Development of a Universal Seeder System to Be Applied in Drones

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Abstract—**The number of applications that Unmanned Aerial Vehicles (UAVs), or drones, can have is absolutely amazing. From applications for military purposes to personal requests undergoing civilian applications, the literature demonstrates the extent and usefulness that drones represent nowadays. This paper aims to contribute positively to the growth of the economic sector of agriculture since it has the purpose of developing a seeder that will be able to be coupled to any type of drone. Besides being used to make a random seed, this seeder allows for the deposition of seeds with positional accuracy, i.e., seeds will be accurately deposited at pre-established distances between plants. A coupling system between seeder and drone that regards the specifications of UAVs manufacturer to ensure that operations are carried out safely was also designed. Furthermore, a communication interface between UAVs and a peripheral integrated system that enables operation of the assembly was also developed.**

Index Terms—**UAVs, drones, seeder, plantation, agriculture, agro-ecological**

I. Introduction

"*Let them fly and they will create a new remote sensing market in your country*" is the message that Colomina and Molina [1] send with their paper, published in June 2014, to local policy makers, regulatory bodies and mapping authorities all around the world. This message is irreproachably sustained in the review study presented by Ref. [1] where, an extensive list of UAVs, also known as Unmanned Airborne Systems (UASs), applications devoted to photogrammetry and remote sensing, is described. More recently, in April of the current year, Liu and coauthors [2] also published a very in-depth and comprehensive literature review on the history, developments, applications, methodologies and challenges of UAVs. From 1985 to now UAVs are used for a very wide range of applications and here we report only some of them: forest-fire fighting [3]; police surveillance and protection [4], [5]; environmental factors, such as radiation and infectious diseases, monitoring and control [6], [7]; search and rescue missions [8], [9]; ecological research studies [10], [11]; oil and gas industry security [12]; mapping and surveying [13]; weather monitoring [14], seismic and geothermal monitoring [15], to deliver medical supplies and products in times of critical demands across both accessible and inaccessible or dangerous locations [16].

Concerning the agricultural economic sector, the replacement of large and unwieldy aerial or land vehicles for UAVs in agricultural operations is now a reality. The use of UAVs in advanced agriculture meets eco-innovation requirements helping to reduce the negative impact that agricultural activity causes in ecosystems, in particular by reducing the use of fossil fuels and their replacement by electric energy that can be provided from renewable sources. Another advantage lies in increasing productivity and economic gains, a key sector of economic activity such as agriculture. In addition, when compared with conventional agricultural equipment, UAVs present greater operating flexibility, lower initial and operating investment costs, reduced size and increased profitability by reducing costs related to the reduction of human resources, since a single operator can control several simultaneous UAVs in a safe and comfortable way [17]-[24].

Agricultural operations such as the prediction of fungi appearing and movements [22], weed mapping and control [20], application of fertilizers, insecticides, pesticides, fungicides spraying or other spraying chemicals, as well as other crop protection materials or [18]-[21]; analysis of vegetative condition, are performed more efficiently, effectively and economically with UAVs use. In addition, UAVs are a powerful tool on the crop monitoring and damage assessment, i.e. on agricultural surveillance, maintenance and decision support for food security [23], [24]. However, seeder operations using the UAVs are limited to their use in crops where seed deposition can be made within a predetermined area, but on a random basis, without the need to respect distances between plants as is the case in some cultures forage (e.g. rice) whose characteristics meet the conditions to be performed by UAVs. This culture is usually carried out in flooded sites (submerged) in water, which ensures germination of seeds without the need for plowing. With The distribution of seeds, this culture can be made by spreading density control but without meeting pre-established uniform distances between plants. The use of UAVs in seed cultures, where the substrate/soil by itself does not guarantee the germination/viability of seeds and wherein the placing of the plants should be made with pre spaces determined and

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very low (e.g. 100 mm between plants) is unfeasible. The development of a precision seeder, coupled to a UAV is presented as a technological challenge, with great potential for creating new business opportunities. This new equipment is part of a market segment with strong growth potential and is presented in this work.

Another requirement that has to be provided by the substrate/soil is the viability of seed germination and plant development. In this respect the authors developed a system which ensures seed germination and subsequent plant growth with a high success rate because the necessary protection of seeds and their germinative and vegetative conditions which increases the success of planting is ensured. This issue will be addressed in a forthcoming publication of the authors.

II. Design of a Seeder System

The use of UAVs in agricultural tasks and on the analysis of health and vegetative conditions represents, as mentioned before, a powerful tool in modern agriculture. This paper presents the design and development of a seeder system that is coupled, as in, to a UAV that is the spatial positioning and propulsion system. Fig. 1 and Fig. 2 show the tridimensional Computer Aided Design (3D CAD) model of the seeder developed. This seeder system will deposit seeds with accurate distances pre-established between plants. The seeder is composed of several subsystems, namely a sensor system of seed level, a communication interface with a UAV central controller system, an electro-pneumatic drive system for seeds deposition, a chassis, the fastening system of UAV, illustrated in Fig. 3, and a seeds warehouse.

The seeder is fixed to the chassis 1 through the lever 3, that in a quick and efficient way, allows for the assembly/disassembly of the seeder thanks to the action of the spring 2. The brake 4 is the safety system of the fastening system.

Figure 1. 3D CAD model of the whole drone plus seeder.

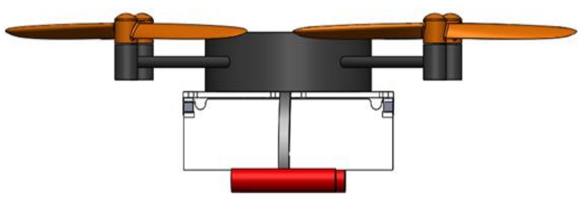
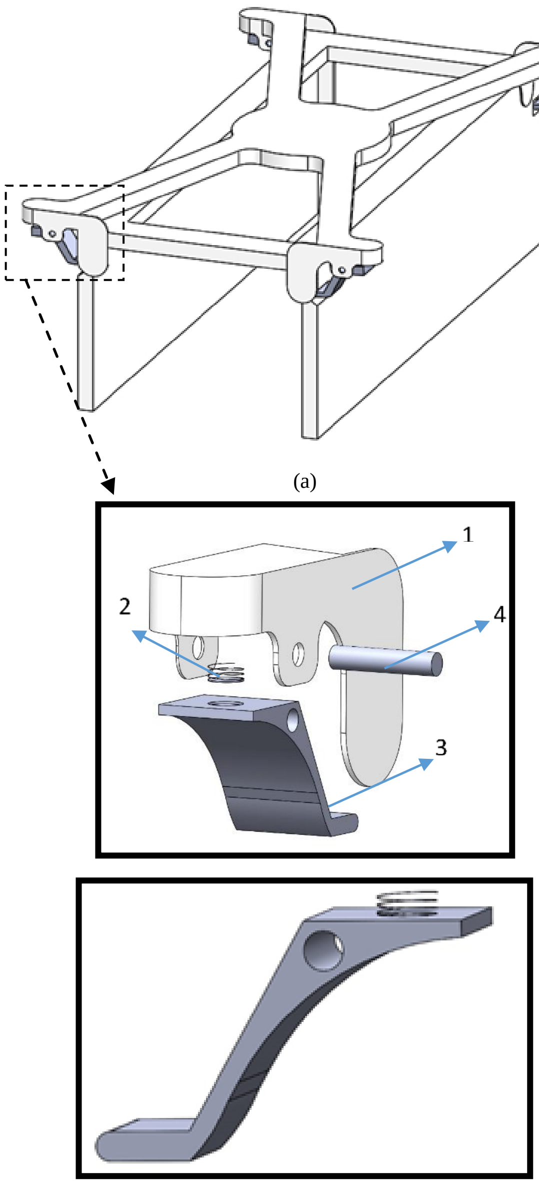


Figure 2. Lateral view of the 3D CAD model of the whole drone plus seeder.



(b)

Figure 3. (a) 3D CAD model of the seeder system chassis. (b) Seeder system chassis constructive details.

The seeder is controlled by a UAV board that controls, according to the preprogrammed positions and trajectories, the release of seeds. The UAV controller sends a signal to the sower actuators to enable the seed release, and this liberation is promoted by linear movement of a window selector/cassette ensuring the release of a single seed at the desired position. Then, the UAV moves to a new position and the procedure repeats itself. At the end of the release of all seeds the UAV returns to the base for eventual battery replacement and for replenishment of the deposit of seeds.

III. Seeder System Numerical Modeling

The Finite Element (FE) simulations can provide, in a quick way, detailed information on stress and deformation distributions when structures are submitted to several loading and boundary conditions. This is not only very useful for the structures´s optimization process, but it also allows for the characterization and quantification of structure responses, which are difficult to measure experimentally. FE models need, however, to be accurately formulated to produce realistic results.

To analyze the structural behavior of the seeder system, when it is submitted to a resultant force corresponding to the full seeds deposit, a 3D CAD numerical model was built and several Finite Element Analyses (FEA) were performed through a commercial finite element code. Fig. 4 displays the solid mesh high quality of the FE model developed as a result of the previous meshing sensitivity study performed. For better accuracy, a relatively fine mesh of triangular elements was applied. Concerning load and boundary conditions, also shown in Fig. 4, numerical study was conducted by applying a static load of 45N, corresponding to around 5kg of seeds. Constraints of no displacements and no rotations were applied to the connection seeder/drone, which means that it was rigidly fixed. Table I summarizes the mechanical properties of ABS, which is the material selected for the seeder system.

TABLE I. MECHANICAL PROPERTIES OF THE MATERIAL SELECTED FOR THE SEEDER SYSTEM.

Material	Young's modulus (Nmm^{-2})	Poisson coefficient	Yield strength (Nmm^{-2})	Density (kgm^{-3})
ABS	8300	0.35	45	1200

Fig. 5 and Fig. 6 illustrate the Von Mises stress and displacement fields obtained, respectively. As expected, maximum stresses occur where the geometric conditions are more unfavorable reaching a punctual value of 32MPa. A maximum value of 0.6mm is found for displacements.

From these figures it can be concluded that regards stress values, for the level of load applied, the yield material strength is never reached, which means that no plastic deformation occurs. In addition, no significant deformations are observed. This demonstrates that, from a structural point of view, the seeder system developed is well design since no structural problems are report in the numerical study conducted.

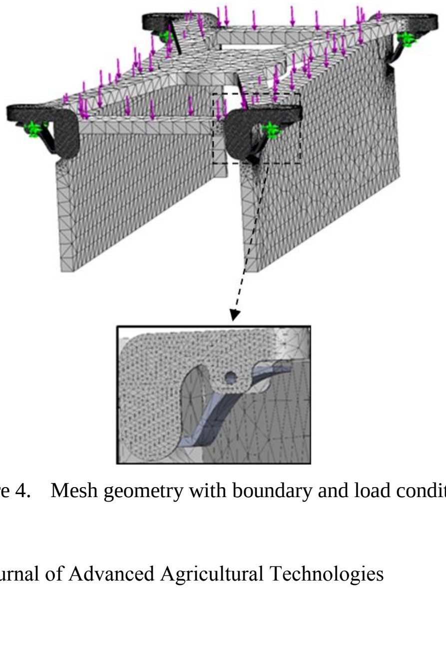


Figure 4. Mesh geometry with boundary and load conditions.

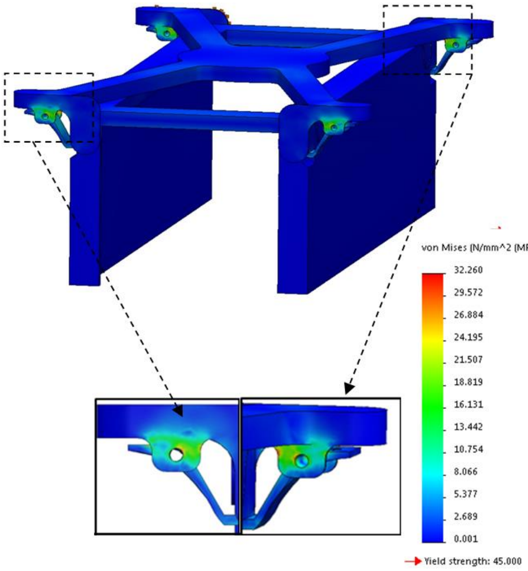


Figure 5. Von Mises stresses distribution.

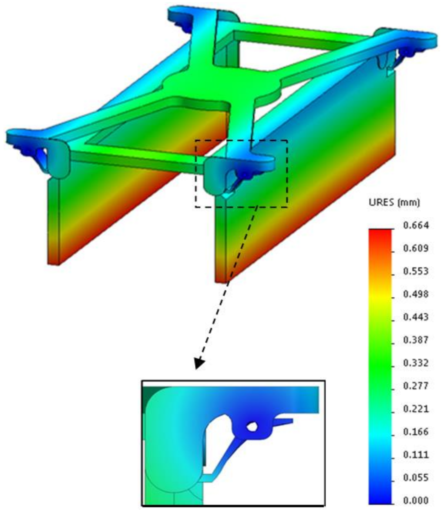


Figure 6. Displacement field.

Although numerical results reveal that the developed seeder system is well designed, it is, however, of paramount importance to have efficient means to understand the flow-field around the UAV and in its wake in order to design, develop, and test under operational conditions aerodynamic devices that would improve the UAVs autonomy. Future work will be focused in Computational Fluid Dynamics (CFD) flow simulations to assess the flow structure around UAV and the influence of frontal and/or lateral deflector geometries on UAV aerodynamic coefficients.

IV. CONCLUSION

The seeder system here proposed will give farmers an essential tool for a modern and highly productive agriculture because it allows to overcome the limitations imposed by conventional equipment. Additionally, due to the control and operating accuracy inherent in using UAV's, this system is also suitable for replanting in places where germination has not occurred or for planting in areas of difficult access.

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