Study on the Counting Sensor for Threshing Control*

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Abstract

Harvesting rice using a head-feeding combine, the amount of grain that passes through the threshing unit varies in accordance with the cutting width of the combine, the field speed of the combine, and the field’s yield. In this study, a counting sensor with a piezoelectric element was attached inside the grain tank of a head-feeding combine in order to monitor the grain feed rate in harvesting operations. The objectives of this study are to reduce grain loss and improve the separation of grain from chaff by controlling the threshing operation. As a result, it was found that there was a significant correlation between the sensor’s output and the yield rate (R=0.92 and 0.97). It was also found that the sensor was a very precise and reliable device for controlling threshing operations.

[Keywords] Threshing Control, Grain Feed Rate, Piezoelectric Element, Counting Sensor, Head-Feeding Combine

I Introduction

Harvesting rice using a head-feeding combine, the amount of grain that passes through the threshing unit varies in accordance with the cutting width of the combine, the field speed of the combine, and the field’s yield. For example, harvesting under unfavorable conditions, such as in a wet field or when the plants are lodged, it is difficult to keep high field speed, resulting in a low grain feed rate. On the other hand, harvesting in a field with a high yield, results in a high grain feed rate. In either situation, grain loss may increase due to excessive air blasting by the fan, or straw and chaff may remain in the grain due to insufficient air from the fan (Auernhammer and Schueller, 1999). It is necessary to keep grain losses and other crop material which consists of mainly chaff and broken straw pieces within certain levels, regardless of changes in the grain feed rate. Therefore, operators must continually monitor the grain feed rate and accordingly alter the speed of the cleaning fan and the angle of the sieve in the cleaning unit. If the operator can instantly monitor the grain feed rate, the condition of the cleaning unit within the threshing unit can be estimated, and as a result, the most appropriate fan speed and sieve angle can be set. Grain losses and other crop material in the grain will thus be reduced.

Yield sensors can be used to monitor the amount of grain. Yield sensors are often used to draw up yield maps in precision agriculture. Some of these sensors are a potentiometer-type (Auernhammer and Schueller, 1999) and others are a load-cell-type (Shoji and Kawamura, 1998., PAMI, 1999., Chosa and Kobayashi, 1999a, 1999b., Makino et al., 2000., LEE et al., 2000a, 2000b., Makino et al., 2001). Although load-cell sensors are already commercially available (PAMI, 1999), they are not always appropriate devices for obtaining information necessary for controlling the threshing operation. This is reason for taking a long time to obtain results (Makino et al., 2000) and frequent calibration to maintain the required level of accuracy is also needed (Makino et al., 2000). In addition, the noise is generated due to vibration (LEE et al., 2000a), sensors are difficult to handle in general, some sensors are not accurate when the feed rate is low (Makino et al., 2000), and they are often cost prohibitive. Thus, numerous issues of these sensors should be resolved for practical application. In this study, we developed a new sensor to monitor the grain feed rate in order to control threshing operations. We also devised a system for using this sensor. In developing the sensor, we intended to keep grain losses due to changes in the feed rate within a certain level. In this paper, we report on the outline of the piezoelectric counting sensor to monitor the grain.

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feed rate and the detection accuracy of the sensor.

II Tested machine and methods

1. Outline of the counting sensor

Figure 1 shows the counting sensor. The sensor consists of a piezoelectric element and a signal output circuit. When the grain hits the sensing area in the center of the sensor (approximately 230 mm²), the sensor generates a signal for 1~1.5 ms. Output voltage will change to 0 V from 5 V of no output signal. Although it is necessary to face the sensor in the direction of the incoming grain, considerable flexibility is available in respect to the location of the sensor because of its compact size (diameter: 33 mm, thickness: 15 mm). In addition, as signals are generated only by the impact of the grain on the sensing area; the sensor is not influenced by the vibration of the combine.

2. Data collection using the tested machine

In indoor tests, the sensor’s output was recorded directly by the data recorder every 500 μs. Field tests were conducted in Oita Prefecture in November 1999 and in Okayama Prefecture in November 2000. In the field tests conducted in Oita Prefecture, the field speed of the combine was measured using a pulse signal from a photoelectric sensor attached to the end of the shaft of the gearbox for traveling. A crop sensor using the switch with actuator was attached at the beginning of the pathway of crop in the header for detection of passing the crop, and a stopwatch was used to measure the time taken to harvest a designated area of the field. The counting sensor itself was attached within the grain tank facing the grain that entered from the grain auger, as shown in Figure 2. The grain count was recorded in the memory of the sensor every 200 milliseconds. This data was then recorded on a computer with a sampling cycle of 250 ms. After each test, grain was discharged from the grain tank through the grain unloader, and the grain was weighed on a spring scale. In the tests conducted in Okayama Prefecture, the counting sensor was attached approximately 100 mm further behind from the entrance of the incoming grain (Figure 3) in order to determine whether the accuracy of detection would depend on the position of the sensor. In addition, a potentiometer was attached on the support of the straw holder at the threshing unit and the stroke was measured in order to examine the relationship between the amount of crop and the grain feed rate. The output signal from each sensor was directly recorded by a data recorder every 500 μs.

3. Methods

The sensitivity of the sensor was tested indoors. The sensor was fixed on a level surface with the sensing area facing upwards. Rice grains were dropped from the height of 300 mm onto the sensor and the output signals were then recorded. The rice planted in the field test (in Oita Prefecture) was Yumehikari.
The water content of the grain in the test was 18%. There were 18 ears per plant and 110 grains per ear on average. The tested machine was a head-feeding combine (three rows) produced by Company I. Eight harvesting operations were carried out at a specified speed each time (from 0.6 to 1.1 m/s) in order to observe the changes in the grain feed rate. The machine passed along three or four rows at a constant speed, for approximately 38 m per harvest. In addition, two harvesting operations were conducted in which the direction of the machine was varied three times during each harvest in order to measure the time required to return to the head land. The average time required to change direction was 12 seconds. Then another four harvesting operations were carried out in which the machine was stopped about halfway for 12 seconds.

The rice planted in the test field (in Okayama Prefecture) was Akitakomachi. The water content of the grain in the test was approximately 17%. There were 22 ears per plant and 100 grains per ear on average. Seven harvesting operations were carried out at different speeds (from 0.5 to 1.1 m/s) in order to observe the changes in the grain feed rate. The machine passed along three rows each time for approximately 13.2 m per harvest.

III Results and discussion

1. Indoor test

Figure 4 summarizes the output signals from the counting sensor. Each signal indicates a hit on the detecting area of the sensor due to grain impact. The average mass of a grain used in the test was 0.025 g. The velocity of grain hitting the sensing area was thought to be no more than 2.4 m/s in this test. It was found that the sensor was able to detect to an approximate accuracy of $7.4 \times 10^{-5}$ J. It is therefore thought that the counting sensor is capable of counting grains discharged from the auger at a velocity of 6.0 m/s.

2. Field tests

The results of the harvesting experiments conducted in Oita Prefecture are shown in Figure 5 and Figure 6. Figure 5 shows the recorded data when the machine passed along four rows with a field speed of 1.1 m/s. The increase in the voltage of the crop sensor indicates when crop started to enter the header. Approximately 10 seconds later, the counting sensor starts to output signals. This shows that the grain had reached the grain tank. Another 10 seconds later, the grain feed rate starts to fluctuate within a certain range. This indicates that the amount of incoming grain equals the amount of grain that had passed from the threshing unit into the tank. The feed rate remained the same for approximately 10 seconds after the last straw passed, and decreased during the subsequent 10 seconds. The last 10 seconds shows that all of the grain was discharged from the tank. Figure 6 shows the recorded data when the harvesting operation on three rows of cutting was carried out with a field speed of 1.1 m/s, stopping for 12 seconds halfway (which represents the change in direction that would occur in a practical operation) and re-starting at the speed of 0.6 m/s. As was seen in Figure 5, the counting sensor starts to output signals for approximately 10 seconds after the crop first begins to enter the header. This shows that the grain had reached the grain tank. After another 10 seconds, the figure shows that the grain feed rate starts to fluctuate within a certain range. During the last 10 seconds, the feed rate decreased and all of the grain was discharged in the tank. The slight time lag occurred by the low feed rate appears due to changes in the conveying speed at the header in accordance with the field speed of the combine. However, the time required for grain to reach the tank after being threshed was the same, regardless of the feed rate. The changes in the feed rate due to the field speed were clearly illustrated by this count. The faster the field speed, the higher the count, and the slower the field speed, the lower the count. The grain-count, as expressed by the counting sensor, thus varies in accordance with the field speed.
Fig. 5 Results of the Oita experiments in continuous harvesting

Fig. 6 Results of the harvesting experiments in which the machine was stopped about halfway for 12 seconds

Figure 7 shows the relationship between the count (from the beginning of the test to the end) and the mass of grain harvested in Oita. This shows that there is a significant correlation between them (R = 0.92).

Figure 8 shows the results of the harvesting experiments conducted in Okayama Prefecture. As the position of the counting sensor had been changed, the number of output signals was lower than in the test in Oita. However, changes in the feed rate had the same tendency as in the test case in Oita. There was a lower correlation between the stroke of the straw holder and the grain feed rate because of the force of the straw holder spring in the area of low grain feed rate. Figure 9 shows the relationship between the count (from the beginning of the test to the end) and the weight of grain harvested. Although the total yield was low due to the small size of the tested area, it was found that there was a significant correlation between the count and the weight of grain harvested (R = 0.97). The yields in each test were within 5.9 kg to 9.1 kg.

Table 1 shows the number of output signals from the sensor and the yield of the tested area. The sensor generates signal for 1~1.5 ms. Since grain continued hitting the sensor during this time, the count per
specified weight does not greatly influence the accuracy of detection. Thus, it is believed that the counting sensor is capable of accurately detecting grain feed rate.

### IV Conclusion

We developed a sensor to monitor grain feed rate in order to control the threshing operation. We also constructed a system for using the sensor. In developing the sensor, the purpose was to reduce grain loss due to changes in the feed rate, and to improve the separation of grain from chaff. In this paper, an outline of the piezoelectric counting sensor to monitor grain feed rate was given. Moreover, the detection accuracy of the sensor was reported.

The results of this study can be summarized as follows.

1) An indoor test was conducted using a sensor only (i.e. not attached) in order to ascertain the sensitivity of the sensor, and the probability of the sensor attached in a head-feeding combine used for detecting grain was examined.

2) The harvesting operations were carried out using a counting sensor attached within the grain tank. It was found that alterations in the grain feed rate could be accurately monitored.

3) The sensor was attached in a different position in order to examine differences in accuracy of detection due to positioning.

In conclusion, through these tests it was found that it is possible to monitor changes in the grain feed rate when the counting sensor is attached within the grain tank of a head-feeding combine. It was also confirmed that the level of accuracy obtained is adequate for practical use. This study intended to reduce grain loss and other crop material which consists of mainly chaff and broken straw pieces by controlling the threshing operation. Grain loss and other crop mater-
rial are caused by changes in the grain feed rate during operation. It was clearly shown that this sensor is a very precise and reliable device for controlling the threshing operation.

References
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[Research Paper]

[Keywords] Precision Measuring, Grain Flow, Performance of Combine Harvester

[Comments]

[Comment from the Reader]
In this report, the authors present a comparison of three yield monitors and GPS receivers. The study shows that the sensors are highly precise and reliable for controlling the threshing operation.

[Comment on the Author's Opinion]
The authors discuss the importance of yield measurement systems in precision agriculture. They highlight the significant impact of changes in grain feed rate during operation. The study clearly demonstrates that the sensor is a precise and reliable device for controlling the threshing operation.

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