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STUDY ABOUT MAGNUS EFFECT ON SPINNING CYLINDERS AND ITS USE ON MICRO AIR VEHICLES

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Abstract. *It is described in this article a Magnus Effect research done on Magnus Effect on Spinning Cylinders and how the Drag and Lift varies as the Cylinder increase or decrease its tangential velocity, as other properties, vorticity and structures of the flow as well.*

The final objective of this study is to use a Spinning Cylinder, with success, instead of a wing as the component responsible for lift force on a Micro Air Vehicle, with this purpose in mind, some simulations were done in order to find the optimum cylinder for this application. The motivation of a study like that is to discover if it's feasible the use of rotating cylinders on aircrafts that operates on low Reynolds numbers, which is the case of MAV's.

It was used as tool to obtain the results the CFD software STAR-CCM+®, to find the best cylinder configuration (more lift and less drag) based on the limitations of the project, several configurations were tested, varying the number of end-plates, the aspect ratio of the cylinder, and the Reynolds number of the plane through the mission.

To be sure about the results of the simulations, a validation with experimental data was done, and a good agreement was met for the α (ratio between tangential velocity and the velocity of the flow) of interest to this research.

Keywords: *Magnus Effect, Aircraft, MAV, Rotor Airplane, CFD.*

1 INTRODUCTION

It's always important to research and find new ways to improve aircraft performance in all kind of missions, this paper show the results about a study on a very specific kind of aircraft and its mission, an unusual MAV. To improve the knowledge about an almost unexplored field, the Rotor Planes, on this research was proposed an initial size to the MAV and then in place of an usual wing, a spinning cylinder was used to generate Lift.

To begin the project was defined that the cylinder would have 60 mm of diameter and a maximum Aspect Ratio of 10 to limit the moment of Inertia and the hazard it represents to Lateral-Directional Stability and Control of this aircraft, because of the big influence of the gyroscopic effect on it. Also, due to the gyroscopic effect and because it wouldn't be necessary on low velocities, the angular velocity of the rotor was limited to 1000 rad/s, that was used as fixed parameter on all the analysis, so to vary the velocity ratio (α), just the flow velocity was varied. The tool used to obtain the values of C_D, C_L and other properties of the cylinder and the flow, was the CFD software STAR-CCM+®.

2 VALIDATION

Firstly, to begin the study, a validation process was necessary to discover the best model and solver would be used on further simulations. The validation was done with the experimental data of Badalamenti (2010) for C_D and C_L of a rotating cylinder without end-plates with Re=19000.

To validated the simulation results three different models of solution were used: DNS, URANS (k-ε model of turbulence) and URANS (k-ω model of turbulence).

A good agreement between the simulation results and experimental data was found for both URANS models of turbulence, except for a velocity rate of 1, all the solvers failed to give good results for this velocity ratio. A very interesting fact occurred, the simulations without turbulence model in the solver, gave the best aerodynamic effectiveness (lift to drag ratio) approach to experimental results. The results are presented below.

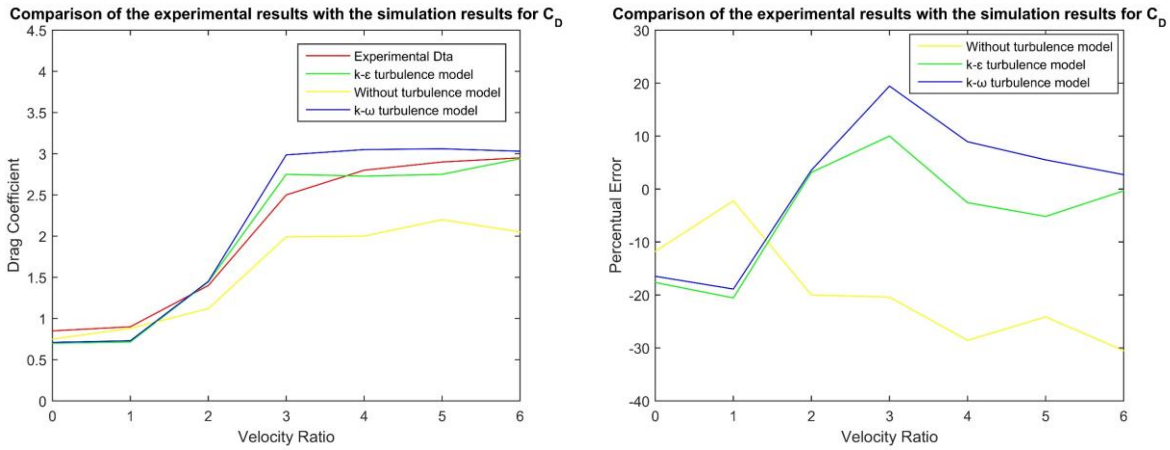

Figure 1. Results of the validation for the Drag Coefficient

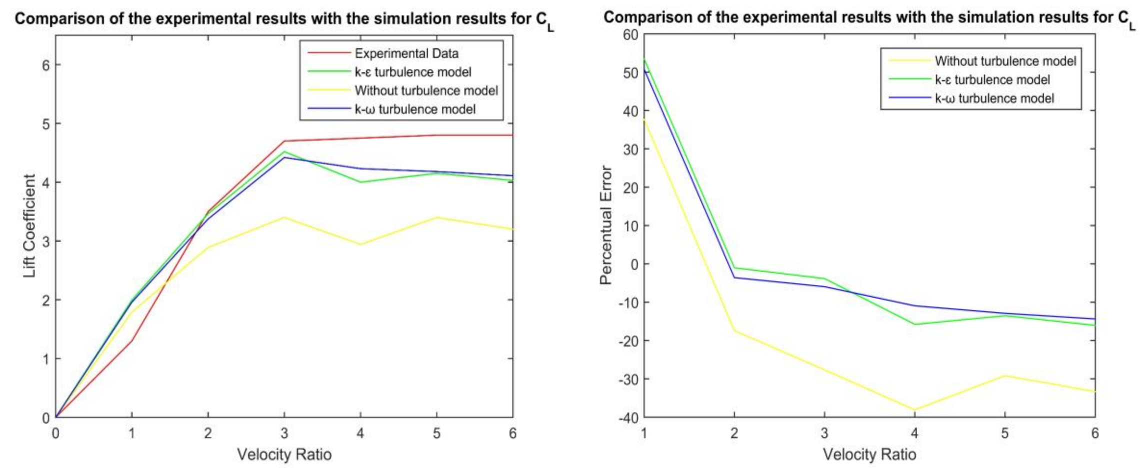

Figure 2. Results of the validation for the Lift Coefficient

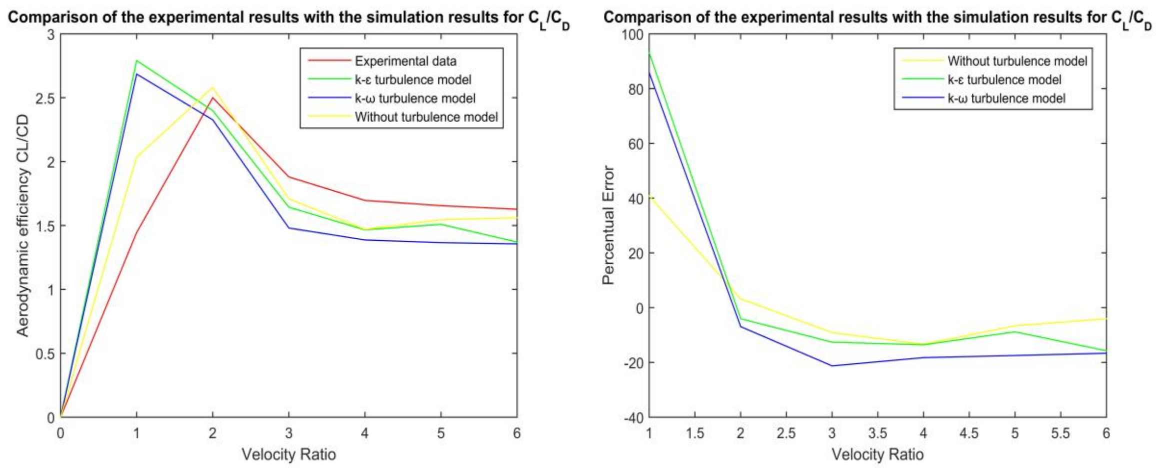

Figure 3. Results of the validation for the Aerodynamic effectiveness

3 ANALYSIS OF DIFFERENT CYLINDER CONFIGURATIONS

After the validation, three different configurations of cylinder were tested, with the diameter defined before, all with an aspect ratio of 10. The three configurations are: a simple cylinder, a cylinder with two end plates, one on each tip, with a diameter of twice the cylinder diameter, a cylinder with 4 end-plates, that have same size of the former configuration, the plates are equally spaced.

It was found that the best cylinder configuration for this project is the cylinder with 2 end-plates, this configuration gives a maximum C_L near of the one with 4 end-plates, but it has a higher aerodynamic efficiency. By the results can be noted that as the velocity ratio increase, C_L and C_D both tends to a constant value.

The results are shown below as a function of α, as defined before the cylinder has a fixed tangential velocity of 1000 rad/s, so the lift and drag decreases with α because of the reduction of the flow velocity.

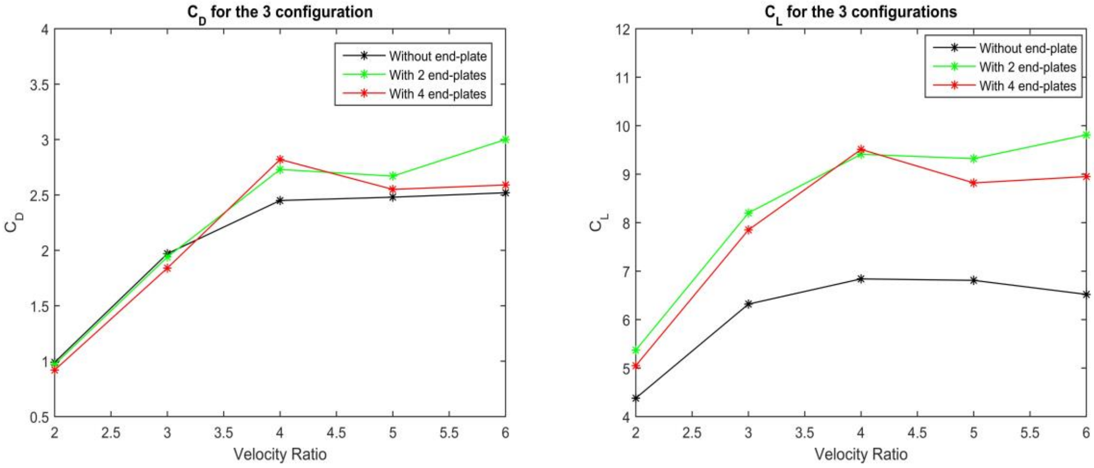

Figure 4. Drag and Lift coefficients results for the three configurations, varying with α

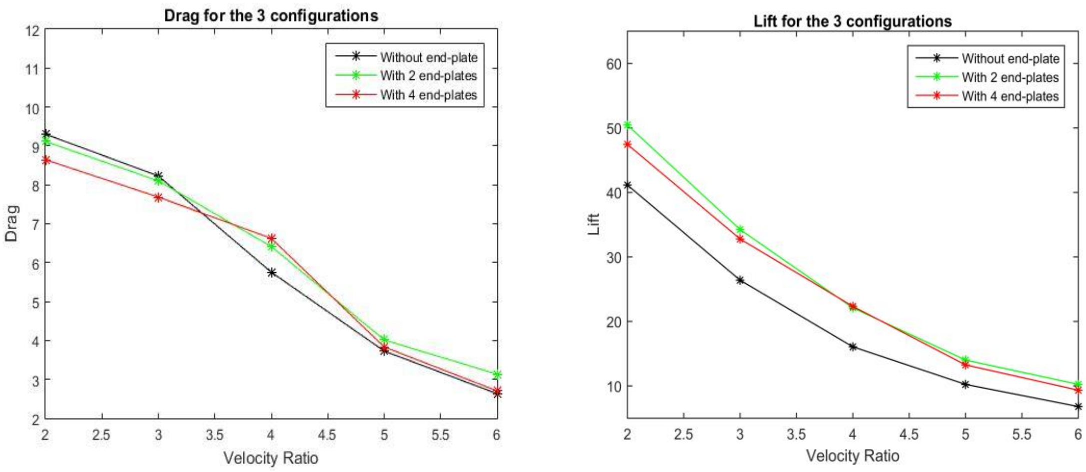

Figure 5. Drag and Lift results for the three configurations, varying with α

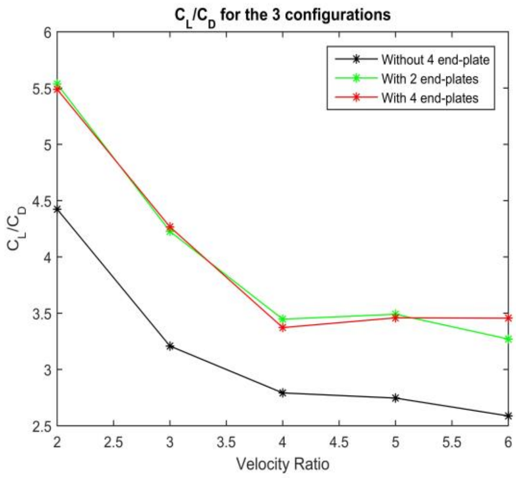

Figure 6. Aerodynamic effectiveness coefficient for the three configurations, varying with α

4 CONCLUSION

The first step to this project was done, the best cylinder configuration was found, and the best flight velocity which is 10m/s, that occurs for an α of 3, that's the best velocity because for higher velocities the drag would be very high, so a strong and heavy engine would be necessary for the propulsion of the aircraft, and for lower velocities the cylinder would have a bad aerodynamic efficiency.

On this cruise speed with the previous defined rotation this aircraft would be capable to take-off with a maximum weight of 38N, a big MTOW considering the size of the cylinder, that's very important for MAV's design because of the relative low payload they have, due to the high weight of the propulsion and electronic system in comparison to its total weight.

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