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

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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:
- High capacity poly-articulated machines, with a wide working width

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

Bibliography sources very poor
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

\[
\begin{align*}
    x_0 &= \frac{1}{k_r} \int_{y_0}^{y_{0\max}} \cos\left(\frac{1}{k_r L_0} \ln \cos y_0\right) dy_0 \\
    y_0 &= \frac{1}{k_r} \int_{y_0}^{y_{0\max}} \sin\left(\frac{1}{k_r L_0} \ln \cos y_0\right) dy_0
\end{align*}
\]

Circular tractor trajectory \( R \in [R_{\min}, R_{\max}] \) consequently: \( y_0 \in [0; y_{0\max}] \)

\[
\begin{align*}
    x_c &= x_0 + R_{0\min} \cos \delta_{0\max} \\
    y_c &= y_0 - R_{0\min} \sin \delta_{0\max}
\end{align*}
\]

Towed elements trajectory

<table>
<thead>
<tr>
<th>Input ( y_1, y_2, y_3 )</th>
<th>Output ( y_2, y_3, y_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equations and master parameters</td>
<td></td>
</tr>
<tr>
<td>( y_1 = \frac{L_1 + c_0}{L_0} y_0 - L_1 (1 - e^{-\frac{y_0}{L_1 k_p}}) k_p )</td>
<td></td>
</tr>
<tr>
<td>Master parameter: ( y_0 )</td>
<td></td>
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<tr>
<td>( y_1 = y_1(\tau_1) e^{-\frac{R_0 \varphi_k}{L_1 k_p}} + \frac{L_1 + c_0}{L_0} \left(1 - e^{-\frac{R_0 \varphi_k}{L_1 k_p}} y_{0\max}\right) )</td>
<td></td>
</tr>
<tr>
<td>Master parameter: ( \varphi_k )</td>
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<tr>
<td>( y_1 = y_1(\tau_2) e^{-\frac{y_{0\max} - y_0}{L_1 k_p}} + \frac{L_1 + c_0}{L_0} \left(y_{0\max} + L_1 k_p \left(1 - e^{-\frac{y_{0\max} - y_0}{L_1 k_p}}\right) - y_{0\max} + y_0\right) )</td>
<td></td>
</tr>
<tr>
<td>Master parameter: ( y_0 )</td>
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<tr>
<td>( y_1 = y_1(\tau_3) e^{-\frac{S_0}{L_1}} )</td>
<td></td>
</tr>
<tr>
<td>Master parameter: ( S_0 )</td>
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</tbody>
</table>

Andrii YATSKUL - MODELING AND ENERGY CONSUMPTION OPTIMIZATION OF THE OPERATIVE PARTS OF AIR-SEEDERS
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
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:

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

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

Minimum flow concentration for wheat:

![Graph showing flow concentration vs. material flowrate for different pipe diameters (Ø20 mm, Ø25 mm, Ø30 mm).]
3. Optimization of air-stream loading systems
Optimization of air-stream loading systems

Provide a fundamental physical justification of choosing between the pressurized hopper and Venturi injector

Comparing criteria: energy, conveying performances, metering precision
Optimization of air-stream loading systems

Conclusions

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.

Material flow rate vs metering roller speed

Power consumption, kW

Venturi Injecteur

Pressurized hopper

Pressurized hopper

Venturi Injecteur
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 outlet closing |
| Influence of differences in outlet pipe lengths |
| Influence of distribution head tightness |
| Influence of distribution head slope |
| Influence of the functioning conditions 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 |
| Influence of the divider device structure on the distribution accuracy |

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
Thank you for your attention!
Any questions?