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Prize 2012

[F] PhD Extended Abstract Form *(Please select the Calibri 10 typeface)*

SPECIFICATION, DESIGN AND EVALUATION OF AN AUTOMATED AGROCHEMICAL TRACEABILITY SYSTEM
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Extended Abstract

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1. Introduction

Traceability through all the stakeholders in food production is an issue of increasing importance, being specifically required by the regulations for food safety and quality (EC 178/2002), and for compliance with environmental protection. The agricultural market perceives a need for systems and technologies to automate the currently manual process of producing records of agrochemical inputs loaded into a spraying machine.

The aim of the project was to develop a system that can assist in the loading and automatic recording of agrochemical inputs as a primary input of food product traceability. The system will deliver the required performance while operating in a farm environment to meet the goals of operator, food and environmental safety.

The objectives were as follows:
1) To develop a prototype system to integrate the identity and quantity of agrochemicals as an initial "input" record for traceability systems.
2) To integrate the prototype system with appropriate hardware and software to meet the required performance.
3) To evaluate the system in terms of speed, efficiency, safety, resolution, accuracy, and operator satisfaction.
4) To make recommendations for system improvements to further meet the requirements of operators.

2. Automatic identification of agrochemicals

Food traceability systems require identification of items involved in the food chain. A traceable item, e.g. a container of agrochemical, should be appropriately labelled so as to identify it to an automatic system and not require manual intervention. Radio Frequency Identification (RFID) has previously been demonstrated to be the most suitable solution for automatic agrochemical identification in agricultural environment.

A format has been proposed as a standard for data held on RFID tag applied to agrochemical containers. This uniquely identifies single packs whilst associating the product type with existing national agrochemical databases. The proposed format allows verification of authenticity and current chemical registration, while being operable on-sprayer without live access to an international item level database. The automatic identifier complements the measuring systems by providing information about the physical characteristics such as the density of the product required for correct measurements of agrochemicals. Widespread adoption of this or a similar system is a recommendation of this work.

3. Design and construction of the automated agrochemical traceability system

The rational way to design an Automated Agrochemical Traceability System (AACTS) is to complement the existing hardware and software by developing and integrating the functions which are currently missing. A comprehensive

automatic traceability system capable of improving upon the manual practice must be able to communicate to and take commands from the operator, detect the agrochemical products to be inserted into the application machinery, quantify the dispensed amount, generate electronic job records, exchange data, and interface with the existing hardware and software (ISO 11783). The AACTS delivers the functionality to automatically generate records of tank contents by using and complementing the functions of task controller and farm computer.

The AACTS has the following specification:

1) Identification of agrochemical products
   The RFID reader (Feig MR100 with aerial ANT100/100) is able to uniquely identify the containers of agrochemicals tagged with RFID labels within 100 mm of distance and within 1 s of speed of operation. The AACTS is able to trace individual agrochemical containers, associate the product identity with national agrochemical databases.
2) Quantification of agrochemical products
   The self cleaning pyramidal stainless steel weighing funnel with a volume of 1.4 litre mounted on a 3 kg load cell within the induction hopper is capable of measuring agrochemical products both liquids and granules sold to the farms. The resolution of the quantification system is 3.6 grams on a fully operational sprayer. Being located inside the induction hopper, the weighing funnel enables pouring the agrochemical product directly into the hopper which improves the health and safety of operators and reduces contamination of the environment.
3) A graphical user interface
   A screen of 200×200 pixels and three user command buttons (Yes, No, Back), and a progress bar made of 8 coloured LED's (green, amber, red). The AACTS assists the sprayer operator and controls the workflow by prompting appropriate information (such as filling instructions, actual measured quantity, warning messages) on the screen and waiting for user commands. In addition to the numeric high resolution output on the screen, the LED-bar provides a simple progressive visual indication of quantity against requirement directly in the line of sight of the operator during filling.
4) Data exchange
   Input of an electronic task file with prescribed agrochemical products and quantities. Output of an electronic record file with dispensed agrochemical products and quantities. Generation of records of sprayer inputs and interfacing with task management as set out in standard ISO 11783-10.

4. Signal conditioning analysis

The operating environment and gravimetric embodiment requires signal processing in order to achieve the required resolution and accuracy. Primary source of noise is mechanical vibration imparted by the engine principal exciting force of 33–83 Hz. A low pass digital filter with a cut off frequency of 3 Hz (−3 dB) combined with second stage averaging filter with a window of five values demonstrated a reduction of the error seen on the screen from 2240 grams to 3.6 grams with system response appropriate to suit human reaction time. A combination of analogue and digital filtering delivers noise suppression similar to total mechanical isolation – the value indicated to the operator varies by less than 2 grams. Digital filtering enables advanced software controlled strategies such as alteration of engine operating speed or complete switch off to be implemented in integration with ISO 11783 engine control unit for further improvements of measuring accuracy. The error seen on the screen was within 1 gram if the engine is switched off which satisfies the design specification.

5. Evaluation of the operator performance

An experiment with 10 sprayer operators has proved that in the majority of cases (92%) an accuracy equal or better than ±5% is achieved regardless of dispensing speed. The dispensed amounts (100.36% of target) and recorded (100.16%) are in accordance with prescribed values (100%; $LSD_{(5\%)}$ 2.166%), where amounts dispensed by manual methods (92.61%) differ significantly from prescribed and recorded value (100%). The AACTS delivers a statistically similar work rate (211.8 s/task) as manual method (201.3 s/task; Δt = 10.5 s/task; $LSD_{(5\%)}$ 28.2 s/task) in combined loading and recording cycle. Considering only the loading time (181.2 s/task) of manual method, the difference is 30.6 s/task ($LSD_{(5\%)}$ 30.1 s/task). In practice this difference is believed to be marginal compared to the time required to load the water, random external events during the spraying session and in time moving, checking and storing paper records.

The integration of a high frequency 13.56 MHz RFID reader-antenna system into the induction hopper of the spraying machine has been demonstrated to be a robust and reliable method for the automated identification of agrochemical containers. During the experiment more than 250 agrochemical product identification operations with RFID were carried out without a single failure. In all of the cases the system was able to read the information stored on the RFID product label, decode it, reference with database and record the unique identifications of each container. The RFID system provided a true automatic record of the product containers used in the experiment. The speed of operation (<1 s) and reading distance (100 mm) of the RFID were found to be adequate for agrochemical identification.

The participating 10 operators accepted the new user interface very well. The trial demonstrated that such a user interface is most economical and efficient for prompting the operator and taking commands regarding the task of filling the sprayer. The ability to assist the operator and control the workflow is beneficial in terms of reducing human errors. The robustness and reliability of the system were seen as a key commercial success factor. The operators assumed the automatic system is more accurate than manual measuring without knowing trial results. Thus accuracy is an important marketing argument. The AACTS was rated to be safer than the manual method regarding operator health and safety and risk of spillage. All operators who evaluated the AACTS were interested in purchasing such a system. The operators saw great advantage in the capability to generate electronic records.

6. Conclusions

A novel prototype Automated Agrochemical Traceability System (AACTS) has been developed, where the results of the design, construction and evaluation phases have proven such a system capable of
   1)   identifying and weighing agrochemical products,
   2)   controlling the workflow and prompting the operator,
   3)   recording and transferring data
can be successfully used to generate automatic records of tank contents of crop sprayers. The results of this can be directly used as the design parameters for a commercial prototype.

It is recommended to produce a production prototype following the design methodology, analysis techniques and performance drivers presented in this work and develop the features of user interface and records of tank content into software for ISO 11783-10 cabin task controller to deliver business benefits to the farming industry. The results with RFID encourage the adoption of RFID labelling of agrochemical containers.

Final remarks concerning the competition benchmarks and strength points

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The novel Automated Agrochemical Traceability System fills the gap on the market by automating the currently manual process of generation of records for sprayer inputs. The prototype integrates into existing hardware and software (ISO 11783). The results of the work can be directly used as the design parameters for a commercial prototype. The AACTS is a practical management tool for farmers. It improves food safety, reduces human errors, and provides traceability records of agrochemicals.

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