Influence of drone's nacelle conicity on the air flow dynamics

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Abstract. Humankind is facing more and more specific problems in technology area and the concept of using controlled or autonomous air systems knows as drone is present in several industries caused by the variety of options they provide. To connect the problems with the drone usage and to achieve a reliable solution drones needs optimization and technical characteristics to be changed. In the agriculture field they must offer an accurate construction of the nacelle so the air flow can be controlled properly so the process of phytosanitary treatment can offer more precision and efficiency. The paper suggests the research of air flow dynamics according to the geometry (conicity) of 4 different nacelle construction at different angles (55°, 65°, 75° and 85°) by numerical analysis method and parameters as velocity, pressure and airspeed.

Keywords: nacelle, conicity, angle, UAV, agriculture, velocity

1. Introduction

In the past few years the sector of agriculture became one of the most promising one even if farmers are dealing with more and more problems regarding inefficient application of fertilizer, infections, diseases, weather events, etc. With a continuously growing population, there is an urgent need to fulfil the food demand of each and every person. The final report of the Food and Agriculture Organization of the United Nation (FAO) that was published in 2020, and one of the conclusions was that the Covid-19 pandemic has not affected the food and agriculture sector as much as it did in other fields. FAO showed an increase of grain, oil crops, meat, dairy products, sugar etc. in 2020-2021 period of time [1].

The key for a sustainable agriculture mechanism is to achieve an improvement regarding the use of unmanned aircraft vehicles (UAV) in processes like chemical application (fungicide, pesticide, insecticide, etc.). M. Hazwan et.al [2] analyzed five different drone application in agriculture including crop monitoring, crop spraying, mapping and soil analysis, planting tasks and livestock farming. The conclusion drawn regarding the use of UAV was that drones will become more popular in agriculture especially for the possibility of tailoring assuming the necessary hardware and knowledge are obtainable. In agriculture the process of crop spraying and spot spraying is considered by R. B. Kalamkar et.al [3] one of the most important operation in crop life cycle in order to maintain high yields crops. Drones can help crop spraying by making the process more safer and more cost-effective for farmers. Meivel S et.a [4] has discussed the use of a drone with a pesticide spraying system for the zones that are not easily accessible for human beings. The system is considered also a safe measure for farmers due to the high death reported by World Health Organizations [5] (about 2.2 million people) caused by pesticide poisoning.

Droplet size is among the most crucial factor in spray equipment systems when it comes to drift. Larger droplets keep their momentum for longer and are less susceptible to wind displacement, which can lead to drift [6].

The goal of the current paperwork is to examine a portion of the findings from research that was done to improve the spray process by examining the air flow dynamics in accordance with the conicity of four alternative nacelle constructions at various angles (55°, 65°, 75° and 85°).

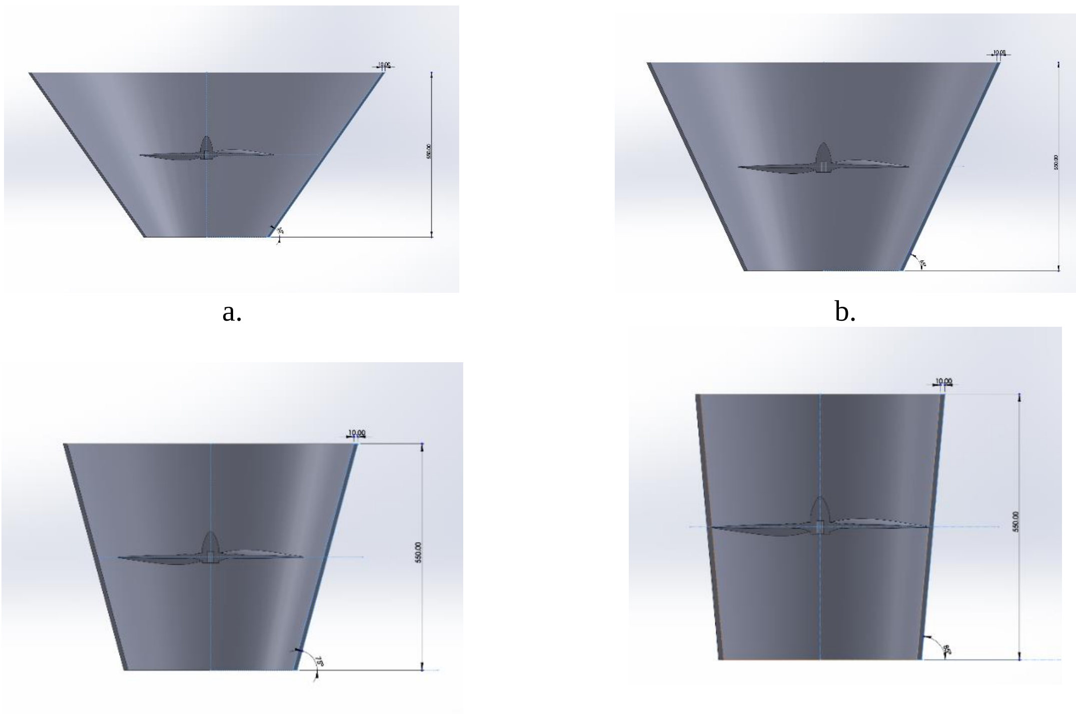
2. Material and Method

Regarding UAV there are certain parameters associated with crop spraying and drones are classified based on flight time, size, specific application purpose or field area. The air flow was numerically analysed for the velocity and pressure fields in circumstances where the rotor was designed with two blades. Solid Works software was used to simulate air flow dynamics and to develop the 4 models of the nacelles (55°, 65°, 75° and 85°) . Depending on the conicity and angle in Table 1 are represented the general geometrical dimensions of the models.

Angle	Inlet platform diameter (mm)	Output platform diameter (mm)	Platform length (mm)	Blade diameter (mm)	Thickness of the platform walls (mm)
55°	1190	420	550	450	10
65°	932	420	550	450	10
75°	714	420	550	450	10
85°	516	420	550	450	10

Tabel 1. General geometrical dimensions of the models

To obtain the analysis of the velocity and pressure air was used as the fluid flow, with a density of 1.205 kg/m^3 and a temperature of 293.2 K (20° C) and also the rotor with 2 blades has a speed of 250 rad/s (2387 rpm). In Figure 1. the simulation models are presented for all 4 cases.



a. b. c. d.

Figure 1. Model simulation of a. 55°, b. 65°, c.75°, d. 85°

3. Results and Discussions

In Figures 2-17, the results of computational fluid dynamics (CFD) are shown in comparison. It can be observed that the angle of nacelle conicity causes variances in the velocity and pressure field model. The pressure field is shown in Figures 6-9. The graphs regarding pressure variation are shown in Figures 14-17. The maximum pressure was recorded for 65° conicity angle (101326.75 Pa), and for 65° and 85° the maximum value is 101326 Pa. Figures 10-13 depict graphs indicating variations in air flow velocity. The maximum velocity is 4.33m/s for 85° conicity angle and for the rest of two cases 65° and 85° the values registered were 1.34m/s.

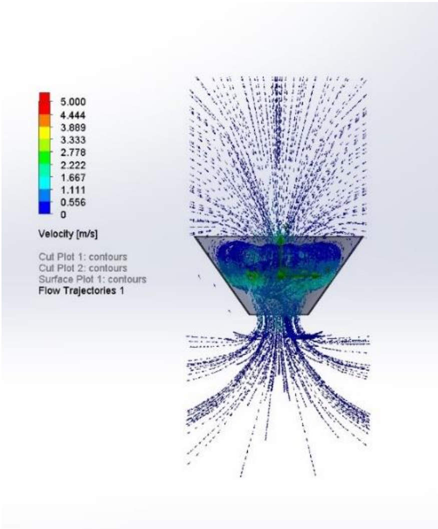


Figure 2. Velocity field at a nacelle conicity of 55°.

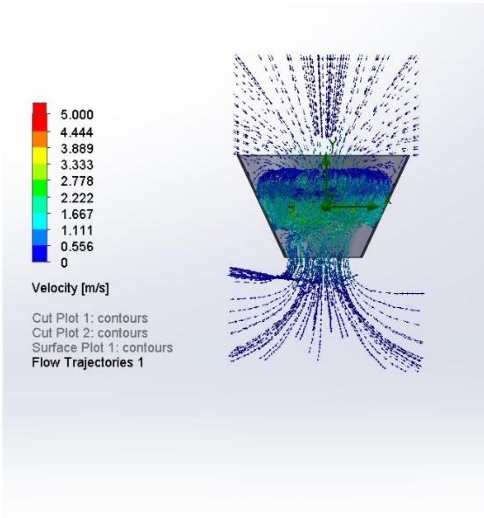


Figure 3. Velocity field at a nacelle conicity of 65°.

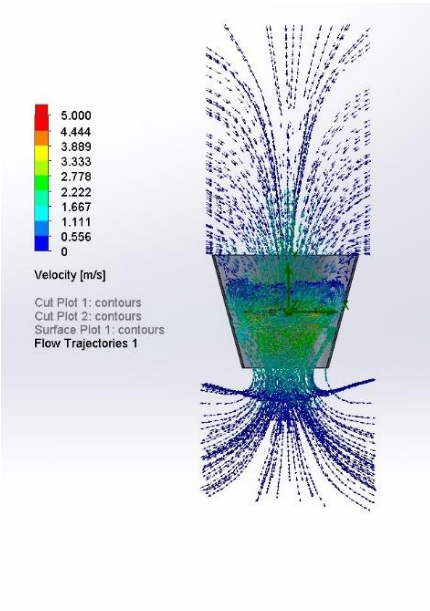


Figure 4. Velocity field at a nacelle conicity of 75°.

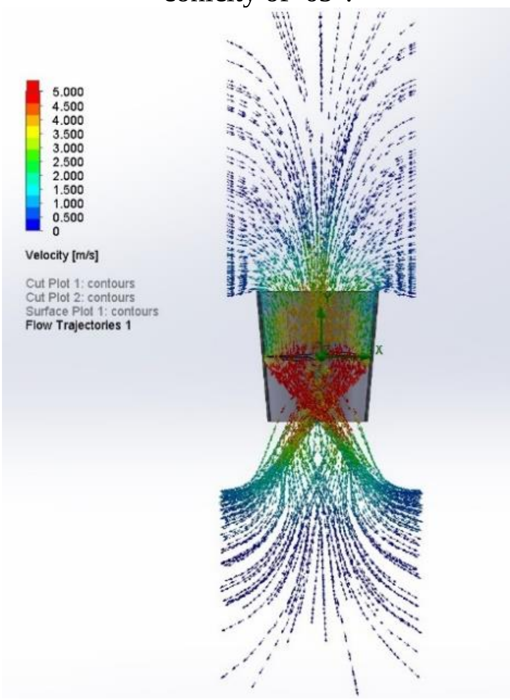


Figure 5. Velocity field at a nacelle conicity of 85°.

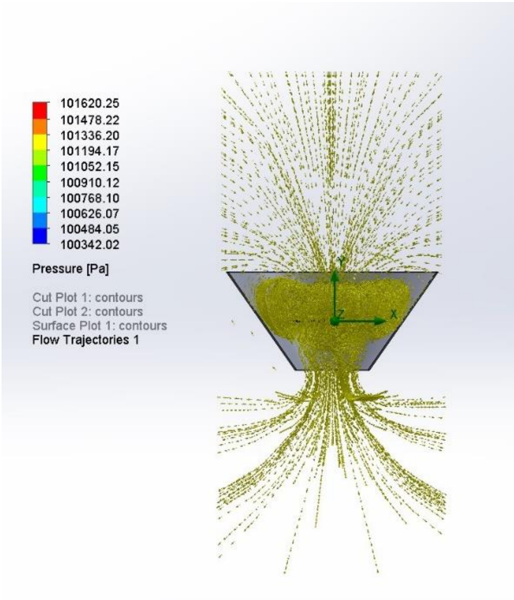


Figure 6. Pressure field field at a nacelle conicity of 55°.

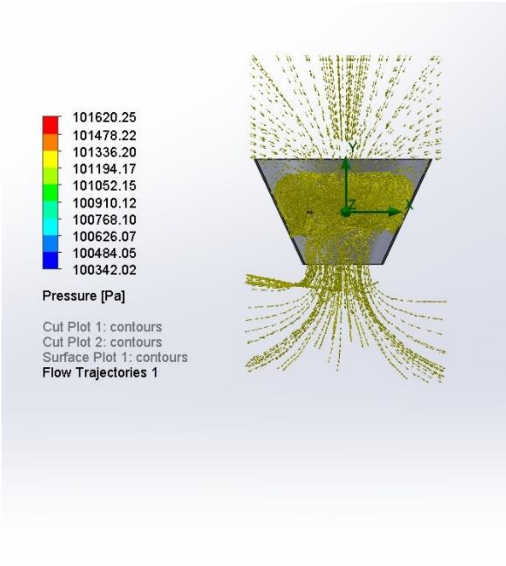


Figure 7. Pressure field field at a nacelle conicity of 65°.

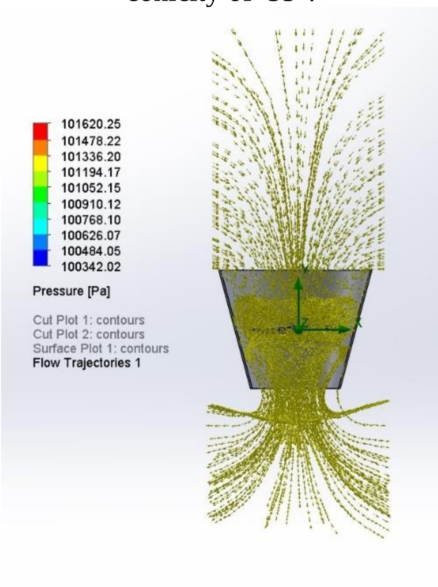


Figure 8. Pressure field at a nacelle conicity of 75°.

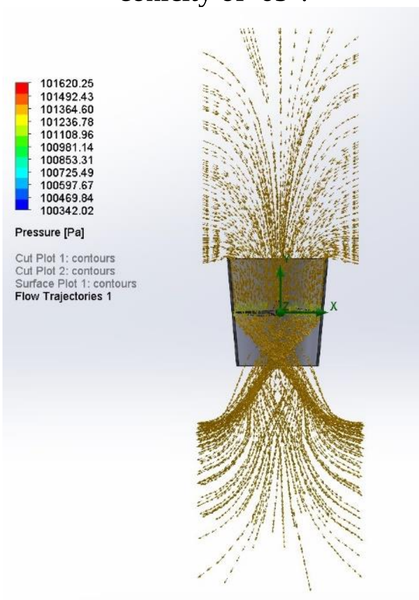


Figure 9. Pressure field field at a nacelle conicity of 85°.

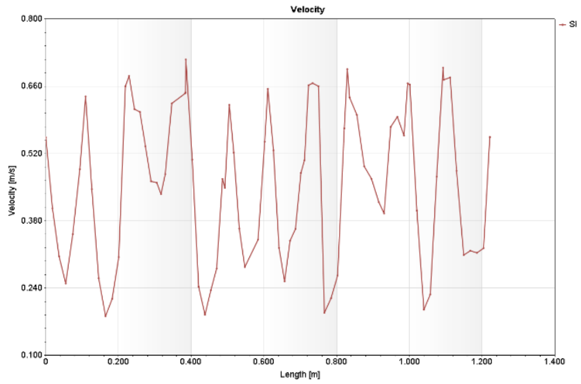


Figure 10. Air velocity variation at a nacelle conicity of 55°.

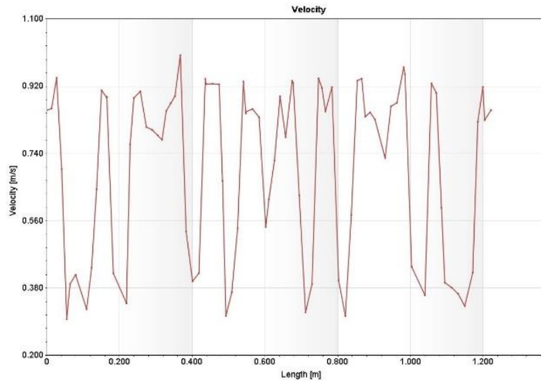


Figure 11. Air velocity variation at a nacelle conicity of 65°.

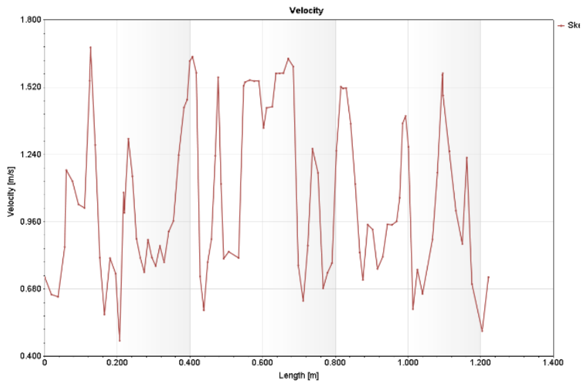


Figure 12. Air velocity variation at a nacelle conicity of 75°.

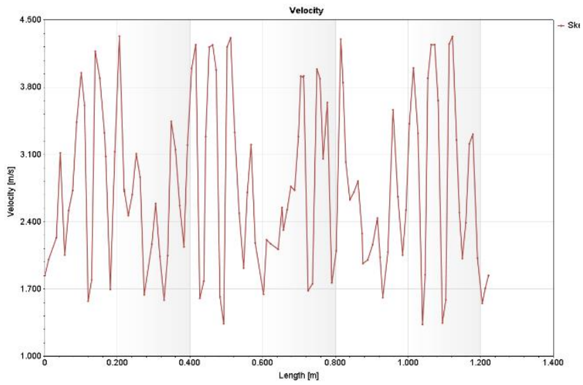


Figure 13. Air velocity variation at a nacelle conicity of 85°.

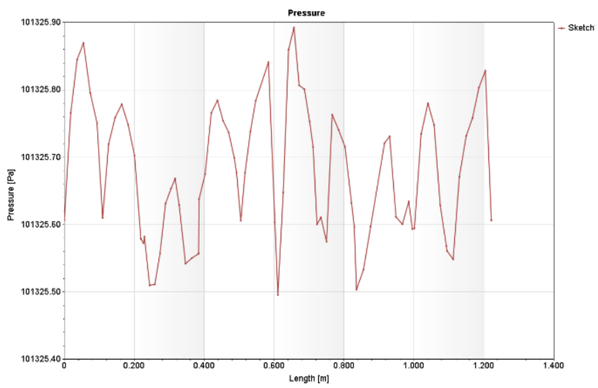


Figure 14. Pressure variation at a nacelle conicity of 55°.

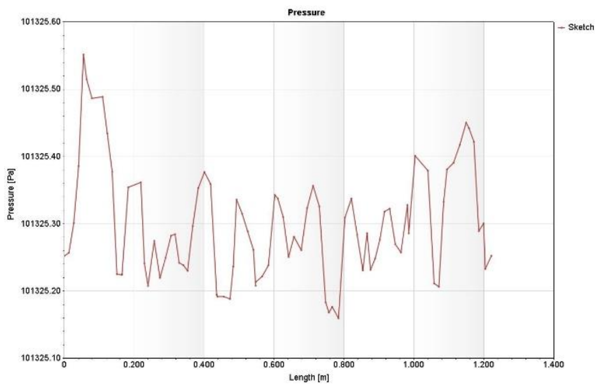


Figure 15. Pressure variation at a nacelle conicity of 65°.

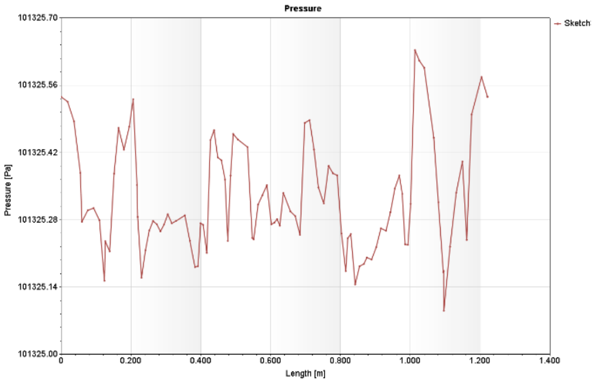


Figure 16. Pressure variation at a nacelle conicity of 75°.

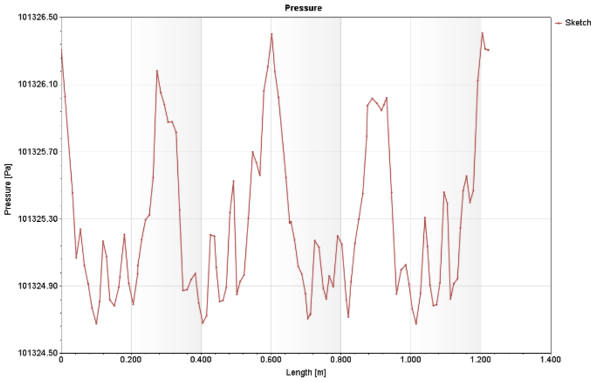


Figure 17. Pressure variation at a nacelle conicity of 85°.

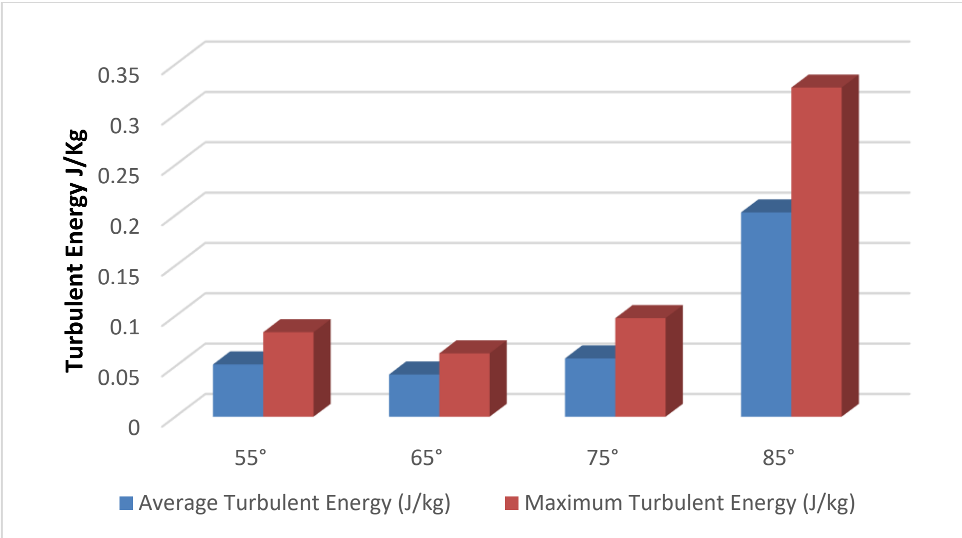


Figure 18. Average/ Maximum Turbulent Energy values

The average values registered were between 0.042 J/kg for 65° and 0.203 J/kg at 85° and the maximum turbulent energy are situated between 0.063 J/kg for 65° and 0.327 J/kg at 85°. Based Marco Crialesi-Esposito et al. previous research findings [6], it can be concluded that at 85° turbulence determines the droplet size distribution while a higher velocities enhance turbulence.

The most part of the values registered were between 0.55 m/s for 55° and 2.77 m/s at 85° and the maximum velocities are situated between 0.85 m/s for 55° and 4.33 m/s at 85°. Based David Nuyttens et al. previous research findings [7], it can be concluded that at the highest velocity in spray cropping a higher droplet is formed at an 85° nacelle conicity while in the rest of the cases a smaller droplet will be formed.

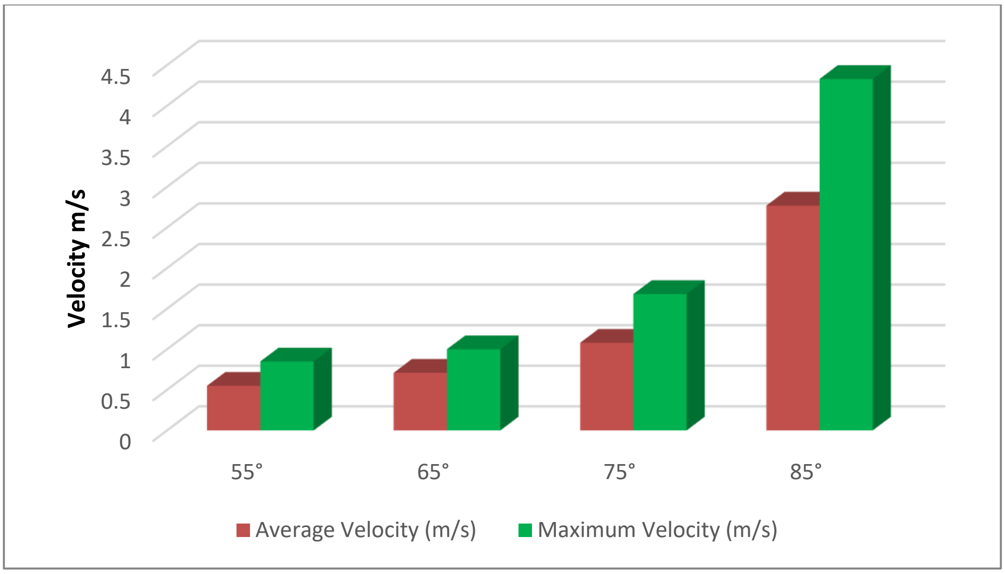


Figure 19. Average/ Maximum Velocity values

4. Conclusions

The research outcomes can be drawn based on a computerized numerical analysis of the impact of the conicity angle of a nacelle on a UAV (drone) employed in plant protection activities in agriculture.

In the application of plant protection products, the quality of agricultural spraying is critical. The ideal pressure and velocity should maximize spray efficiency helping farmers to improve the process of spraying and minimize residues in this case at a conicity of the nacelle of 85° due to the connection between the turbulent energy and the droplet size distribution

UAVs are in a continuous process of optimization when it comes to apply them in the field of agriculture. In the future it is necessary to optimize the angle on nacelle so the phytosanitary treatment can be evenly distributed and the effect of drift to be minimised.

Future research will make use of the findings to enhance the geometrical configuration and nacelle angle of a UAV employed in crop spraying and plant protection operations.

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