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## [F] PhD Extended Abstract Form

**MODELING AND ENERGY CONSUMPTION OPTIMIZATION OF THE OPERATIVE PARTS OF AIR-SEEDERS**

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**Abstract**

### Chapter 1: Introduction

Nowadays, agricultural mechanization is facing to two key-challenges: correct energy management and agronomic efficiencies, as most important factors for agricultural production and farmers. The first point can be improved by the rational dimensioning of machines and components, the agronomic efficiency could be achieved with the precision inputs management, seeding material placement etc.

In order to improve the efficiency, the working width of seeding implements increases. The use of conventional mechanical seed drills, with hoppers above all the implement working width, has reached its limits. Air-seeding appears thus as the best solution, where one storage hopper is able to supply the working width of 24 metres or more.

The use of wide width air-seeders in the cropping systems in large farming areas of US, Canada, Australia, Ukraine, Russia and Kazakhstan, generally demonstrated a higher efficiency compared to traditional machines, adapted for reduced and no-till farming. Air-seeding is also used in European countries, especially in combination with powered tillage implements and against a background of working width increasing. However, the air-seeders, regardless their size, have a lot of shortcomings as: high energy consumption, difficult manoeuvrability, low transversal distribution accuracy and high clogging risk.

Within the initial aim to reduce general energy consumption, our research addressed some specific goals. We aimed to ensure that the whole energy reduction does not come at the expense of the agronomic quality of seeding (effective rooting and space occupation), finally securing the benefits for farmers. Secondly, we developed a new equipment design approach. Insofar, methods for air-seeding design appeared inadequate. Generally, engineers tend to rework "historical" solutions, resorting from intuitive "by eye" design, though without a clear understanding of the underpinning physical process. The design is therefore based on series of tests and/or simulations for validation. Use of unappropriated design approaches from other industries, leads to dysfunctioning risk or oversizing of operative parts.

We propose an interdisciplinary approach (agronomy, physics and engineering) based on new measurement and observation methods, to enhance classical deterministic approach to optimize the above listed functionalities. The novelty of this work is first, to improve the air-seeders' functioning through a clear understanding and mastering of the relevant physical processes; second, in a new research and design approach, applicable to other farming operations (tillage, spreading).

We started by the definition of the air-seeders' architecture, from which we derived the orientation of air delivery system (follow towards, follow behind or side follow). Then, we determinated the critical points of air-delivery system: the outlets pipes between soil openers and distribution heads. This is high clogging risk area, which could damage seeding quality. Once the convening conditions in the down-stream are founded (pipe diameter, air velocity, flow concentration), it was possible to size the conditions in the upstream (airlines, divider heads) and to choose a blower. Finally, we chosen the loading device for air delivery system and optimisation of divider head in terms of transversal distribution accuracy.

**Chapter 2 Choice of architecture of air-seeders**

Been, the start point of air-delivery system design, architecture of future air-seeder must also ensure the maneuverability and visibility of seed-bar. The air-seeder architecture is globally defined by the hopper position, towards the seed-bar. Among possible solutions (towed before, behind seed-bar or mounted on seed-bar), the storage hopper mounted on a seed-bar don't allow to obtain a regular pressure to the openers and necessary capacity of storage hopper. That's way, increasing of the working width and working speed of air-seeders, increase the number of towed elements. That leads to more complicated and accident-potential driving. In fact, it is difficult for an operator to choice an optimum trajectory, and manage headland width. In this chapter we worked on the establishment of the rational hopper positioning vis-à-vis the efficiency of the maneuvers. The storage hopper position don't have a significate impact on energy consumption, but this step was unavoidable to follow study.

To answer on this problem, we proceeded by establishment of the predictive model, describing the cinematics of the coupled tractor-air-seeder assembly, including U-turns at headland, which takes into account dynamic interactions, and its experimental validation in the field conditions. We showed, that the architecture with the "towed behind" storage hopper is most interesting, allowing the earlier positioning of the seed-bar on the seeding line, assuring in addition visibility on the seed-bar.

As the consequence of predictive modeling, we proposed to use them as instruction for the automation of maneuvers, resulting in the patent. Proposed method that will facilitate the maneuverability of poly-articulated air-seeders and reduce the time use and energy consumption.

**Chapter 3 Establishing the conveying parameters**

The next step, was design of the air-delivery system. From the experience of air-seeding, we can show, that the air-delivery systems are wrongly dimensioned. As the result: high energy consumption, seed damage, clogging of pipes. Further: painfulness of operator's work, loose of the time and of the yield.

The flow of seeding material during conveying must be high and regular. There are three parameters that ensure the conveying of seeding material in a pipe: air velocity, flow concentration and pipe diameter. It is demonstrated that the outlets of the divider heads are the most critical part of the conveying system. Outlet pipes relatively small diameters and must allow for the highest seeding rates without clogging. It was showed, that the air velocity in outlet may be used as an input data for design of all conveying system. Today, design engineers don't have these data. The values of air velocity and flow concentration adopted from the food industry are not compatible with the air-seeding requirements. Attempts to determinate them, using Pitot-tube in the small loaded pipes got ambiguous, multiple-values data, enable for the forward design.

In this chapter we I) determines a minimal air velocity and flow concentration per type of seeds relative to pipe diameter; II) establishes a precise method to measure the velocity of the loaded airflow, based on static pressure difference III) describes a global design methodology for air-seeder conveying systems; IV) reports an comparative study of energy of the most commonly used outlet pipe diameters; V) describes a method for calculating the energy consumption; VI) prescribes the optimum outlet pipe diameter deduced from our experimental results, necessary for the design of the divider head. Tests were carried out using for wheat and barley seeds, starter fertilizers and a wheat-fertilizer mixture, for currently used pipe diameters. It was demonstrated, that 25mm diameter pipe is an optimal compromise, for the most of seeding rates and species.

Experimental data in the combination with the new measurement approach, allowed to elaborate a method of air delivery system regulation, system of clogging anticipation, described in the patent.

**Chapter 4 Optimization of air-stream loading systems**

To ensure the loading of seeding material into the air delivery system, we are faced by the problem of pressure difference between the hopper and the airline. Most modern air-seeders are equipped with a Venturi-injector or a pressurized hopper. Even if both systems are largely used, there are no theoretical and scientific justifications in favour of these systems, since few evaluation reports based only on practical observations are available. Thus, this chapter deals with a study on the influence of an air-stream loading system type on the total energy consumption and seeds-metering precision. Moreover, this chapter proposes an explanatory model of the functioning conditions of each system. Experimental demonstrations show that pressurized systems are more efficient, allowing a gain between 11 and 29KW, compared to the Venturi-injector.

**Chapter 5 Optimisation of divider head geometry**

Once optimal conveying conditions are known, divider device must be adapted for the new conditions. Agronomic requirements must be also respected: we used the common notion of variation coefficient, according to ISO-7256/2, which must be less than 5% for the cereal seeds. The average value for modern air-seeders is between 5 and 21%. In order to better understand physic phenomena of seed distribution, this chapter deals with a study on the influence of divider head geometry and functioning conditions on the seed's distribution accuracy, in a larger domain. The first part concerns the study of the influence of the air velocity and the material flow rate on the distribution accuracy. A second study deals with the influence of the outlet closing, of different outlet pipes lengths, of distribution head tightness, of the angle position of distribution heads. Finally the influence of the structural elements such as the pipe elbow, the tower configurations, the tower height and the cone shape deflectors' implementation on the divider lid is proposed. Moreover, observation of the seed's behaviour is undertaken using a high-speed camera system.

This approach allow as to show, that the distribution accuracy is defined by the distribution of concentration of seeding material through a tower cross-section before dividing. Namely, it is the effect of elbow, which provoke a saltatory movement of the particles' flow core. This chapter also proposes practical explanations of the observed effects and recommendations for future divider heads design.

**Final remarks concerning the competition benchmarks and strength points**

1. This thesis, was realised within the company Kuhn SA, in Saverne (France).
2. Originality of this work consist in development of a specific design approach for an air-seeders, reaching of the initial goal to optimize general energy consumption of air-seeders,
3. The results contributed to design of new air-seeder, currently in pre-series phase (Fig. 1), sales pitches and two patents (*Yatskul et Lemiere, 2016, Potier et al. 2015*).
4. We propose an innovative sensor systems, based on static pressure difference, ensuring precise velocity control of loader airstream.
5. The proposed methods observation, based on high speed camera, could be applied in research of tillage tool geometry, having a minimal agro-ecological impact (*Yatskul et Ugarte, 2018*)
6. Famers' benefit could be reached by general energy economy and seeding quality, defying the future yield.


Figure 1. Model of prototype air-seeder Kuhn (Agritechnica, 2017)

## Related publications

Yatskul, A., & Ugarte, C. (2018). Soil-tool interaction for an agroecological performance of tillage implements. In *2nd AXEMA-EurAgEng Conference" Intensive and environmentally friendly agriculture: an opportunity for innovation in machinery and systems", Beauvais, France*. European Society of Agricultural Engineers.

Yatskul, A., Lemiere, J. P., & Cointault, F. (2017). Influence of the divider head functioning conditions and geometry on the seed's distribution accuracy of the air-seeder. *Biosystems Engineering*, *161*, 120-134.

Yatskul, A., Lemiere, J. P., & Cointault, F. (2018). Comparative energy study of the air-stream loading systems of air-seeders. *Engineering in Agriculture, Environment and Food*, *11, 30-37*.

Yatskul, A., Lemiere, J. P., (2018). Establishing the conveying parameters required for the air-seeders. *Biosystems Engineering, 166, 1-12*.

POTIER, P., YATSKUL, A., et LEMIERE, J-P. (2016) Agricultural coupling with a system for managing and guiding manoeuvres and method implemented by said coupling, EP Patent EP3165061 (A1).

Yatskul, A., & Lemière, J. P.. (2016) Méthode d'anticipation de bouchage d'un circuit de distribution pneumatique de machine agricole. FR Patent FR3050902 (A1).