

Numerical analysis of the influence of the relative position of the drone's rotor inside the nacelle on the airflow dynamics

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Abstract. The use of drones in different economic sectors has become a usual thing at present, being present in a varied and diverse range from a constructive point of view. A special attention is given for agricultural sector where drones can be used for: plant protection and pest control, vegetative crop surveillance, disease and pest estimation, surveillance, etc. However, the big problem that characterizes the performance of a drone remains the flight autonomy, autonomy directly related to the drone's own weight and the configuration of the propulsion system. The paper aims to use computerized numerical analysis methods to study the effect of the relative positioning of a drone's rotor, inside the nacelle, to characterize (and study) the flow characteristics of the airflow. The parameters considered in the study for the comparative evaluation of the research hypothesis are related to the parameters that characterize the dynamic flow of airflow (airspeed and pressure). Based on the results obtained the researches can be further developed by modifying the geometric construction of the rotor nacelle in order to optimize the flow of airflow used for crops' spraying process.

1. Introduction

One of the problems that the agricultural field has faced and continues to face is to limit the losses of agricultural crops due to the effect of diseases and pests. In this sense, chemical solutions are used to reduce and / or eliminate these negative effects. The method of treating agricultural crops is based on the sprinkling process with the necessary liquid of the plants, generally the process being a mechanical one, with agricultural installations and equipment dedicated to this operation.

Unmanned aerial vehicles (UAVs, drones) have been rapidly implemented (and seen in the future) as a new technology in agriculture in the fields of: plant protection and pest control, vegetative crop surveillance, disease and pest estimation, surveillance, etc.

In the field of plant protection and pest control, the most widely used function of UAVs is to automatically perform crop spraying processes. Still these agricultural works are performed on relatively small agricultural surfaces due to the autonomy/total weight of the drone.

However, in estimating the efficiency of the sprinkling process of agricultural crops besides the productivity offered by the use of a drone, it must also be taken into account the important factors that affect the deposition of drops of liquid used on the surface of the leaves: the speed and the height of the drone's displacement, the temperature of the environment. and liquid solution, wind speed, propeller pitch, spray nozzle shape and type, etc. For this purpose, many researches have been made that have

studied the influence of these factors on the quality of the primary process of spraying process, both experimental and research carried out by means of numerical analysis [1-6]. Also, lately there are also researches that study the possibility of implementing the Artificial Intelligence techniques in order to increase the efficiency of the use of UAV in the process of sprinkling agricultural crops [7].

The general feature of these researches was that they were made for a classic UAV construction, which consists of a common splash ramp (with a predetermined number of spray nozzles) positioned at the bottom of the UAV. The liquid sprayed through the nozzles is driven to the plants by the random airflow created by the blades of the drone's rotors.

The present paper intends to study the possibility of replacing the spray common ramp with a system embedded in the drone rotor's nacelle. In order to obtain primary data related to the subsequent feasibility of the project, computerized numerical analysis methods were used, simulating the cases in which the drone rotor has 2 and 3 blades in construction. Also, two additional cases of analysis were considered, namely when the rotor is positioned higher respective lower from vertical axe of symmetry in the construction of the nacelle. The quantities considered for the efficiency analysis were the flow velocity and the air pressure to decide further the optimal placement of spray nozzles.

2. Material and Method

For the numerical analysis of the velocity and pressure fields caused by the air flow considering different relative position the rotor of a drone (with 2 and 3 blades in construction), a model was developed using Solid Works software (figure 1). The general geometrical dimensions of the model are: inlet platform diameter 550 mm, output platform diameter 550 mm, platform length 550 mm, blade diameter 450 mm, thickness of the platform walls: upper part 16 mm, lower part 1.58 mm. As main boundary conditions, the density of air (fluid flow) is considered to be 1.205 kg/m^3 (corresponding to ambient temperature of 293.2 K). Drone's rotor speed is set to 2387 rpm for both 2 and 3 blades configuration.

The analysis of the velocity and pressure fields of the air flow was performed for the cases in which the rotor has 2 and 3 blades in design, and the measurements of the obtained values were made both in in the vertical plan of rotor's nacelle.



Figure 1. Simulation model for 2-blade case construction of rotor (a-lower positioning; b-upper positioning).

3. Results and Discussions

The computerized numerical analysis (CFD) was applied for following distinctive cases: use of 2 and 3-blade in rotor's construction and upper and lower positioning of rotor related to the symmetry of vertical axe of nacelle. The results obtained from CDF simulation are presented in figures 2-5, analyzed and interpreted from two major parameters point of view, parameters that characterize the air-flow pattern (air speed and relative pressure). Comparative variations on nacelle's vertical axe of air speed and relative pressure for considered cases are presented in figures 6 and 7.

In Table 1 are presented the results for both configuration of rotor taking into consideration the average and maximum values, and the values registered in horizontal plan at the exit of rotor's nacelle are presented in Table 2.

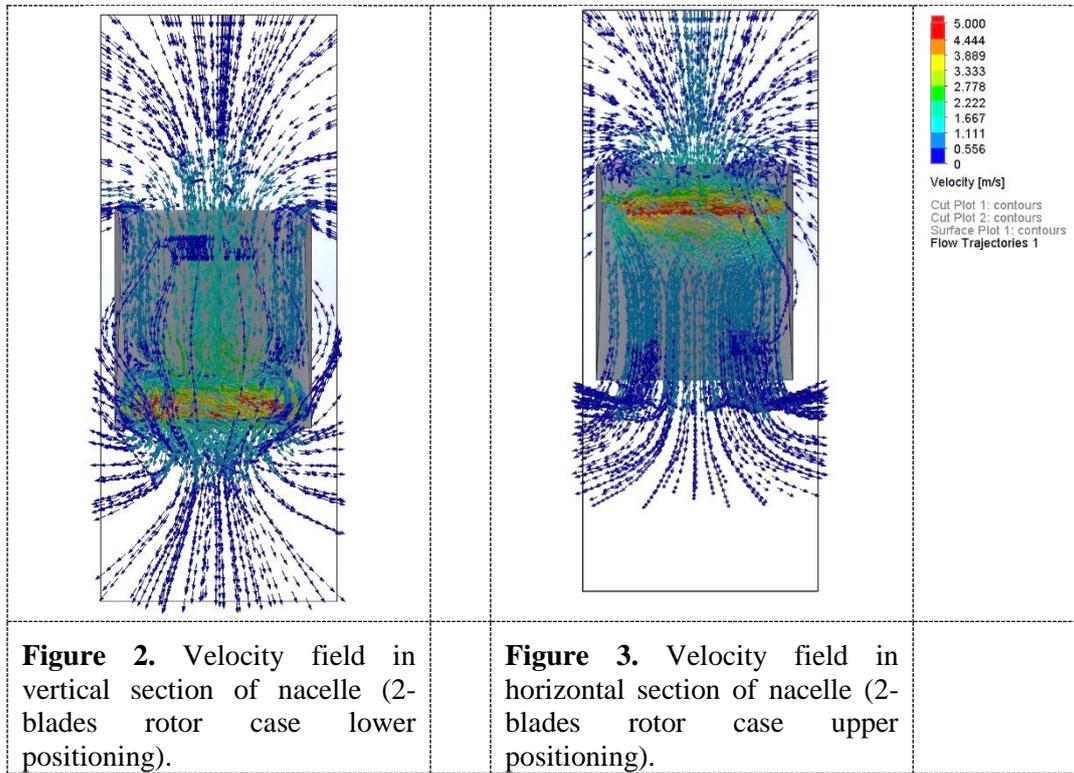
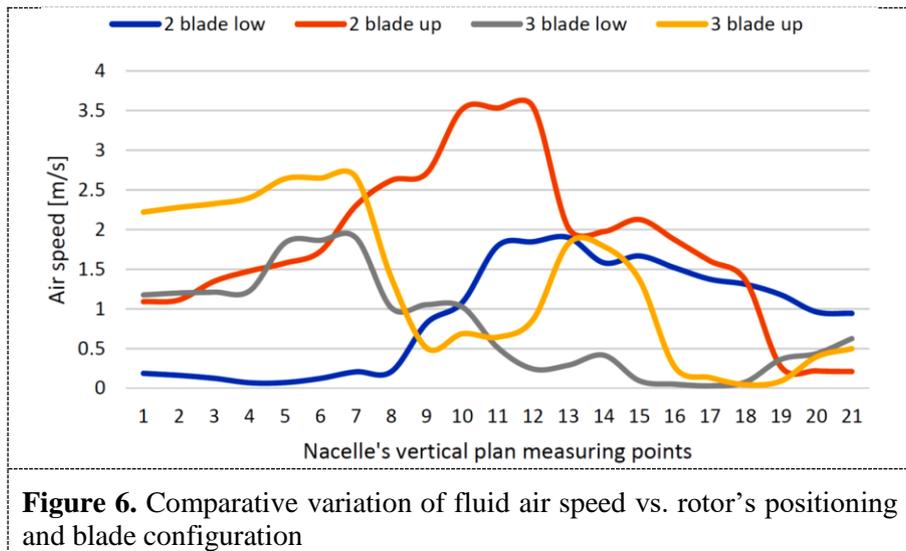
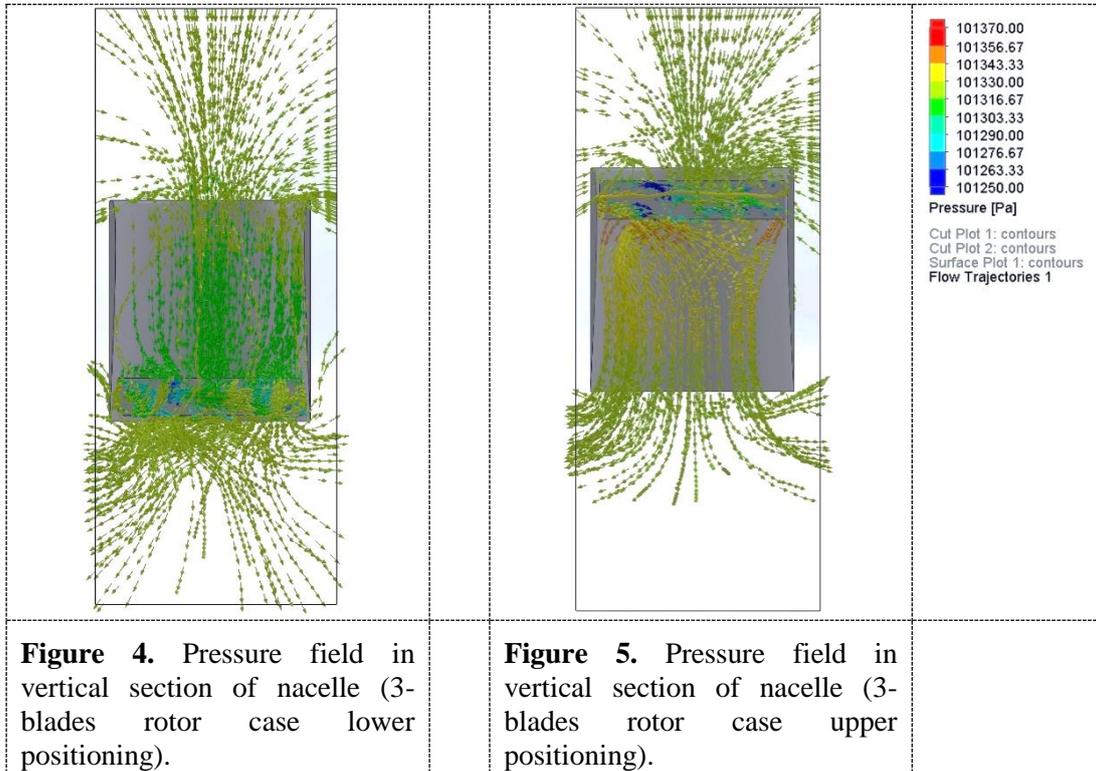


Table 1. Air flow characteristics in vertical plan.

Case	Air speed [m/s]				Air relative pressure [Pa]			
	upper positioning		lower positioning		upper positioning		lower positioning	
	2-blade	3-blade	2-blade	3-blade	2-blade	3-blade	2-blade	3-blade
Average	0.78116	1.257491	0.909947	1.819513	101308.2	101312.3	101316.3	101314.2
Maxim	1.895055	2.658613	1.899145	3.548052	101324.6	101334.5	101322.0	101321.4

Table 2. Air flow characteristic at the exit of rotor's nacelle (horizontal plan).

Case	Air speed [m/s]				Air relative pressure [Pa]			
	upper positioning		lower positioning		upper positioning		lower positioning	
	2-blade	3-blade	2-blade	3-blade	2-blade	3-blade	2-blade	3-blade
Value	0.651039	0.76612	0.942191	0.209003	101324.6	101333.7	101322.0	101319.6



From the CFD analysis, it is observed that there is a characteristic of airflow, directly related to the positioning of the rotor in the vertical plan of the platform. Regardless of the construction version, with 2 or 3 blades, if the rotor is positioned lower, the air flow is concentrated towards the center of the horizontal section of the platform. In exchange for a higher positioning of the rotor, the air flow at the exit of the platform is made towards the circumference (edge) of the horizontal section of the platform.

From the point of view of the measured values (Table 1) it is observed that between the average air speed between the two constructive cases of the rotor considered for the construction with 2 blades the value is with approx. 50% lower than in the case of the construction with 3 blades, for the lower positioning. For the upper position of the rotor the difference is 38% smaller. It should be specified that the maximum speed values are obtained in the blade rotation area.

Similarly, in the case of air pressure (Table 1) the measured values are approximately equal (with relative differences between them less than 1%) both for the constructive variants of the 2 or 3 blade rotor and for the cases related to the relative positioning of the rotor inside. nacelle.

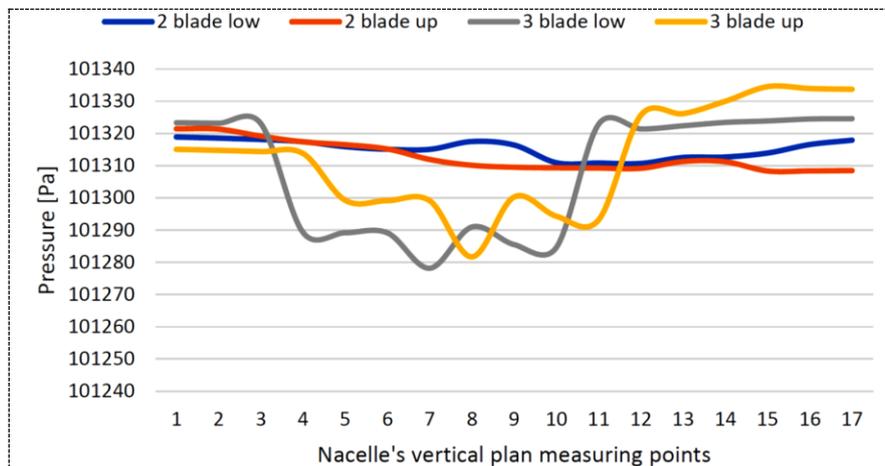


Figure 7. Comparative variation of fluid flow pressure vs. rotor's positioning and blade configuration

When using the model presented for agricultural operations related to crop spraying, it is important to analyse the air flow parameters at exit from the nacelle. Based on the results presented in Table 2 it can be stated that the highest value of air velocity is for the case of 2 lower positioning blades (0.94 m/s) and the smallest value is for the case for the case of 3 blades (0.21 m/s).

The relative difference between these values is 77.6%. In the case of pressure, the measured values are approximately equal (as in the case of speed), the highest value is 101333.7 Pa (lower positioning) and the smallest value of 101319.6 Pa (upper positioning) is recorded for the case of 3 blades.

4. Conclusions

There is a continue development of UAVs applications in agriculture due to the immediate and specific benefits that can be offered. Still, being an emergent technology there are a lot of supplementary researches to be made to optimize their functionality and exploitation.

In the case of using UAVs for plant protection activity (crop's spraying) there are necessary to have a enough autonomy of work (depending of overall UAV's total weight), an uniform fluid flow pattern transmitted to plant surfaces and possibilities to compensate the direct influence of environmental factors (wind, temperature).

The considered hypotheses and specific cases presented in present work shown that the vertical relative positioning of the rotor inside the nacelle have a direct influence on air flow pattern at the exit of nacelle. In both constructions types of the rotor (2 or 3 blades), the spray nozzles will be placed in the center of the horizontal section at the exit of the nacelle when the rotor is located inferiorly, and on the circumference of the horizontal section at the exit of the nacelle when the rotor is located superior, in order to optimize the efficiency of the crop's spraying process.

Acknowledgments

The authors thanks to "POC-A1-A1.2.3-G-2-15 Knowledge transfer partnerships, Project title: Technologies for intelligent urban electric vehicles URBIVEL, ID: P_40_333" research program for help and support.

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