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Common causes of failure of pneumatic distributors in high precision pneumatic seeders: Proposals towards predictive maintenance

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Abstract. *Modern precision pneumatic drills (1-500 kg/ha) used in the cultivation of high density crops such as winter cereals (up to 400 plants/m2) are very high performance equipment that triple the working width (up to 9m) and rates (up to 14 km/h) compared to those used fifteen years ago. Most of enterprises commercialize such devices using as cornerstone a central pneumatic distributor in combination with a large number of radial outlets (24-48). In spite of the unquestionable advantages of these devices with regard to more conventional gravitational distributors, the main drawback remains the lack of transversal uniformity which has proven to be fairly sensitive to seed size and shape, to slight air flow changes related to partial obstructions of outlets, elbows and grips in discharge outlets, or vibrations and inclinations of the central distributor, as well associated to inadequate maintenance of the machine by untrained operators. Moreover, the lack of behavior predictability derives in a certain discredit of the pneumatic procedure. This work proposes a theoretical-empirical methodology to analyze the pneumatic circuit and its interaction with a variety of seeds types to be delivered, and selected operational machinery settings, within the aim of elaborating a test protocol which combined with low cost instrumentation will serve a base for predictive maintenance. Experimental data gathered in static and dynamic tests performed by the authors on at least two different seeders together with published information available on technical papers will be reviewed and used for further discussion on reliable diagnosis procedures.*

Keywords. Granular product; advanced mechanization systems, agricultural machinery; fault diagnosis.

Introduction

Pneumatic drill is a well established practice that allows large working widths together with centralized hopers which enable transport folding mechanisms. Frequently used machinery includes working widths with up to 9 m, with working rates of 14 km/h.

The American Society of Agricultural and Biological Engineers awards yearly the 50 outstanding innovations in the field, the so called AE50. In the last five years, seven air drill systems have been awarded: two in 2007 (3310 Paralink Hoe Drill, SD550 Air Hoe Drill), three in 2008 (84 Air Drill See Hawk, Bourgault 6700ST Air Seeder, YP2425 Yield-Pro Planter) and two in 2010 (1260 Early Riser Planter, P2070 Precision Hoe Drill). All of them hold in common the even larger work width (up to 21 m) compared to conventional systems, and high folding performance together with precision depth control. Figure 1 highlights the complexity of the pneumatic circuits that are required for upcoming machinery.

Figure 1. 3310 Paralink Hoe Drill. AE50 outstanding innovation in 2007.
http://www.asabe.org/resource/ae5011entry.html

There is but little technical information about the performance of pneumatic drills (Profi Test 2010 & 2011, Gil-Quirós et al., 2007; Barreiro et al., 2010; Diezma et al. 2011), and none scientific analysis of the pneumatic circuits, even though the ultimate quality of seed distribution relays on the homogeneity of the transversal distribution of seeds.

Standard machine testing includes static and dynamic analysis of seed distribution, and sensors are continuously evolving to assess the amount of seeds being distributed by the pneumatics http://www.dickey-john.eu/. Supervision of the pneumatics is restricted to the rotating speed of the turbine or alternatively the hydraulic pressure that drives it, which must be adjusted according to the type of seeds, since its physical properties (size, shape, and specific weight) greatly affecting the flow properties (Barreiro et al., 2010).

Figure 2 shows an example of static test on the transversal distribution of seeds for a 25 seed hoes machine (Diezma et al., 2011). A clear difference can be found between the areas where the tubes are clean and free of obstructions (left hand side) and the rest (right hand side). Any obstruction either partial or full has as counteract the increase in seed delivery for adjacent tube.

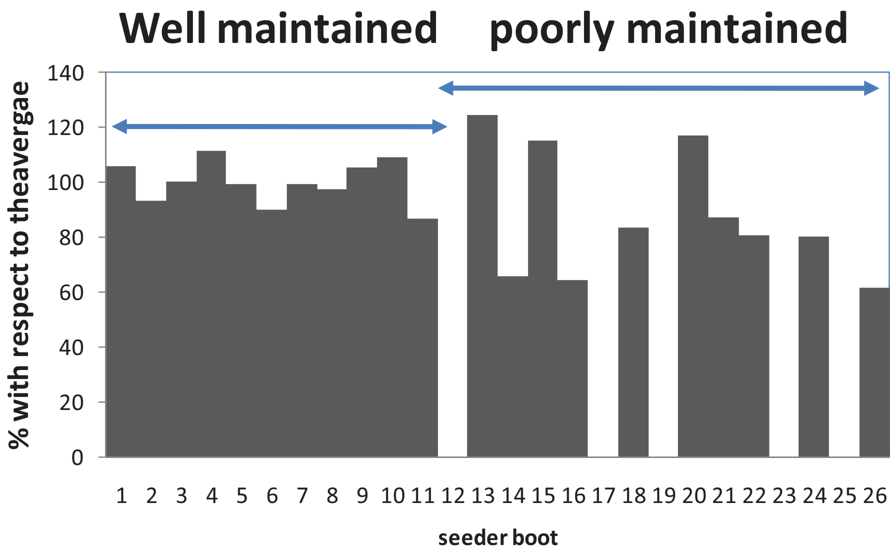

Figure 2. An example of static test on the transversal distribution of seeds for a 25 seed hoes machine (Diezma et al., 2011). Note the difference between correctly maintained tubes (hoes 1-11) compared to those with poor revision (12-25).

Some of the technical papers published lately (Profi Tests 2010 & 2011) refer the fact that smaller seeds such as oilseed rape show far poorer transversal distribution than large seeds as wheat. Figure 3 compares the transversal distribution with the same machine Pottinger Terrasem 3000 for peas (left) and barley (right) as referred by Gil-Quirós et al. (2007), several of the authors also contributing to this work.

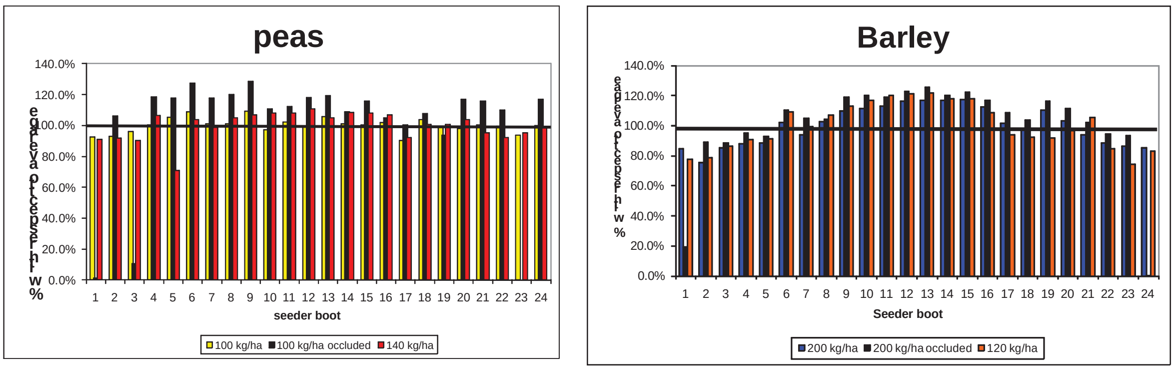

Figure 3. Comparison of transversal distribution with the same machine Pottinger Terrasem 3000 for peas (left) and barley (right) as referred by Gil-Quirós et al. (2007

The primary objective of this work is to analyze the pneumatic circuit of two pneumatic drills: 4F-AIRSEM-SNL 5032, and AIRSEM-6040, to study the variation of airflow in various situations throughout their width, as a mean for reflecting on the needs for prognosis and diagnostic tools to be developed in the near future.

Material and Methods

In this paragraph an overview is given on the machines and instruments used for this study

Figure 4. One of the seeders used for this study.

Pneumatic seeders

Two different machines have been used: 4F-AIRSEM-SNL 5032 and AIRSEM-6040, one of which is presented in Figure 4. Note that boots are gathered in several rows: 4 and 3 for each machine respectively.

To this end, a measurement was made on each tube during 30 seconds to get 7 speed data regarding the air rate (m/s) through the tubes. Each tube is characterized for three different turbine rates at 3000, 3500 and 4000 rpm. Also several strategic seed tubes have been characterized measured according to air rate (m/s) at the so called mushroom distributor.

As a result, a total amount of 1708 air speed data has been obtained for the two pneumatic drills: 32 and 40 boots respectively.

Machine	4F-AIRSEM-SNL 5032	AIRSEM-6040
Working Width	5.0 m	6.0 m
Transport width	2.7 m	2.0 m
Number of boots	32	40
Hopper capacity	1400 L	1400 L

Table 1. Technical details of the pneumatic drills used for the tests.

Instrumentation

The pneumatic distributor of each seeder is analyzed by means of an electric motor (15HP) driving a hydraulic pump (30L/min) that powers the air turbine. The air speed is measured through a digital manometer with Pitot coupling. Details of the test assembly are given in Figure 5.

Figure 5. Details of the test assembly: hydraulic pump (left) and Pitot digital manometer (right).

Data Analysis

Data are analyzed by means of Matlab 7.5 (Mathworks Inc.) using statistical analysis toolbox and dedicated data gathering routines.

Results and discussion

Effect of turbine speed and boot row

The average air speed (m/s) for air drill 5032 is significantly higher from that of air drill 6040, 9.91 $\pm$ 0.06 m/s and 8.51 $\pm$ 0.04 m/s respectively, which reflects the fact that a higher number of tubes (40 compared to 32) is used for the latter under the same turbine. Figure 6 and 7 show the results of means comparison for two factors studied (X1, row) and (X2, turbine regime). The effect on air speed as a result of turbine regime is clear and higher for 6040 compared to 5032 (F value of 812 and 115 respectively). The effect of seeder row is higher in 5032 than for 6040 (59.6 and 30.5 respectively) and the interaction is significant for the former (F=24.4) and not for the latter (F=2.2). Table 2 summarizes the results of ANOVA.

Generally speaking in both seeders the differences among rows increases for increasing turbine regime (Figures 6 and 7). As expected the tube length is related with seeder row, since longer path is needed to reach the tubes (F=48.2 and 33.8 for model 5032 and 6040 respectively).

The effect of turbine speed on air speed drop between the distributor and the end of the tubes is higher for model 6040 compared to 5032, while row a significant interaction with turbine regimen for the latter which is inexistent for model 6040. In General the air speed drop is higher for higher air speed.

	5032			6040		
	air speed	air speed drop	tube length	air speed	air speed drop	tube length
Seeder Row	64.0	59.6	48.2	30.5	53.2	33.8
	**	**	**	**	**	
Turbine rate	812.1	0.2	-	1515.4	29.9	-
	**	ns		**	**	
Row*Tur. Rate	3.4	24.4	-	0.3	2.2	-
	**	**		ns	ns	

Table 2. Analysis of Variance on air speed flow, air speed drop between pneumatic distributor and the end of tubes, and tube length. The level of significance is indicated as follows: ** <0.01, * < 0.05, ns non significant.

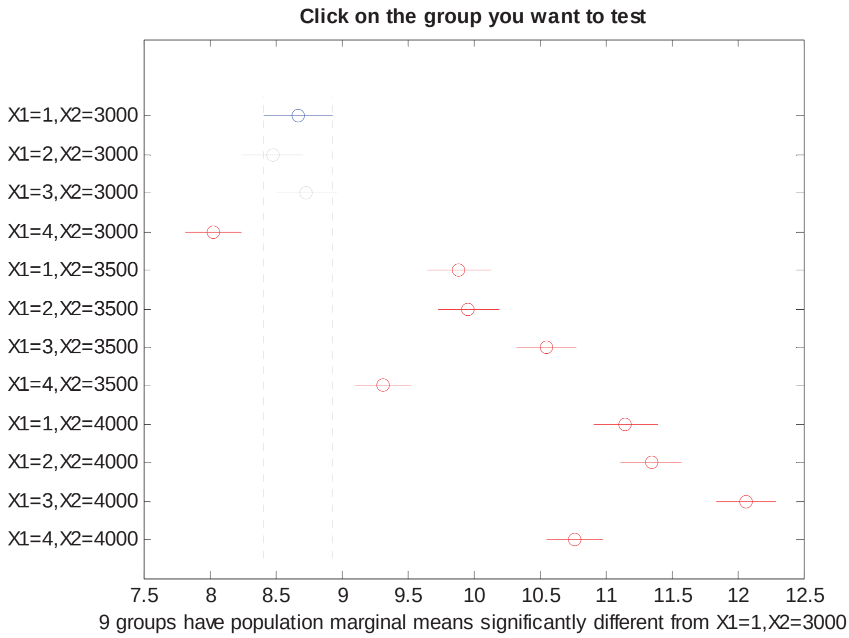

Figure 6. Means separation for pneumatic seeder 5032 according to air speed (m/s, x axis) the different factors (X1=row, X2=turbine regime) together with all interactions is displayed.

Tube length versus air speed

Figure 8 and 9 provide a scatter plot of air speed (m/s) versus tube length (m) for seeders 5032 and 6040 respectively, comparing the effect of the different turbine regimes. Data from the 32 and 40 boots are available and can be recognized as block of data. Seeder 5032 shows much higher varaibility in air speed as turbine regime increases (7.2%, 8.2% and 9.2 % for regimes 3000, 3500, 4000rpm), compared to model 6040 (6.0%, 6.2% and 6.4% for 3000, 3500 and 4000 rpm).

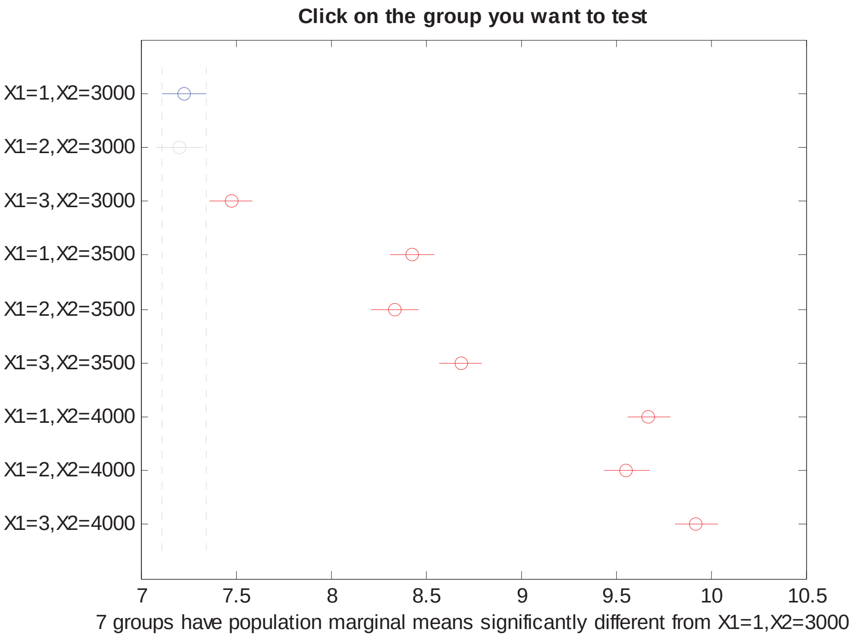

Figure 7. Means separation for pneumatic seeder 6040 according to air speed (m/s, x axis) the different factors (X1=row, X2=turbine regime) together with all interactions is displayed.

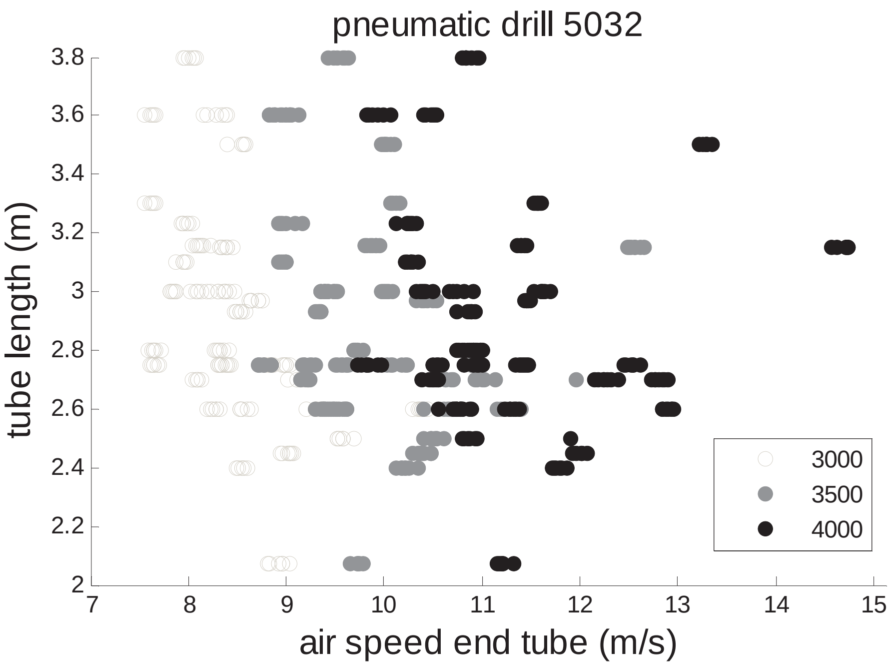

Figure 8. Scatter plot of air speed (m/s) versus tube length (m) for seeder 5032, comparing the effect of the different turbine regimes.

Air speed at the distributor versus air speed drop

Figures 10 and 11 present the scatter plot of air speed at the distributor compared to air speed drop in the seed pipes, for both seeders 5032 and 6040. The air speed drop is higher for increasing air speed and slightly higher for model 6040 compared to 5032 (3.02 $\pm$0.11 and 2.91 $\pm$0.11 respectively)

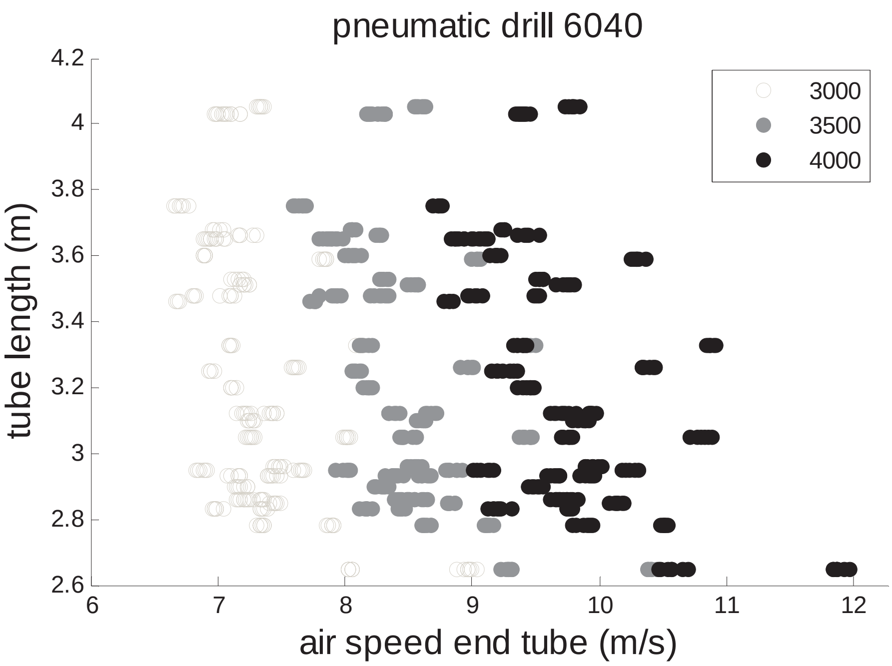

Figure 9. Scatter plot of air speed (m/s) versus tube length (m) for seeder 6040, comparing the effect of the different turbine regimes.

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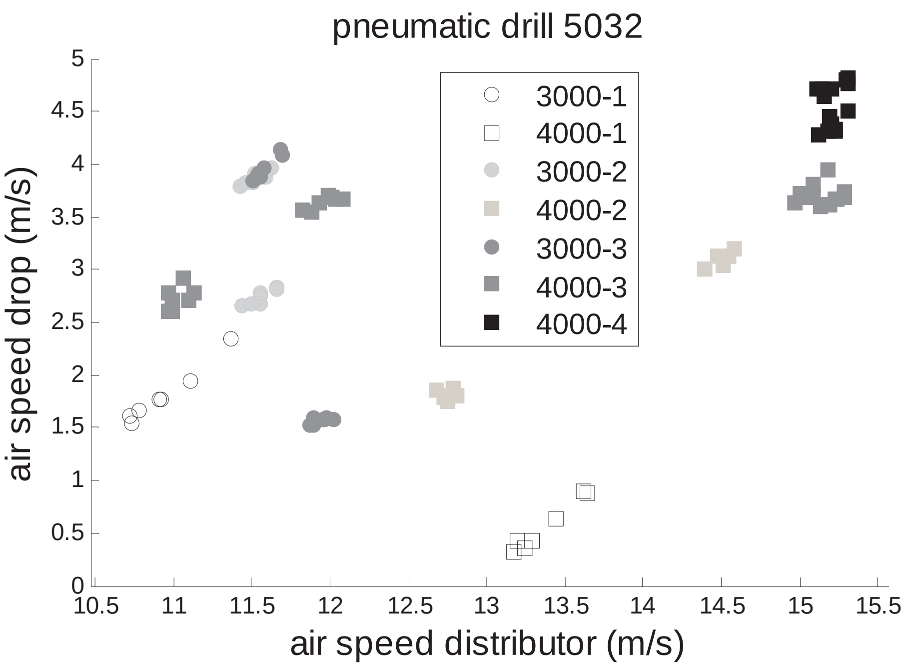

Figure 10. Scatter plot of air speed at the distributor compared to air speed drop in the seed pipe for seeders 5032.

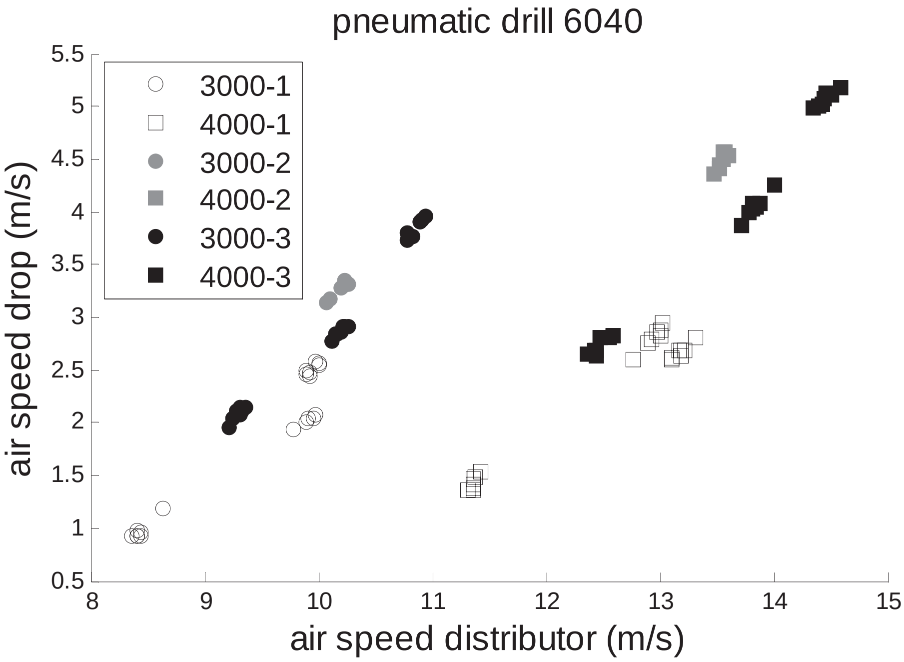

Figure 11. Scatter plot of air speed at the distributor compared to air speed drop in the seed pipe for seeders 6040.

Conclusion

The starting point of this work was the demonstration that pneumatic seeders are becoming increasingly complex with working widths up to 21m, while technical field tests indicate that transversal uniformity is poor depending on maintenance and type of seed used.

Any prognosis system needs to take into account the pneumatic characteristics yet no published data are available on the pneumatic behavior.

The use of simple Pitot manometer on two models of seeder with varying number of rows and boots has allowed demonstrating the dramatic effect of seeder design and pipes lengths both on air speed and air speed drop.

Monitoring the behavior of pneumatic seeders requires the incorporation of low cost sensors that enable the identification of faulty situations like occlusions.

Acknowledgements

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