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Title: Aplicación de modelos de simulación en el diseño mecatrónico agrícola para la Agroindustria 4.0. "Modelado del dosificador de semillas para sembradora automática de charolas de germinación"

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Editorial label ECORFAN: 607-8695
BCIERMMI Control Number: 2020-04
BCIERMMI Classification (2020): 211020-0004

Pages: 10
RNA: 03-2010-032610115700-14

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Introduction

In the present work the analysis for the agricultural mechatronic design of a seed dispenser for automated pneumatic seed drills for germination trays was made, assuming that the design of agricultural machinery is not simple or easy, for a long time this type of development was worked under the concept of trial and error, the aim of this work was to model and simulate a seed metering device through the use of critical design parameters, such as speed and working pressure, by using the average air speed that produces the adhesion of a grain in the cylinder, as well as the geometric dimensions of the cylinder. This allows to determine the optimal parameters for the design of the system.

Methodology

A seeder, metering roller or seedbed, is the element that allows to contain and direct the seed towards the sowing line, depending on the type of seeder that is chosen, in the case to be treated it is considered a band seeder, so the seedbed, or metering roller will be considered as a roller that makes the seeds only experience centrifugal force and the acceleration of gravity.

The equation that expresses the force of the seed is (Álvarez Lorenzo, 2003):

$$\boldsymbol{F_{seed} = (r\omega^2 + g)m} \qquad (1)$$

Where:

$F_{seed} = Seed\ power, N$

$\omega\ = roller\ speed, rad/s$

$r = radius\ of\ the\ roller\ to\ the\ center\ of\ the\ cell, m$

$g = acceleration\ of\ gravity, 9.81 m/s^2$

$m = seed\ mass, kg$

The air flow is calculated with the following expression::

$$Q = V_{roller} \times A_{total} \times r \times N_{hopper} \times F.S. \qquad (2)$$

Donde:

V_{roller} = *roller speed*, rad/s

A_{total} = *total area of the number of cells passing through the suction zone*

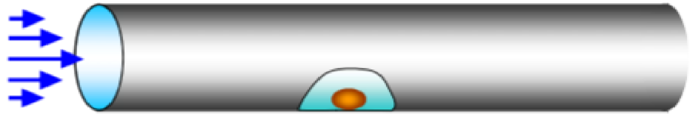
r = *roller radius*

N_{hopper} = *number of required turfs*

$F.S.$ = *factor of safety*

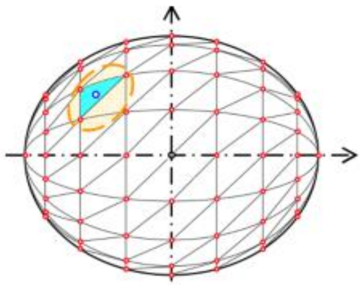
For the simulation of the air flow in the duct, the Navier-Stokes equations are proposed, solved with a standard Reynolds Average Navier-Stokes (RANS) technique, with a turbulence model k - ε (Wilcox, 1994), being the Reynods number in the flow between 42000 and 170000. It is assumed that the air velocity gradient will not be affected by the presence of grain-size particles (Tashiro, 2001). The algorithm is stationary and will be solved with the CFD technique for seed dosing.For the duct, the following considerations were taken, a circular section tube of diameter 0.065 m (see Figure 1) composed of a horizontal section and an ascending elbow. The grain was considered as a solid of revolution being the value of its three semi-axes 0.0030m, 0.0030 m and 0.0030 m (see figure 2), being its specific weight of 1200 kg/m3 . The grain enters through an orifice in the upper part of the duct at initial speed.

Figure 1 General diagram of the model



Source : ansys own authorship

Figure 2 Grain model



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Second order tetrahedral elements are used for speed and first order for pressure, with refined meshes in the proximity of the grain. Figure 3 shows a sector of the three-dimensional mesh around the grain in a 0.040 m diameter tube.

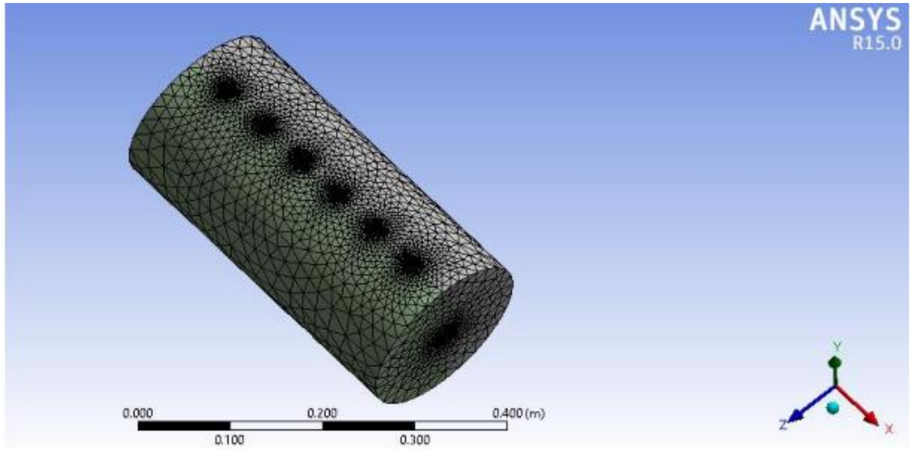


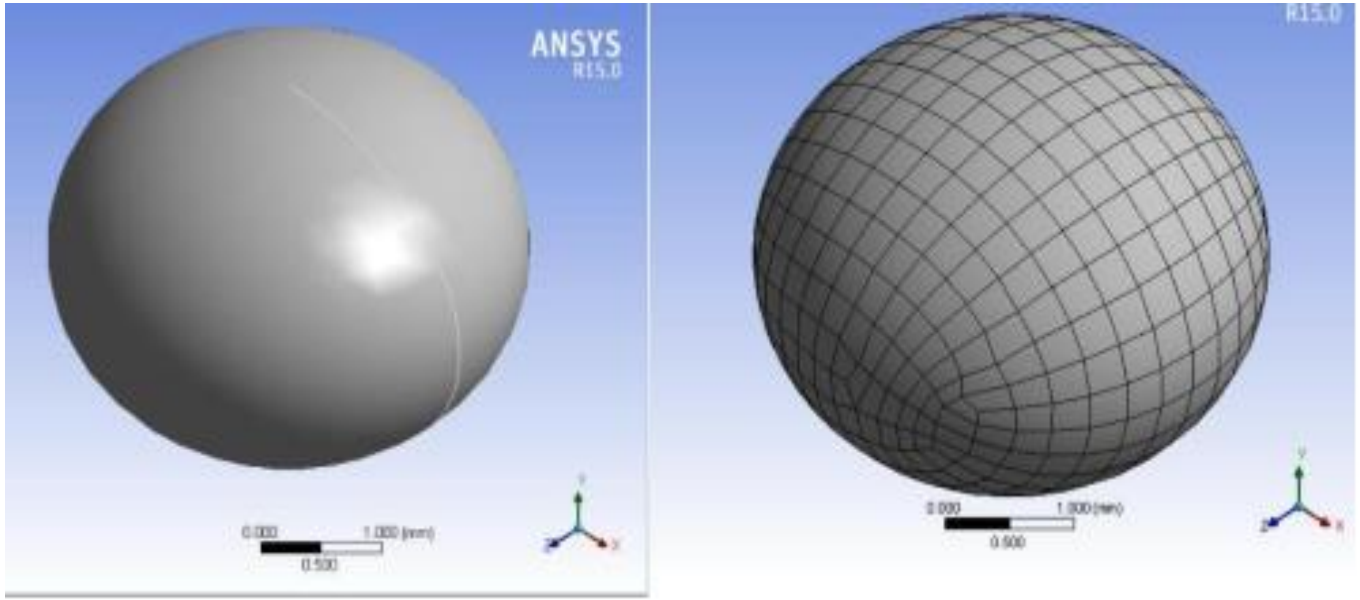
Figure 3 Three-dimensional mesh in a 0.040m diameter duct with refinement in the grain zone

Source : ansys own authorship

Results

For the calculation of the lifting force, the lifting force boundary was modelled using ANSYS R15.0 with 3-sided surface elements. A total of 544 nodes and 543 surface elements were defined, see figure 4.

Figure 4 Meshing over the grain



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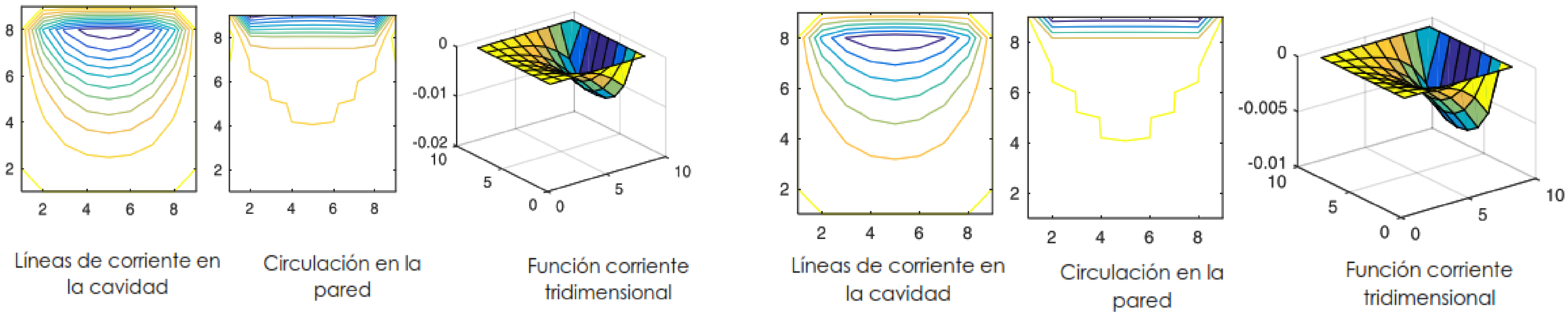
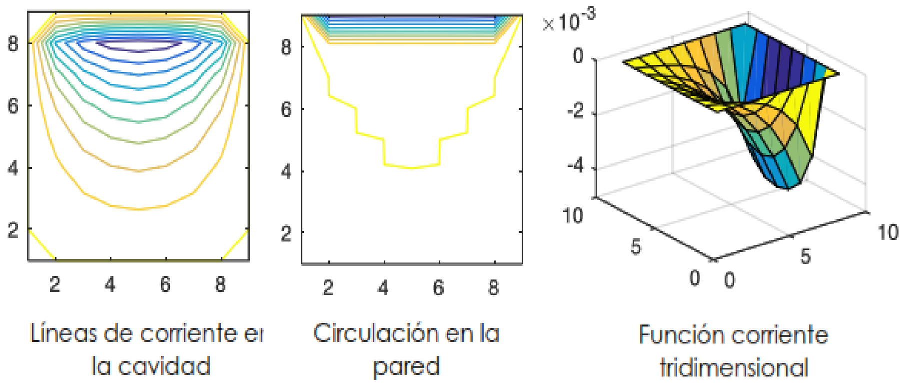
To consider the best flow rate of the grain, tests were made, under different recommended speeds. The boundary conditions are pressures at the inlet of the tube that allow the flow to develop. Null normal flow is adopted on the side walls and over the grain, for this case the vacuum pressure is kept constant at 32,763 Pa, which is the one recommended by Gaytan (2004).

This situation can be seen in Figure 4, , where it can be seen that the speeds adhere to the grain to the cylinder during the vacuum stage, or generate phenomena that cause the seed does not ensure its adherence, and logically does not perform the required work.

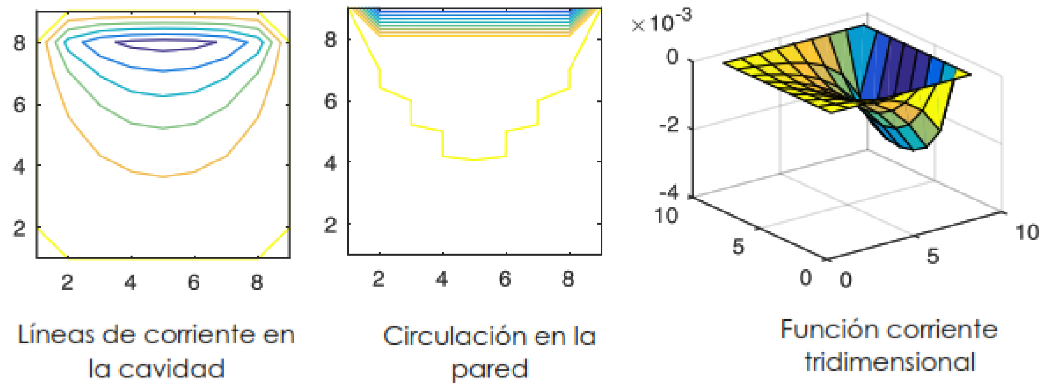
Figure 4 Grain velocity response



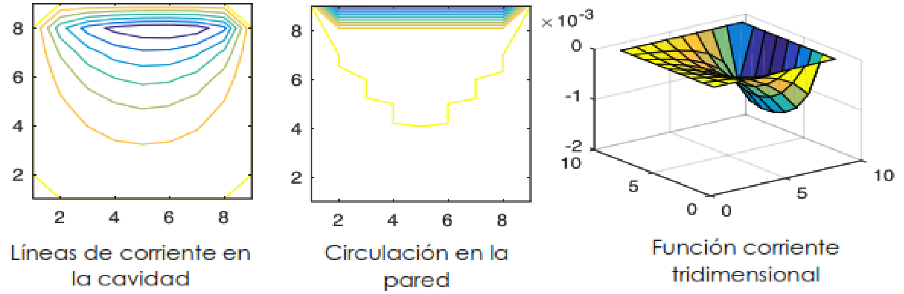
(a) Speed response of 0.3133 m/s (b) Speed response of 0.6266 m/s



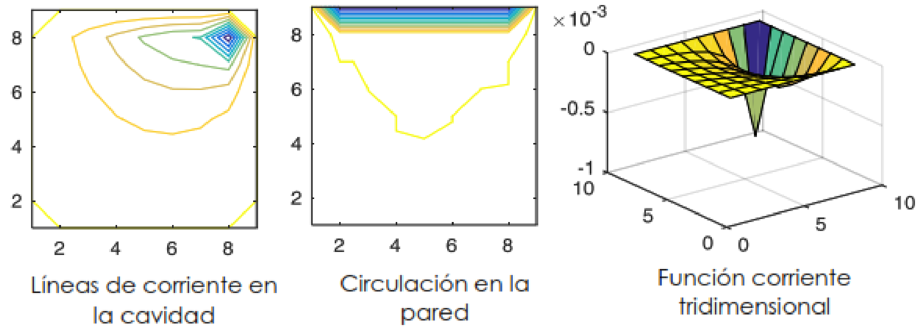
(c) Speed response of 0.9399 m/s



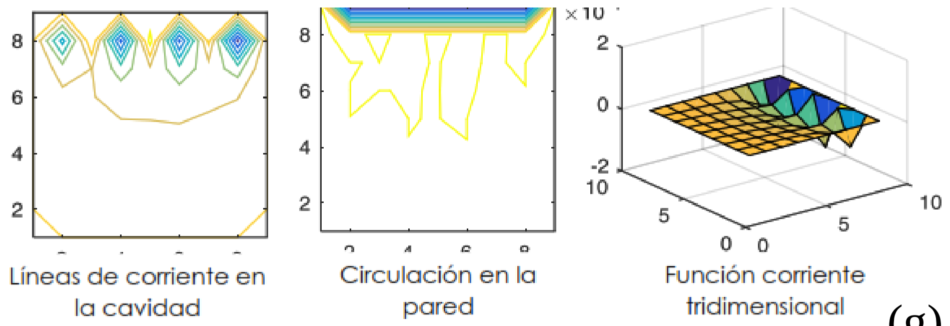
(d) Speed response of 1.725 m/s



(d) Speed response of 3.45 m/s



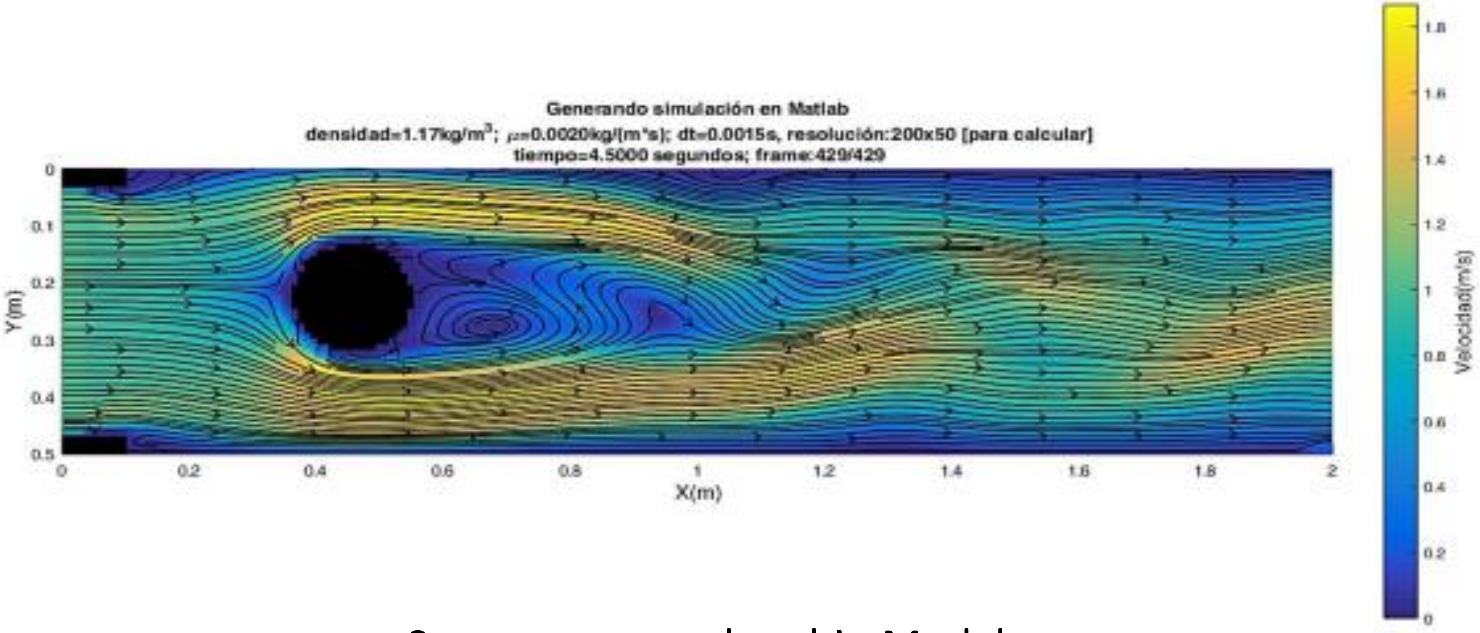
(f) Speed response of 6.9 m/s



(g) Response speed of 13.8m/s

It can be seen that once again the optimum working speed that guarantees the adherence of the grain to the cylinder is in the order of 0.3 y 1 m/s, which guarantees that the behaviour of the grain is as intended, i.e. that the necessary working conditions are generated in the place of the hole so that the grain remains adhered to the working stage. Figure 5 shows the field lines of the speed around the grain, which again ensures the adhesion process, considering the constant pressure of 32,763 Pa.

Figure 5 Airflow behaviour at the start of the process and 0.015 seconds later



Source: own authorship Matlab

Conclusions

The design and construction of agricultural machinery has always been very complex and empirical, many data have been obtained by the construction of laboratory models, which allow the measurement of values under specific techniques, such as the placement of high-resolution cameras, vision systems, special sensors, so as a result of this situation has begun the design of an experimental way.

This specific work generated more questions than answers, but when the resolution of these problems began, it opened a very large door of knowledge. It is not easy to generate models of systems that already exist in the market, but that do not have an analysis, a modeling and a simulation.

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