Proceedings of International Conference on Robotic Automation System 2011

# ICORAS

## Proceedings of International Conference on Robotic Automation System 2011

TATi UNIVERSITY COLLEGE

Co-organizer :

MIE UNIVERSITY

INSTITUT PERTANIAN BOGOR

Queen's University Belfast

# INTERNATIONAL CONFERENCE ON ROBOTIC AUTOMATION SYSTEM

The 1st International Conference on Robotic Automation System 2011 is a forum for scientists, engineers, and practitioners to present their latest research results, ideas, developments and applications in the areas of *Robotics, Artificial Intelligence Method & Applications, Mechatronics System & Automation* and *Biomedical Engineering*.



**CO-ORGANIZERS**

Institut Pertanian Bogor, Indonesia.
MIE University, Japan.
Queen's University Belfast, UK.

# ICORAS 2011

# International Conference On
# Robotic and Automation System

23-24 May 2011

Terengganu, MALAYSIA

# PROCEEDINGS

## ORAL PRESENTATION

## POSTER PRESENTATION

# Design and Performance Test of Embeded Module Metering Device for Variable Rate Fertilizer Applicator

P.A.S. Radite [1], W. Hermawan [1], A. Azis[1], B. Budiyanto[2]
[1] Dept. Of Agricultural Engineering, Fac. of Agricultural Engineering andTechnology, Bogor Agricultural University, Indonesia. E-mail: iwan_radit@yahoo.com
[2] Dept. of Meteorology and Geophysics, Fac. of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia

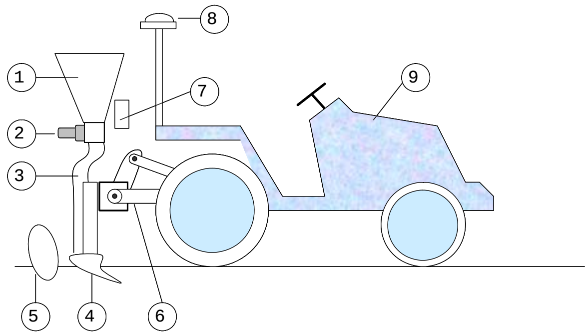
*Abstract* — Uniform rate of fertilizer application (URA) practice is disregarding the productive potential of the various areas within the field. Thus, it is not efficient method because some area is less fertilized and other is over fertilized. With variable rate application (VRA) machines, the dose and the position of application could be given precisely as required by crops. Machinery with variable rate capabilities impressed as technologically sophisticated and expensive. In Indonesia, implementation of VRT in crop production is also still questioned, because fear of the complicated and expensive prices of the machines. Therefore the objective of this research is to develop an embeded system for variable metering device of granular applicator. The metering was equipped with two rotor, which could be operated as single rotor or double rotor. The dose of granular fertilizer could be controlled by controlling the rotation of the rotor. The rotation of the rotor was controlled using digital PID algorithm. The result of the test showed that using single rotor the output of urea, SP-36 and NPK are 0.84, 0.96 and 1.2 g/rotation respectively. Test on double rotor showed that the output of urea, SP-36 and NPK are 1.14, 2.22 and 2.1 g/rotation respectively. All results showed that the prototype of metering device can control fertilizer dose of urea, SP-36 and NPK fertilizer precisely with coefficient of determination of more than R2=0.99. For field operation in the future, the developed VRT applicator will be mounted on multi-purpose vehicle which was modified from riding type rice transplanter. Position of the vehicle in the field will be acquired using agriculture type RTK DGPS.

## INTRODUCTION

### *Design Of Variable Rate Applicator*

*Vehicle:* Concept design of developed VRT granular fertilizer applicator is shown in Fig.1. In this concept, the applicator is mounted on a multipurpose vehicle or light tractor using three-point hitch. The concept of VRT applicator has four mains components, electric parts (motor and controller), fertilizer bins with total capacity 120 liters, 2-4 metering devices and 4- 8 nozzle spreaders.

The applicator works as follow; first the fertilizer was metered by a roller feeder, the grains are then released gravitationally or transported pneumatically by pressured air stream, through delivery hoses and finally put in the soil. The fertilizer is put into the soil to dept of 5-10 cm, in order to avoid vapor losses in dry season or losses due to water runoff during rainy season.




| | | |
|---|---|---|
| 1. Fertilizer hopper | 2. Servo motor | 3. Delivery hose |
| 4. Furrow opener | 5. Cover | 6. Hitch frame |
| 7. Controller module | 8. GPS Antenna | 9. Tractor |

Fig.1. Concept of variable rate applicator

As shown in Fig. 2, computer or controller module was utilized to organize the system. This machine performed variable rate application based on fertilization mapped. The map contained desired rates of application (kg/ha) as well as their position in the field will be used to guide the operation of the machine in the field. Change of the desired application rate was implemented by precisely control the rotor speed of metering device while monitoring the ground speed of the vehicle An agriculture purpose RTK-DGPS with accuracy of 5 to 10 cm is used to perform accurate positioning during fertilization, and the data were sent to the PC computer through serial port (RS232) at 5 Hz. While the speed of the vehicle was monitored, through the vane disc and a magnetic proximity sensor

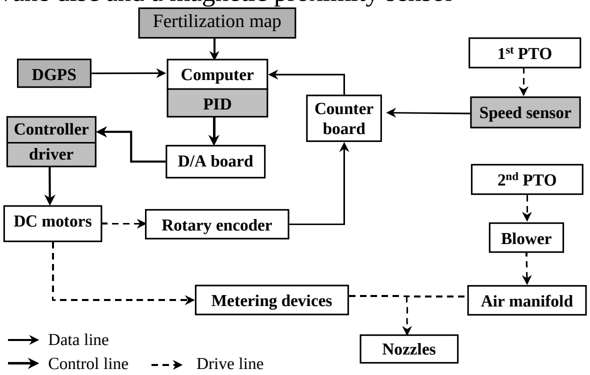


Fig.2. System control of variable metering.

*Metering rotor:* As shown in Fig.3, the metering rotor was star-types with 6 fins with cylindrical notched chambers. For single rotor, if the rate of application is decided, the rotor speed ($N_m$, in rps) can be simply calculated as follows:

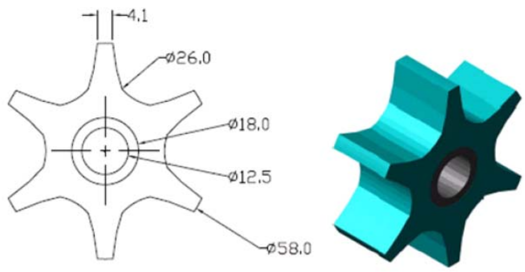


Fig 3. Design of metering rotor

$$N_m = (10\ S\ W\ D_s)/Q \qquad (1)$$

where,

$N_m$ = Rotor speed (rps)
$Q$ = Metered fertilizer per rotation(g/r)
$S$ = Ground speed of the applicator (m/s)
$W$ = Effective width covered by one metering device (m)
$D_s$ = Rate of application (kg/ha)

*Motor and Controller:* DC geared motor was use because it is tough and reliable for field application, beside it is also cheap and availability in local market. Through a careful design a DC motor can be directly coupled to the shaft of fertilizer metering device for simple construction. A 30 W DC motor has specification of 22 V/ 2600 rpm equipped with 1/20 reduction gear box. The whole system is knock-down, thus easy for maintenance. The motor is equipped with an optical rotary encoder of 30 pulses per rotation.

The controller module for metering system controller consists of microcontroller module (DT-51 Minsys), Smart Peripheral Motor Controller (SPC Motor Controller, and motor driver (EMS Hybrid 30A) made in Innovative Electronics. For flexibility, a 3 x4 keypad was functioned as input device, while a 2 x 20 line LCD display was used as output of the controller. With input and output devices, the controller parameters could easily be adjusted and the result could be easily monitored.

The specification microcontroller used was 8 bit micro-processor base on AT89C51, 8kb EEPROM expandable to 64k, 4 I/O ports (PPI portA, portB and portC, port1), LCD port, and serial port interface for communication with PC computer, laptop or netbook.

A pulse width modulation (PWM) driver (EMS Driver from Innovative Electronics) with hybrid transistors was used. The motor driver has ranges output up to 36 V at maximum current up to 30 A. This driver was interfaced to micro-controller through Smart Peripheral Controller (SPC). SPC motor controller has 2 channel input driver, equipped with four 16 bit counters. Communication between SPC, EMS driver and micro-controller could utilize i2c protocol, UART or parallel port.

*Material And Method*

*Materials of experiment:* Design of granular fertilizer applicator with volumetric metering system is adopted and modified to become variable output. Variable dose is performed by controlling the rotation of metering device rotor by meant of controlling the rotation of a dc gear motor. With digital control it is possible to set the desired speed of the rotor very precise and accurate.

For this purposed, material of experiment will be consists of metering device, dc geared motor, rotary encoder, counter, interface controller, motor driver, usb to serial port and laptop computer. Computer was use to program the micro-controller, and also to monitor and record the data during process development. C programming language was use to developed the system control and data acquisition. Data acquisition was done through serial communication by using usb to RS-232 cable. Data were displayed in the laptop monitor and recorded in computer's hard drives. Microsoft excel was used to do further data processing.

In this technique, the map-based application method was adopted. In this method, soil and plant were sampled and laboratory analyzed prior to fertilizer application. After further calculations, a fertilization map was constructed. The fertilization map contained information of the required application rates (kg/ha) on each plot in the field. The work of soil and plant analysis was conducted by another team of precision farming research, and there is not discuss further.

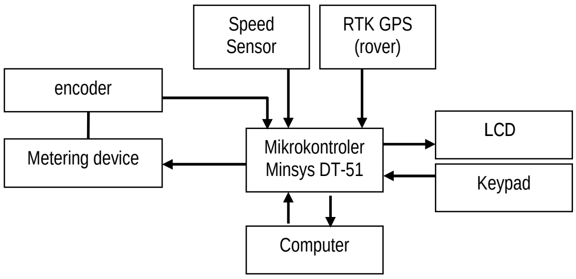


Fig. 4. Block diagram of control system

Block diagram of the system is presented in Fig.4. This system is an open-loop system except at the metering device which used a closed control system to adjust the rotation of the metering rotor. To performed variable rate application in the field, micro-controller should manage accurate information of vehicle position in the field and dose of application. The change of rate of application is done by precisely control the metering rotor while monitoring the vehicle's ground speed. The ground speed was measured by a segmented vane disc and a proximity sensor will be sampling at 1Hz. While an agriculture purposes RTK-DGPS having accuracy 5 to 10 cm will be used to perform accurate positioning in real time (5Hz) during field operation.

*System identification:* The metering system approximated with linear model of first order system with delay, as represented in Laplace transform as follows;

$$G(s) = \frac{R(s)}{C(s)} = \frac{Ke^{-ds}}{1+T\ s} \qquad (2)$$

Where,
$R$ = speed of rotor or output of control
$C$ = set point or input control
$K$ = gain of system (rps)
$T_s$= time constant (s)
$d$ = delay time (s)

The value of K, T and d was determined by using step response model. Curve fitting using Least Square Method was adopted to fit data of response and model as stated in equation (2). Procedure of system identification is presented in figure 5.

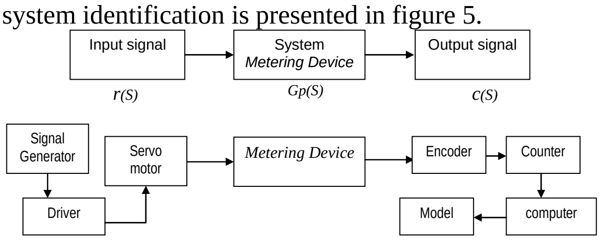


Fig.5. Schematic of system identification

*Digital PID Control:* Digital control based on embedded system will be used in this research. A feedback control with a digital PID compensator, therefore, was adopted to improve the robustness of control. For this purpose, the rotor speed was monitored using an optical rotary encoder with resolution 30 pulses per rotation. A 16 bit counter was used to count the pulses every 20 ms.

$$G_p(s) = \frac{K\ e^{-d\ s}}{T\ s + 1}$$

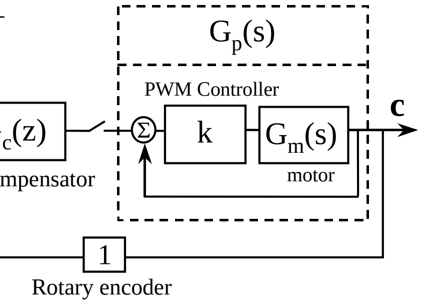


Figure 6. Schematic diagram of digital control

A feedback control is designed to generate an output that causes some corrective effort to be applied to a process so as to drive a measurable process variable(**r**) towards a desired value(**c**) known as the set-point, as shown in Figure 5. PID digital is implemented as follows:

$$C_n = C_{n-1} + K_p\left[(e_n - e_{n-1}) + K_I T e_n - K_D\left(\frac{e_n - 2e_{n-1} - e_{n-2}}{T}\right)\right] \qquad (3)$$

Where,
$C_n$ = next value of control
$e_n$ = error of process
$Kp$, $K_i$, $K_D$ is PID constant for proportional, integral and differential component.

## RESULTS AND DISCUSSIONS

### *Fertilizer characteristic*

Table 1: Particle Size Distribution dan Bulk Density of The Fertilizer

| Type of fertilizer | Particle size distribution (%) | | | | Bulk density (g/cm$^3$) |
|---|---|---|---|---|---|
| | >4.76 mm | 2.36-4.76 mm | 1.4-2.36 mm | <1.4 mm | |
| Urea | 0 | 3.17 | 75.70 | 21.13 | 0.635 |
| SP-36 | 9.20 | 55.27 | 35.53 | 0 | 1.009 |
| NPK | 2.81 | 39.70 | 57.40 | 0.09 | 0.908 |

### *System identification*

Open loop control was done with PWM set point 50, 100, 150, and 250 respectively to run the motor. The speed of the rotor was then monitored and recorded in laptop computer at sampling rate of 30 ms. Rotary encoder was used to sense the rotation speed of the rotor, and output pulse was then counted using 16 bit counter. The data was then plot and curved fitted using model in equation (2), and the result is presented in Fig. 7.

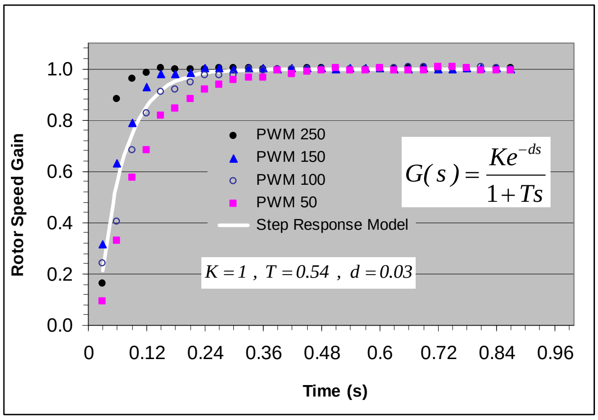



Fig. 7. Curve fitting of model to step response of the system

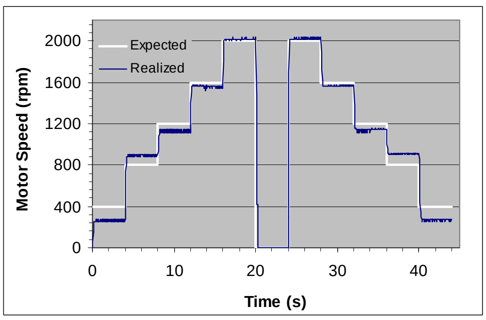
In order to tune the compensator, the process gain *K*, the time constant *T* and the dead time *d* of the system were determined in the same manner as previously explained.

*Stair-step response*

Without properly controlled, motor could not give precise response, for stair step set point change as illustrated in Fig.8 (upper). However, this process could be improved as feed back control is applied in the system as it was shown in Fig.8 (lower), where all the setting points could be followed very precise in quick response either in low speed as well as high speed rotation of rotor.

In order for control loop to work properly, the PID compensator must be properly tuned. Process gain was defined as rotor speed per second (rps) output (Hz) per unit of controller input. Least square fitting was used, where the process gain K= 1, time constant T= 0.054s and dead time d= 0.030s Tuning of the controller was done using modified Ziegler-Nichols method, where the PID constants were defined as the following equations, where:

$K_p = C_p$ 1.2 T/(K d),
$K_i = C_i$ 0.5/d and
(4)
$K_d = C_d$ 0.5 d.



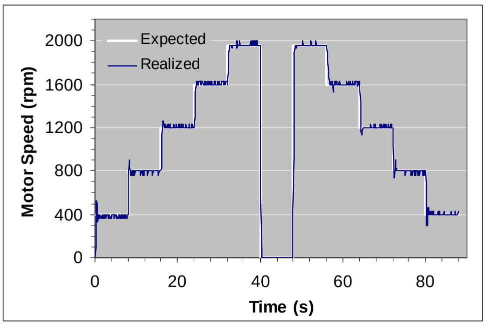




Fig. 8. Stair step response : without control (upper) and with PID control (lower)

Tough the torque on the rotor fluctuated because of frictions and other causes, such as cyclic loading as well as various granules sizes, the controller able to maintain the speed of motor in a good accuracy. It is shown in Fig. 8, digital PID compensator obviously improved the performance of motor. Control loop was run at 16 Hz or period of sampling 60 ms.

*Ouput of metering*

Tests were conducted on several rotor speed set point 400, 800, 1200, 1600 and 2000 rpm. Output of metered fertilizer was then collected and measured using digital balance for period of time 5, 10, 15, 20 and 25 second respecitvely. Output rate of the respective fertilizer was then calculated using least square fitting of the respective data. All tests showed that linear realationship were obtained with coefficient of determination higher than 99% and typical results are presented in Fig. 9.

At every setting of rotor speeds, the ouput rates were then calculated. At tested speed the output rate of Urea fertiliser was 5.55, 12:11, 17.84, 23.66 and 29.64 g/s respectively. For TSP-36 fertilizer, the output rate was 7:54, 15.2 , 22:09, 28.91 and 33.27 g/s respectively. While tests on NPK fertilzer gave ouput rate of 8.4, 16:25, 24.62, 32.42 and 40.5 g/s.

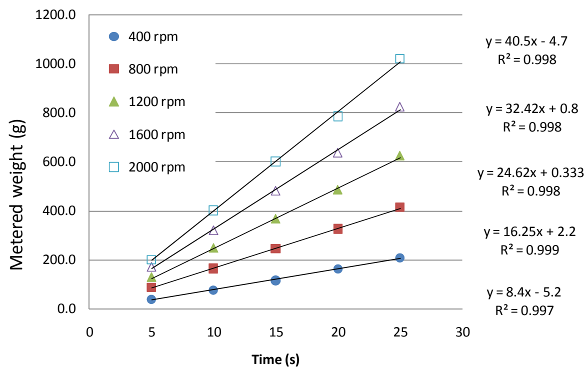



Fig. 9. Metered weight of NPK fertilizer on single rotor operation

As it is shown in Fig. 10, result of the tests using double rotors also gave good linier relatinship. Testing at rotor speed 400, 800, 1200, 1600 and 2000 rpm provided ouput rates of 7.85, 15:46, 23:04, 30.76

and 39.92 g/s for Urea fertilizer; 23:33, 39.24, 54.34 , 68.92 and 82.54 g/s for TPS-36 fertilizer, and 22.92, 38.48, 51.34, 66.53 and 78.80 g/s NPK fertilizer.

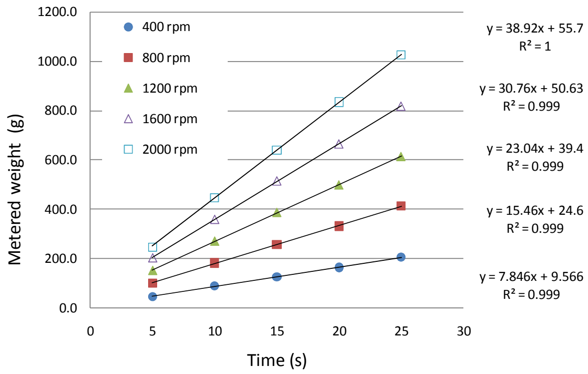



Fig. 10. Metered weight of Ureafertilizer on double rotor operation

*Dose of application*

The result of variable rate fertilizer tests of the metering device using single rotor indicated that the rate of urea, SP-36 and NPK are 0.84, 0.96 and 1.2 g/rotation respectively. Results of the tests using double rotor indicated that the rate of urea, SP-36 and NPK are 1.14, 2.22 and 2.1 g/rotation respectively. All results showed that the prototype of metering device can control precisely.

This prototype will be applied to rice plants. If we assume the distance between rows of rice plants (width application) 30 cm and forward speed of applicator (tractor) is 1.8 km / h or 0.5 m / s, the rate of output of then fertilizer dosage will be obtained for 56 kg / ha of Urea. If the applicator uses four units will be obtained by fertilizing dose of 224 kg / ha. Meanwhile, by using double rotors in which the output rate of urea at 1:14 g / rotation, then fertilizer doses obtained by 76 kg / ha, so by using four units of the metering device the dose could be as much as 304 kg / ha. Since the recommended fertilizer dose of urea is between 250-300 kg/ha (Ministry of Agriculture, 2007) thus it can be achieved by using four units of metering devices.

## CONCLUSIONS

The prototype of variable rate granular fertilizer applicator has been built and tested. The unit equipped with metering device that can be controlled electronically. Change of dose can be done on the basis of rotor speed rotation which was controlled using PID digital control.

Result of the tests on set-point 400, 800, 1200, 1600 and 2000 rpm shows that the ouput rates were proportional with speed and consistent among the tests. Single rotor had metering output for Urea, SP-36 and NPK at 0.84, 0.96 and 1.2 g/rotation respectively. While double rotor had metering ouput for Urea, SP-36 and NPK at 1.14, 2.22 and 2.1 g/rotation respectively. All results showed that the prototype of metering device can control precisely. For application using Urea fertilizer, the prototype with four metering device suitable to be used at maximum dose 250-300 kg/ha.

## ACKNOWLEGMENT

The authors gratefully acknowledge the support of the, Directorate General of Higher Education, Ministry of National Education of Indonesia through IPB I-MHERE Competition Scheme Project which provided a research grant for this work.

## REFERENCES


[1] Radite, P.A.S., M Umeda, M. Iida, M. Khilael, “Variable rate applicator for paddy field”. The 93rd Intl meeting of ASAE, Milwaukee, Wisconsin, USA., 9-12 July, 2000. ASAE paper No.001156.

[2] Radite, P.A.S., W. Hermawan, B. Budiyanto, and M. A. Azis, “Development of variable rate fertilizer applicator module based on 8-bit embedded system”. Proc. of International Seminar of AFITA , October 4-6, 2010, Bogor.

[3] Iida, Michihisa, M. Umeda, P. A. S. Radite, “Variable Rate Fertilizer Applicator for Paddy Field”. The 94rd Intl meeting of ASAE, Sacramento, California, USA, July 29-August 1, 2001. ASAE paper No. 011115.

[4] Deptan, Rekomendasi Pemupukan N, P dan K pada Padi Sawah Spesifik Lokasi: Peraturan Menteri Pertanian No 40 /Permentan/ OT.140/ 04/ 2007. Jakarta. 2007.