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- Giuseppe Pellizzi Prize 2018
  - **28th Members' Meeting of the Club of Bologna**
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MODELING AND ENERGY CONSUMPTION OPTIMIZATION OF THE AIR-SEEDERS' OPERATIVE PARTS

KUHN

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Our goals:

- Anticipate changes in agriculture in order to define farmers' needs to design a new equipment
- Agricultural data management to improve the decision making
- Support the transition to sustainable cropping systems

Global context

Agronomy context:

- Large areas
- Short seeding period
- High fuel cost

Solution:

- Hight capacity poly-articulated machines, with a wide working width

Essantial shortcomings:

- High energy consumption
- Difficult maneuverability,
- Low transversal distribution accuracy
- High clogging risk

Bibliography sources very poor


Source: Horsch


Source: Kuhn


Source: John Deere

Global development methodology

1. Choice of architecture of air-seeders
2. Establishing the conveying parameters
3. Optimization of air-stream loading systems
4. Optimization of divider head geometry

General Scientific roadmap

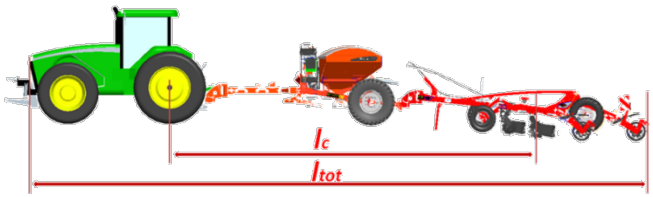
Establishment of limiting factors, and physical modeling → **Experimental validation** → **Technical solutions**

1. Choice of air-seeder's architecture

Choice of air-seeder's architecture

Transition tractor trajectory

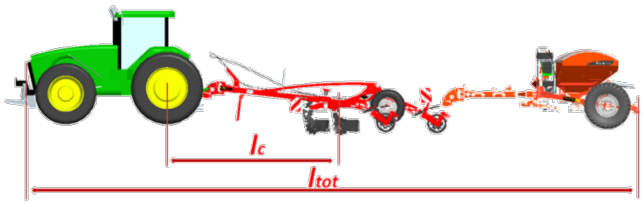
$$\begin{cases} x_0 = \frac{1}{k_r}\int_0^{\gamma_{0max}} \cos\left(-\frac{1}{k_r L_0}\ln\cos\gamma_0\right)d\gamma_0 \\ y_0 = \frac{1}{k_r}\int_0^{\gamma_{0max}} \sin\left(-\frac{1}{k_r L_0}\ln\cos\gamma_0\right)d\gamma_0 \end{cases}$$



Circular tractor trajectory

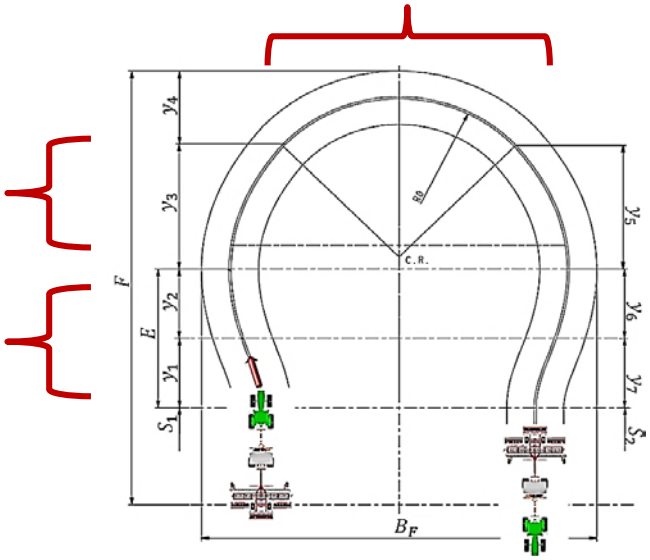
$R \in]\infty; R_{min}]$, consequently: $\gamma_0 \in [0; \gamma_{0_{max}}]$

$$\begin{cases} x_c = x_0 + R_{0_{min}} cos\delta_{0_{max}} \\ y_c = y_0 - R_{0_{min}} sin\delta_{0_{max}} \end{cases}$$



Towed elements trajectory

	Equations and master parameters
Input y_1, y_3, y_6	$\gamma_1 = \frac{L_1 + c_0}{L_0}\left[\gamma_0 - L_1\left(1 - e^{\frac{-\gamma_0}{L_1 k'_p}}\right)k'_p\right]$ Master- parameter : γ_0
Circular movement y_4	$\gamma_1 = \gamma_{1(\tau_1)} e^{-\frac{R_0}{L_1}\varphi_k} + \frac{L_1 + c_0}{L_0}\left(1 - e^{-\frac{R_0}{L_1}\varphi_k}\right)\gamma_{0_{max}}$ Master- parameter : φ_k
Output y_2, y_5, y_7	$\gamma_1 = \gamma_{1(\tau_2)} e^{\frac{-\gamma_{0_{max}} - \gamma_0}{L_1 k''_r}} + \frac{L_1 + c_0}{L_0}\left[\left(\gamma_{0_{max}} + L_1 k''_r\right)\left(1 - e^{\frac{-\gamma_{0_{max}} - \gamma_0}{L_1 k''_r}}\right) - \gamma_{0_{max}} + \gamma_0\right]$ Master- parameter : γ_0
Straight S_1, S_2	$\gamma_1 = \gamma_{1(\tau_3)} e^{\frac{-S_0}{L_1}}$ Master- parameter : S_0



Choice of air-seeder's architecture

Conclusions

- "Towed behind" storage hoper is more interesting
- Maneuverability predictive model and field validation
- Instruction for maneuvers optimization (patent)

2. Establishing of the conveying parameters

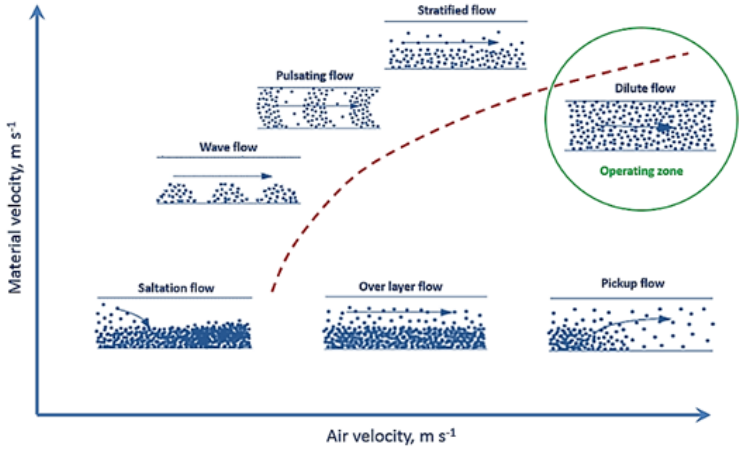
Establishing of the conveying parameters

Goals of research:

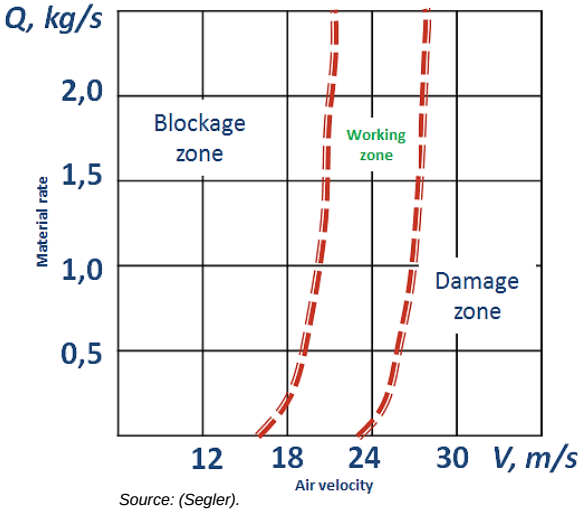
- Reducing of energy consumption
- Improvement of performance (material flowrate, distribution accuracy)
- Definition of conveying system parameters (air velocity in the outlets, flow concentration, pipe diameters, outlets number)
- Exclude clogging risk

Limiting factors:

Critical point: Outlet pipe



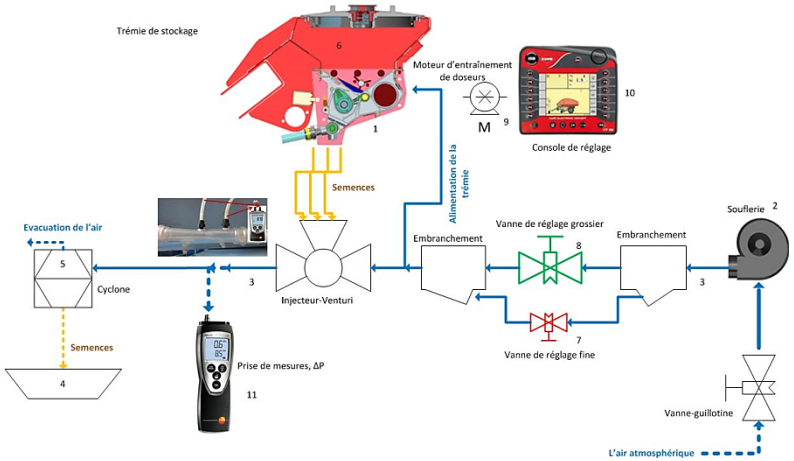
Source: (Binsirawanich, 2011; Barbosa et Seleghim, 2003).



Source: (Segler).

Establishing of the conveying parameters

Experimental setup:

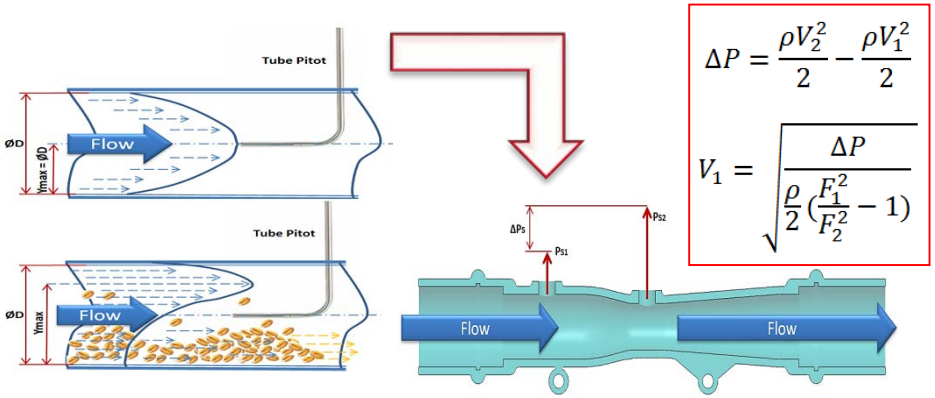


Testing was realized for:

- ✓ Pipe diameters: 20, 25, 30 mm;
- ✓ Wheat, Barley, Starter fertilizers Barley-Fertilizer mixture;
- ✓ Vertical and horizontal conveying;

Establishing of experimental values for the maximum flow concentration and the minimum air velocity

Air velocity measurement:

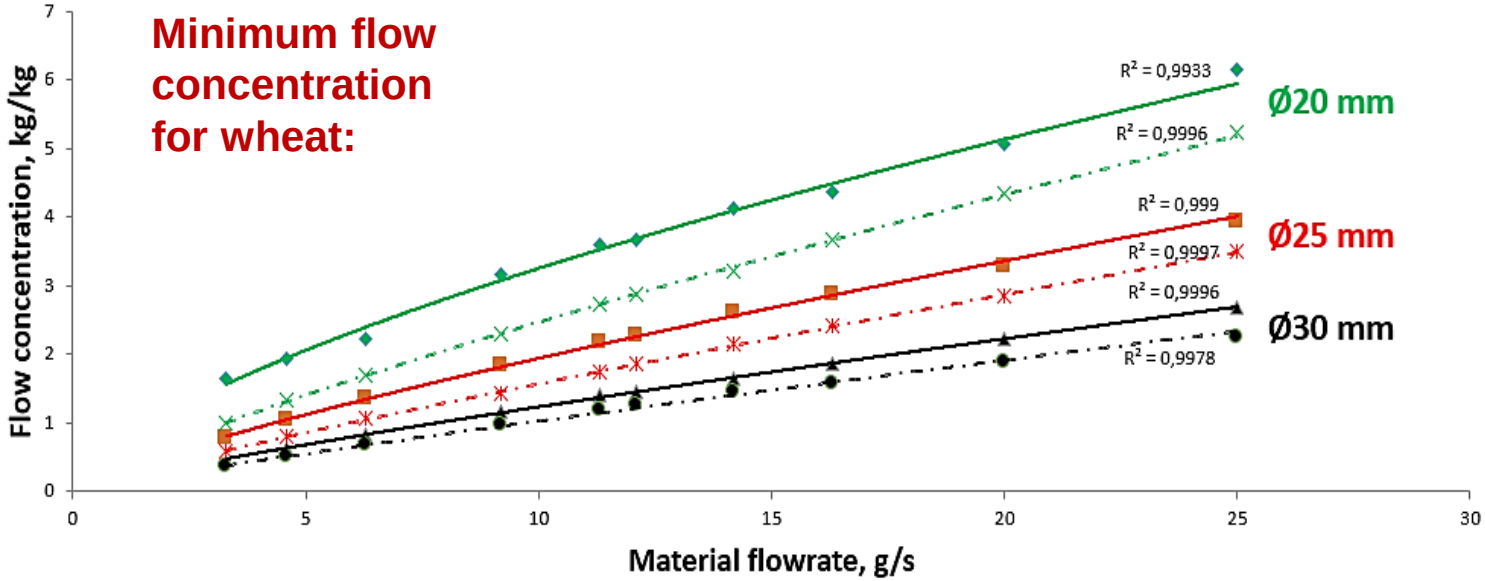


$$\Delta P = \frac{\rho V_2^2}{2} - \frac{\rho V_1^2}{2}$$

$$V_1 = \sqrt{\frac{\Delta P}{\frac{\rho}{2}\left(\frac{F_1^2}{F_2^2} - 1\right)}}$$

Establishing of the conveying parameters

Conclusions

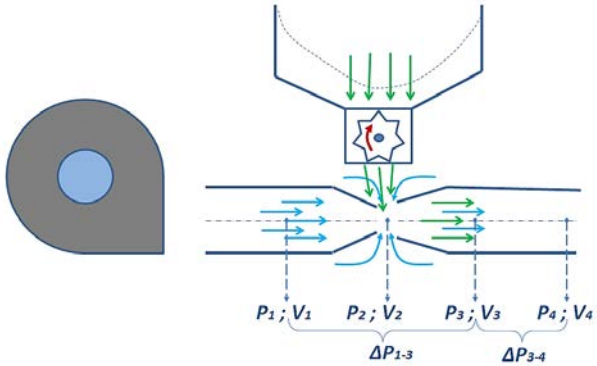


- Starting point of air-stream design must be the optimization of conveying in the pipes after distribution head. The design of the rest of the conveying system will result from this first step
- Design of **new sensor system**.
- It is recommended to use the **pipe sections** as lower as possible to favor a homogenous airflow and to reduce the energetic cost of conveying.

3. Optimization of air-stream loading systems

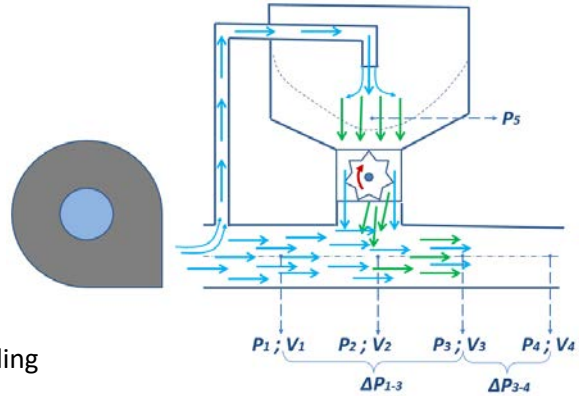
Optimization of air-stream loading systems

Horsch Pronto equipped with an injector-loading system (Photo: Horsch).



Venturi injector functioning.

John Deere (Commodity air-cart 1910) equipped with a pressurized-loading system (Photo: A. Yatskul).

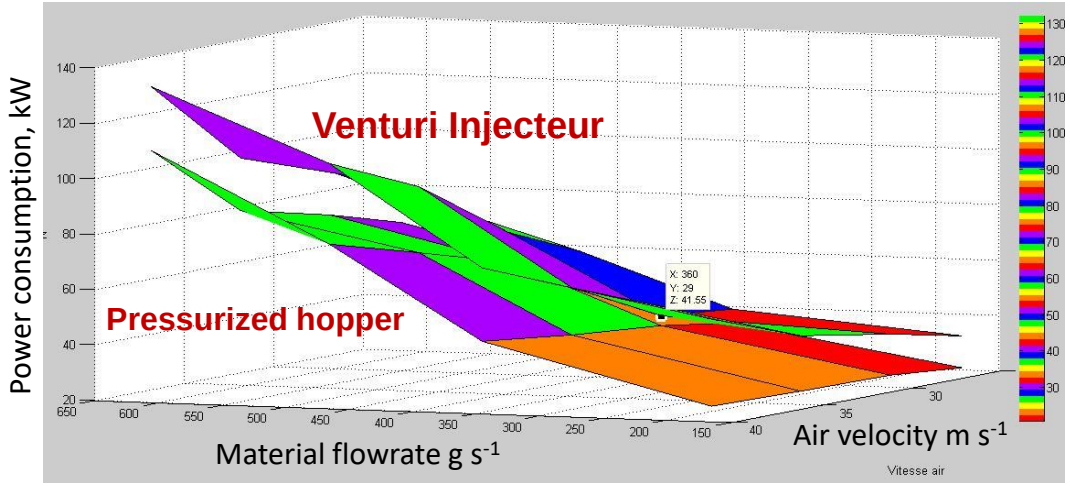


Functioning of a pressurized system.

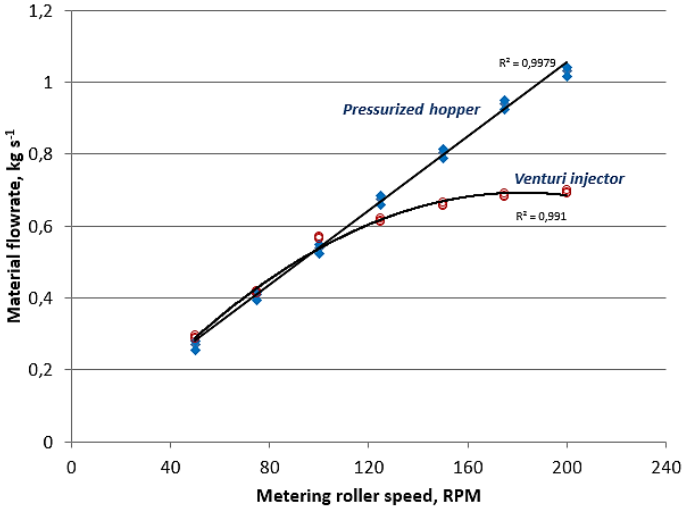
- Provide a fundamental physical justification of choosing between the pressurized hopper and Venturi injector
- Comparing criteria: energy, conveying performances, metering presision

Optimization of air-stream loading systems

Conclusions



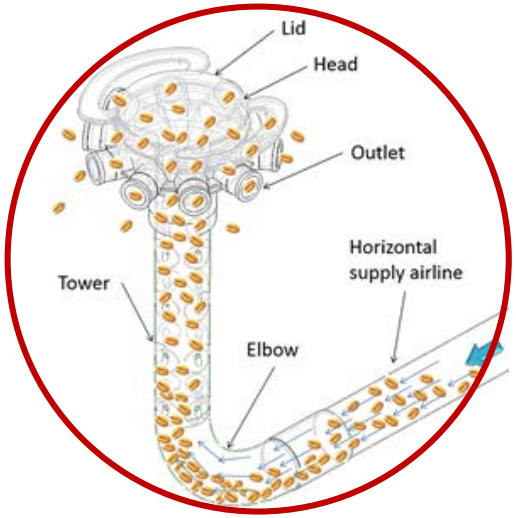
Power consumption, kW

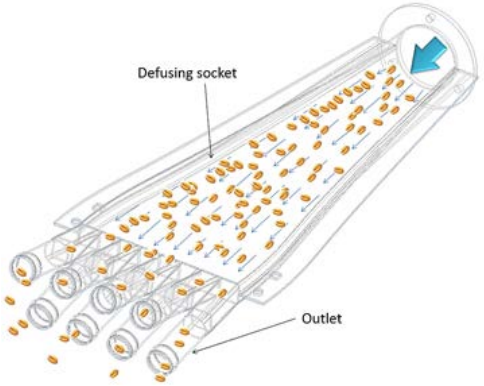


Material flow rate vs metering roller speed

- Pressurized systems are always more energy efficient, allowing a gain between 11 and 29 kW, compared to the Venturi injector system.
- Pressurized systems have the highest transfer capability (maximum possible flow rate mass) and best metering precision
- Shortcoming of pressurized systems is their cost and tightness sensibility

4. Optimization of divider head geometry





Establishing of the conveying parameters

Influence of the air velocity and of the material flow rate on the distribution accuracy	
Influence of the functioning conditions on the distribution accuracy	Influence of the outlet closing
	Influence of differences in outlet pipe lengths
	Influence of distribution head tightness
	Influence of distribution head slope
Influence of the divider device structure on the distribution accuracy	Influence of tower configuration and of tower height
	Influence of elbow
	Influence of the cone shape deflectors implementation on the divider lid

Distribution accuracy was estimated by the **maximum value of variation coefficient CV**, according to ISO-7256/2 → influence on the feeding area

According to agronomy requirements: CV < 5% for seeds, 10% for fertilizers

Yatskul et al., 2017

Establishing of the conveying parameters

Conclusions

- The main reason of low distribution accuracy is the elbow and a **saltaroty movement** of particles induced by it.
- For each divider head and for a given material flow rate of a given seed species, there is **an air velocity ensuring the best distribution accuracy**. It is due to the saltatory movement of the particles' flow core.
- Any **outlet closing** or excessive outlet pipe length variations are **unfavorable**. We advise providing the interchangeable "heads" with the different outlet numbers, taking into account any temporary outlet closing (tramlines etc.).
- **Installation of a deflector** is only useful if the concentration of particles is already perfectly distributed through a tower cross-section before dividing

Yatskul et al., 2017

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Thank you for your attention!
Any questions?