Property testing for fertilizer feeder based on numerical analysis

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Abstract: In order to test properties of a fertilizer feeder, the authors designed a testing system based on single-chip control in the computer platform. The actual working conditions of a fertilizer feeder in the field were simulated by altering the rotating velocity of feeder axle through the stepper motor. The discharging volume data of the fertilizer were acquired through the sampling of the pressure sensor. Eventually the fertilizer flow simulacrum was acquired from the results of the numerical analysis. Compared with traditional means of the optoelectronic sensor and image processing, the testing system illustrated in this paper can evaluate the discharging uniformity of fertilizer feeder with simpler hardware structure and less error.

Keywords: fertilizer feeder property, pressure sensor, numerical analysis

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1 Introduction

In the past five decades agriculture has seen great progress with the development of mechanization and automation. However, fertilizer and pesticide abusing still exists as the area of ploughed land increases. Agriculture development at the price of the overuse of fertilizer and pesticide has brought a series of problems including environment contamination, water wasting, and biosphere damage[1]. To convert the trend to a positive direction, the concept of Precision Farming was raised and technology developed[2-5]. The content of precision farming depends on in-field variables. It is about doing the right thing in the right place, the right way and the right time. It requires the use of new techniques, such as Global Positioning System (GPS), satellites or aerial images, and Geographical Information System (GIS) management tools to assess and understand variables. Collected information may be used to more precisely evaluate optimum sowing density, to estimate the needed amount of fertilizers and other inputs, and to more accurately predict crop yields. It seeks to applying flexible practices to a crop according to local soil/climate conditions, and may help better assess local situations in disease control or lodging.

Precision fertilization technology[6,7] is one of the concrete applications of precision farming. It holds that the amount and ingredients of fertilizer should be altered according to mellowness levels and growth condition of the crop in a small piece of experimental field. Thus the advantages of precision farming such as reducing the amount of fertilizer, increasing the efficiency of fertilizing, and alleviating the water resource pollution can be achieved[1]. Precision fertilization has become an increasingly important component in precision agriculture. The fertilizer feeder is the core component of a precise fertilizing facility and its properties are critical in the success of precise fertilization. How to accurately examine the quality of a fertilizer feeder is a prerequisite in achieving precise feeding and conducting precise fertilizer feeder research and design.

In general, the methods for testing the performance of precise fertilizer feeder are similar to those of a seeding

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machine except for some differences in performance indices. The seeding machine performance index mainly includes the interval between two consecutive seeds and the number of seed possibly omitted, which are primarily examined by means of image, vision sensor and photo electricity, etc.[8-12]. While the performance index puts emphasis upon the uniformity and the amount of fertilizer and neglects the fertilizer continuity. Thus the method cannot be adopted to test the performance of the fertilizer feeder. This paper introduces a new means by which the discharging volume of the fertilizer is obtained by recording the sampling frequency and pressure sensor data, while the fertilizer flow simulacrum is acquired from the results of numerical analysis.

2 Testing theory

The fertilizer feeder is driven by the stepper motor, and the fertilizer falls on the receptacle of the pressure sensor continuously. With the accumulation of fertilizer, the pressure (P) tested by the pressure sensor increases gradually, the value of which equals to the gravity of the fallen fertilizer (G). (Because the distance between the fertilizer feeder nozzle and the receptacle of the pressure sensor is small, kinetic energy produced by the falling fertilizer can be neglected.). Consequently, the amount of fallen fertilizer (M) can be calculated through the data measured by the pressure sensor.

$$M = \frac{G}{g} = \frac{P}{g} \tag{1}$$

Since the total mass of fertilizer is time-dependent, M is a function of t, written, $M = f(t)$. Then from $t_{i-1}$to t_i, the increment of fertilizer (ΔM_i) is

$$\Delta M_i = \frac{f(t_i) - f(t_{i-1})}{\Delta t} \tag{2}$$

Where $f(t_i)$ denotes the total amount in t_i. $\Delta t = t_i - t_{i-1}$ denotes sampling interval. When $\Delta t \to 0$,

$$\Delta M_i = f'(t_i) \tag{3}$$

Since function $M = f(t)$ is continuous on $[t_0, t_n]$, and for each $t = t_0, t_1, \ldots\ldots, t_n$, M has the value $M_0, M_1, \ldots\ldots, M_n$, respectively, the function can be figured out through interpolation. The cubic spline interpolation is taken, because the cubic spline procedure is sufficient to ensure that the interpolation not only is continuously differentiable on the interval, but also has a continuous second derivative [13,14].

$$f(t) \approx P_2(t) = \sum_{k=i-1}^{i+1}\left[y_k \prod_{\substack{j=i+1 \\ j\neq k}}^{i=1}\left(\frac{t-t_j}{t_k-t_j}\right)\right] \tag{4}$$

Where $P_2(t)$ denotes piecewise quadratic interpolation of function $M = f(t)$ on $[t_0, t_n]$.

And then

$$\Delta M_i = f'(t) \approx P_2'(t) = \frac{M_i - M_{i-1}}{\Delta t} \tag{5}$$

Suppose the farming machine velocity is $V_i = v(t_i)$ at the sample point t_i.

$$v(t) \approx Q_2(t) = \sum_{k=i-1}^{i+1}\left[v_k \prod_{\substack{j=i+1 \\ j\neq k}}^{i=1}\left(\frac{t-t_j}{t_k-t_j}\right)\right] \tag{6}$$

Where $Q_2(t)$ denotes piecewise quadratic interpolation of function $V_i = v(t_i)$ on $[t_0, t_n]$.

Then the total fallen fertilizer X at t_i is

$$X = \frac{\Delta M_i \Delta t}{v(t_i)\Delta t} = \frac{p'(t_i)}{q(t_i)} = x(t_i) \tag{7}$$

So at the distance S_i the farming machine has run , the instantaneous fertilizer Y is

$$Y = x[s^{-1}(t)] \tag{8}$$

Where $$s(t) = \int_o^t v(z)dz = \int_0^t q_2(z)dz \tag{9}$$

3 Testing system structure

3.1 Hardware structure

According to the actual on- site working conditions of the farming machine, the system of data analysis was designed to contain 80C52 Single Chip Micyoco (SCM), a pressure sensor, a stepper motor, and a computer, etc. In the SCM module, Timer 0 is used to produce impulse cycle to drive the stepper motor, Timer 1 is taken as a timing interrupt to scan the pressure sensor data, and Timer 2 is selected as the baud generator rate aiming at serial communication with computer. In the stepper motor module, the motor rotating speed is controlled to simulate the practical conditions of farming machine working in the fields, in order to test whether the fertilizer feeder is influenced by the farming machine velocity.

3.2 System software design

The system software is composed of four modules:

the initialization module, the testing module, the calculating module, and the help module. In the initialization module all parameters are set, including the sampling cycle of the pressure sensor, the period of the sampling process, the average fertilizer consumption, and the speed of the farming machine. In order to function coordinately every parameter has its own value range. Only after the initialization module' work is completed, the testing module is allowed to start with the computer sending parameter data through the serial communication to SCM, which then starts following programs. A progress bar is used to display testing progress. In the calculating module, final results are obtained from the data acquired in the testing module using Formula (4). The help module provides users' manual which guides operators use the testing system.

3.3 System program flow

The program flow chart is shown in Figure 1. First of all, every parameter must be fixed because concrete experimentation requires that fixed data be fed into the computer after system initialization. These parameters include the system running duration, the rotating speed of the stepper motor at various times and sampling frequencies. Secondly, SCM starts the stepper motor program upon the receiving of the instruction from the computer through the serial port. Meanwhile, data measured by the pressure sensor are transferred to the computer using the TIME 1 interrupt scanning. Eventually, the computer processes the acquired data, and obtains results which will later be displayed or printed.

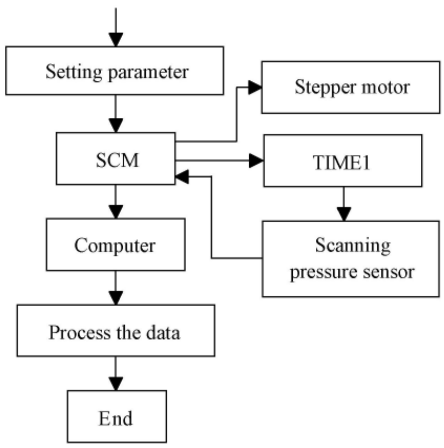

Figure 1 Flow chart of the system program

4 Verifying experiment

4.1 Experimentation facilities and sample

In order to evaluate the performance of the system, the experimentation facilities and sample were chosen according to the actual conditions that the farming machine worked in the fields. The experimentation was conducted in the farming machine laboratory of Henan Agricultural University in September 2008. The external fertilizer feeder was selected as the tested object. The compound fertilizer came from the Ruikesiwang Limited Company of Shandong. The average fertilizer consumption was 300 kilograms per hectare. The speed of farming machine was about 4.5 to 5.5 kilometers per hour, which means that the stepper motor rotating velocity was around 33 to 90 r/min.

4.2 Parameter determination

In this experiment, the sampling cycle of the pressure sensor was set to be 0.5 s, and the period of the sampling process 30 s. Every three seconds, the rotating velocity of the stepper motor was readjusted. The velocity in the whole process was 33, 35, 40, 45, 50, 55, 60, 55, 60, and 55 r/min.

4.3 Results of experimentation

The amount of discharging fertilizer for every sample was obtained from the pressure sensor, which was shown in Table 1. Numerical analysis of those data was conducted by computer and then demonstrated in the fertilization simulating chart which was shown in Figure 2.

Table 1 Test results

Time	M/g	Time	M/g	Time	M/g	Time	M/g
t_0	0	t_{15}	113.2	t_{30}	292.6	t_{45}	525.3
t_1	0	t_{16}	122.1	t_{31}	306.9	t_{46}	540.2
t_2	0	t_{17}	134.5	t_{32}	321	t_{47}	556.8
t_3	0	t_{18}	145.9	t_{33}	335.2	t_{48}	572.4
t_4	8.6	t_{19}	157.3	t_{34}	346.8	t_{49}	588.0
t_5	17.5	t_{20}	168.6	t_{35}	366.4	t_{50}	603.7
t_6	26.9	t_{21}	180.2	t_{36}	382.1	t_{51}	619.3
t_7	36.2	t_{22}	189.6	t_{37}	397.7	t_{52}	630.2
t_8	45.6	t_{23}	202.4	t_{38}	413.3	t_{53}	647.2
t_9	55.1	t_{24}	215.2	t_{39}	429.1	t_{54}	664.3
t_{10}	63.5	t_{25}	227.9	t_{40}	440.3	t_{55}	681.3
t_{11}	73.4	t_{26}	241.2	t_{41}	457.3	t_{56}	698.4
t_{12}	83.3	t_{27}	253.3	t_{42}	474.4	t_{57}	715.6
t_{13}	93.2	t_{28}	264.2	t_{43}	491.4	t_{58}	734.7
t_{14}	103.3	t_{29}	278.4	t_{44}	508.5	t_{59}	746.8

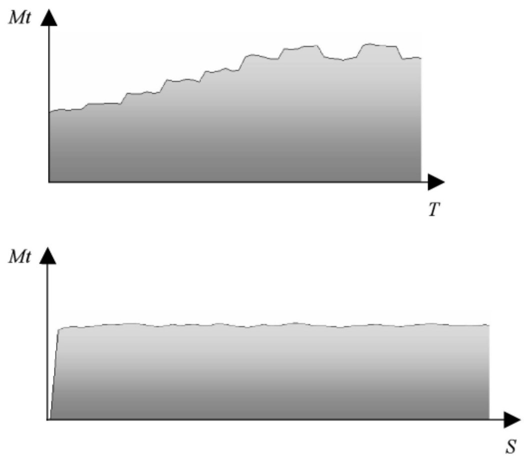

Figure 2 Results of data processing obtained with the pressure sensor

From the Table 1 and Figure 2, it can be found that the falling fertilizer which leaves the discharging nozzle needs several seconds to reach the receptacle of the pressure sensor, during which period the farming machine has moved a short distance. Obviously in this way crops cannot fully receive the fertilizer. It can be concluded that the fertilizer feeder has the characteristic of time-lag. The falling fertilizer quantity must be changed according to the farming machine speed, but it still has error because of the inertia of the feeder axle. These problems commonly exist in the applications of precision farming.

4 Conclusions

In conclusion, utilizing numerical analysis and piecewise quadratic interpolation in a computer simulation mode can precisely obtain a fertilizer feeder's performance parameters and flow figure. Compared with traditional means that use optoelectronic sensor and image processing, the testing system in this study can evaluate the discharging uniformity of a fertilizer feeder with simpler hardware structure and less error.

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