out under such various conditions as height of sensor from soil surface, soil type, moisture content, configuration of the soil surface, traveling speed of the carrier, and so on. The results can be summarized as follows;

1. Detection characteristics of the sensor were not affected by the heights of the sensor and soil types. However, in the case of loam type soils(soil B and D), large measurement errors were observed due to the penetration of the plastic puck on the sampled soil, when the soils reached to a state of saturation (at 30% of moisture contents).

2. The sensor accurately detected the height from soil surface in spite of uneven soil surfaces and the change of the traveling speeds.

3. In conclusion, the experimental results showed the sufficient possibility of application of the sensor as the ground height sensor of the tillage depth control system. But the problem for the loam type soils in a state of saturation should be considered in the future.

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