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Comparative energy study of the air-stream loading systems of air-seeders

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ABSTRACT

The air-seeder became a solution, when the working width increasing of conventional mechanical seed drills having the storage hopper across the all working width had reached its limits. The single storage hopper of a modern air-seeder can supply the working widths up to 24 m, over many operating hours. However, it should be noted that to ensure the accurate loading of metered material into the air delivery system, we are faced by the problem of pressure difference between the storage hopper and the air stream. Most modern air-seeders are equipped with a Venturi-injector or a pressurized hopper (called also: pressurized tank). Even if both loading 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 paper 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 paper proposes an explanatory model of the functioning conditions of each system. Experimental demonstrations show that pressurized systems are more convenient from an energetic efficiency point of view.

Nomenclature

Designation	Description
ρ	Air density
P_1; P_2; P_3	Static pressure in: before loading, loading, after loading zones, respectively
P_i; P_j	Static pressure in: upstream and downstream, respectively
P_5	Static pressure in the hopper
P_{d1}; P_{d2}; P_{d3}	Dynamic pressure in: before loading, loading, after loading zones, respectively
P_{t1}; P_{t3}	Total pressure (sum of static and dynamic pressures in a section) in: before loading, loading, after loading zones, respectively
ΔP_{i-j}	Pressure drops between two sections
V_1; V_2; V_3	Air velocity in: before loading, loading, after loading zones, respectively
V_i; V_j	Air velocity in: upstream and downstream, respectively
V_{min}	Minimum conveying velocity
$\xi_{><}$; $\xi_{\perp}$	Coefficients of local hydraulic resistance for the Venturi injector and pressurized hopper, respectively
P_h	Oil pressure in hydraulic system before the blower
Q_h	Oil flow rate in hydraulic system before the blower
N	Consumed power

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1. Introduction

Very efficient, productive and autonomous, the air-seeder was created in Germany in the 1960's. The single storage hopper (mounted or from a wheeled air-cart) provides the metered seeding material (seeds or/and fertilizers) through the closed air-delivery system and a dividing device(s), to the soil openers, located on a tillage implement (Weiste, 2013; Cedra, 1993; Memory and Atkins, 1990). Nowadays, the air-seeding founded a large application on the wide width machines, used on large area fields (North America countries, Russia, Ukraine, Kazakhstan, Australia also.) and especially for the resource-saving conservation agriculture technologies (Jat et al., 2013; Tow et al., 2011; Astahov, 2007). Nevertheless, air-seeders have a lot of agronomical and environmental drawbacks such as low transverse distribution accuracy, seeds damage, frequent clogging risks and high energy consumption. The two first shortcomings have already been discussed in several publications (Yatskul and Lemière, 2014; Astahov, 2007; Kumar and Durairaj, 2000; Pippig, 1978; Allam and Wiens, 1981, 1983; Heege and Zähres, 1975; Mahlstedt and Heege, 1972). However, the energy aspect often remains ignored. Hence, in order to establish the critical points of the air-seeders, we will use the results of our preliminary study, undertaken statically on the Kuhn Maxima2 planter with a frontal hopper TF1500 fertilizer (Fig. 1).

From the fundamental fluid mechanics (Idelchik, 2005), we can say that the flow pressure is the value characterizing the energy reserve of flow. The local pressure drop is nothing more than energy lost due to the overcoming of the fluid flow structure deformation caused by constructional elements (change of direction, friction also.) and conveyed particles (Mills, 2013; Klinzing et al., 2011). Our preliminary tests consisted in measuring the drop in pressure using the universal micromanometer Testo 512 (Lefebvre (1986)), under the standard conveying conditions (air velocity, seeding rate) proposed by the manufacturers. The local pressure drops were estimated for each of the structure elements, where the airflow is modified.

Fig. 2 shows that most of the pressure drops are related to the loading element (injector), the elbow and the divider device. The total pressure drops in the divider header, due to the lift and seed material distribution are necessary since they provide appropriate distribution accuracy. Therefore, the air stream loading must be studied and optimized. Nevertheless, in the world's air-seeding practices there is another loading solution: the hopper pressurization. This solution seems more effective even if no fundamental scientific justifications have been proposed in publications. In this paper, we are attempting to explore the process of the loading of the seeding material in the air-stream by a Venturi injector and a

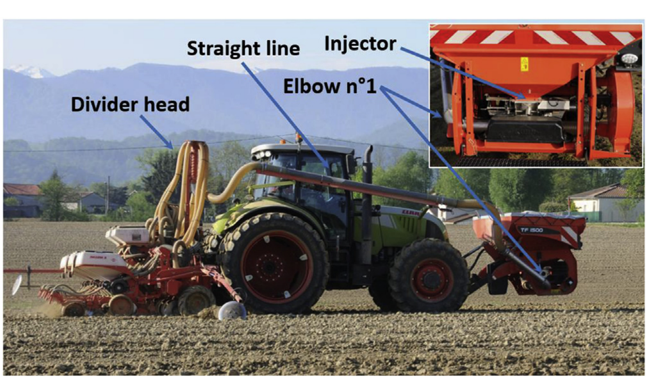

Fig. 1. Kuhn Maxima 2 Planter in combination with a frontal hopper TF1500 fertilizer, with the main components of an air-delivery system (Photo: Kuhn SA).

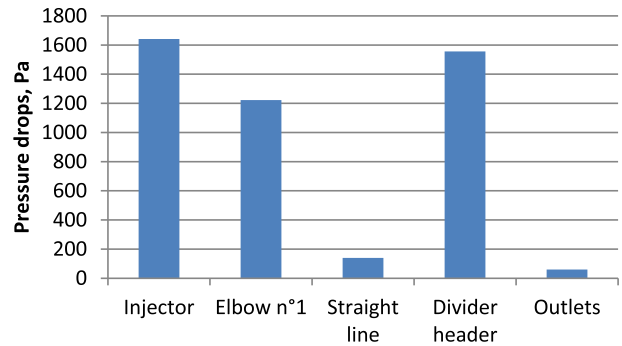

Fig. 2. Local pressure drops in the air-delivery system elements within the Kuhn Maxima 2 planter combined with the Kuhn frontal hopper TF1500.

pressurized hopper. We are also aiming to evaluate the energetic efficiency of different loading devices and different functioning conditions, in order to find an optimal solution. The first section deals with a literature review on air-stream loading, and a theoretical modeling of different modes of air-stream loading. The next section provides an experimental setup, plan and presentation. The last section is dedicated to the analysis of the results and a presentation of future work.

2. Air-stream loading and literature review

Contrarily to the mono-seed planters in which the process is done under depression, the air-seeder distribution systems work on positive pressure mode (Cedra, 1993).

The metering unit provides the bulk of the seeding material into a conveying airline. During the air-stream loading the problem of the air leakage through the introduction window is targeted. It is well known that the airflow will always move according to the least resistance areas. In this manner, the air-stream pressure, produced by the blower, is significantly greater than the atmospheric pressure in the hopper; thus the air will always try to escape through the introduction window. If the barrier layer of materials in the hopper is insufficient to isolate the airline from the atmosphere, the air leakage is inevitable. Stable pneumatic conveying is then impossible.

The loading devices allow the material to be introduced into the air-stream avoiding air leakage through the introduction window. Four different systems have been used for the tests: a rotary air lock, a stealing stack lock, a Venturi injector and a pressurized hopper (Zuev, 1976).

A rotary air lock (Fig. 3) consists of a cell roller feeder incorporated in a body (Srivastava et al., 2003). Owing to the small spacing between the cell roller and the metering unit body, the air cannot

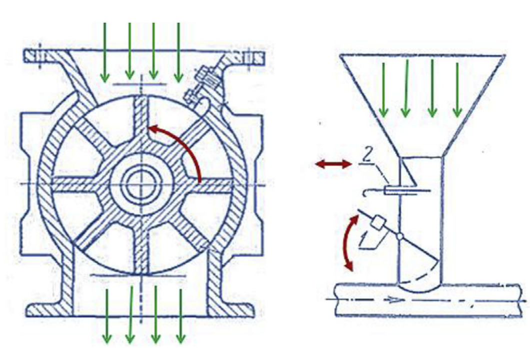

Fig. 3. Rotary air-lock (on the left) and stealing stack lock (on the right) (Zuev, 1976).

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