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Université de Liège

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Gembloux Agro-Bio Tech - Université de Liège – vous prie

de lui faire l'honneur d'assister à la défense publique de la dissertation originale que

Monsieur EL AISSAOUI Abdellah

Ingénieur agronome,

Titulaire d'un diplôme d'Etudes approfondies en Sciences agronomiques et ingénierie biologique

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,

le 15 juin 2016, à 9 heures, en l'auditorium du Génie rural (GR)**,**

Passage des Déportés, 2 à 5030 **GEMBLOUX.**

Cette dissertation originale a pour titre :

« A feasibility Study of Direct Injection Spraying Technology for Small Scale Farming: Modeling and Design of a Process control System »

Le jury est composé comme suit :

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Résumé

The study aims to develop a process controller of direct injection spraying system (DIS) that can fit to carry out precise chemical application using variable rate application based on speed sensing in the context of small scale farming. It has the specific objectives of studying the feasibility of DIS by optimizing the hydraulic system and the process control designs as the main requirements for the best system reactivity and performance. The final design of DIS assessed to implement hydraulic system (hardware) and process controller (software) of a sprayer framework mounted on a rolling chariot propelled by walker operator. A logical approach is used of reviewing the state of art and formulating a specification book to develop a cost effective prototype to eventually adapt DIS expertise to the context of small scale farming. The demarche consists on giving low cost solution of variable rate technology to solve the technical problems related to usage and inefficiency of pesticide application mainly done by portable sprayers.

The state of art gives a light on the development process of direct injection spraying technology (DIS) within the scope of precision agriculture progress. It also deals with technical options, advantages and problems related to DIS and control engineering solutions developed for improving spraying application efficiency and safety measures for human and environment.

After that we have specified requirements of the researched DIS prototype by referring to existing art of DIS technologies and by diagnosing problems of chemical application in the context of small scale farming. It concerns specifically the technical requirements, setting values and performance of DIS process controller according to the working conditions of intensive cropping in small farming.

The materials and methods consist on presenting the approach used for modeling the DIS prototype (splitting the problematic to the two main design aspects of hydraulic system and process control system) and evaluating it in laboratory conditions using simulated velocity data input. The data acquisition system is implemented for assessing the performance of DIS hydraulic and process controller performances. After that, the process controller is implemented in a cost effective electronic kit (box) to be mounted on a small sprayer framework propelled by worker.

The hydraulic modeling of DIS served for optimizing the lag transport task as main problem of system reactivity performance and concentration process change. An algorithm is implemented in VB program to assess effect of hydraulic serial boom design (diameter and number of mounted nozzles in serial scheme) on flow dynamic to find compromise between lag transport, mixing ability (turbulence) and friction loss tasks that yield lateral and longitudinal uniformities application of standard boom layout. The modeling results showed lag transport and uniformity of respectively 2 s and 96 % for optimal conventional boom of 6 mm inner diameter having ten tip nozzles (ISO11003, 1.2 L/min~3bars). To solve systematic problem of lateral miss uniformity of serial boom layout (standard scheme), improved parallel boom layout (equidistant tubing lines of 4 mm diameter) is adopted for obtaining an even lag transport between nozzles. The test of parallel boom layout showed even lag transport approximating 1.5 s for ten mounted nozzles. The total response time of DIS is optimally improved to be within 2.5 s by installing electrical pumps close to boom and injecting chemical in suction side to the carrier pump assumed to perform online mixing without use of static mixer.

The PID feedback controller is modeled in MATLAB software. The process is considered as a first order process having a time constant of 0.2 s and a delay transport less than 2 s. Two control strategies of constant carrier flow control (CCFC) and total flow control (TFC) are modeled and implemented for test in laboratory conditions. Both strategies were tested and evaluated on the basis of different solicitations of variable speed input within the range of 0 - 2 m/s as a field working condition of walker operating a rolling sprayer chariot.

Finally, on the basis of the results of modeling and experimental assessment, an affordable kit of PLC process controller and PWM modules for actuating carrier pump and metering pump is performed in compact electronic box for potential usage on small sprayer framework to be propelled by walker operator in agricultural field. The controller is based on a PLC microcontroller implemented for carrying out a constant carrier flow rate and a variable chemical injection rate proportionally to the operating speed. The prototype is tested for applying variable rate application using simulated step solicitations within the range of the operator working conditions of 0 - 2 m/s. The study showed the feasibility of implementing a cost effective process controller design for applying variable rate chemical in small farming context. The controller is adaptable for sprayer mounted on wheeled chariot to be propelled by worker assumed to walk at variable velocity.