MILITARY UNIVERSITY NUEVA GRANADA

AERODYNAMICS REPORT.

Calculating the lift of a wing using the Vortex Lattice Method

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ABSTRACT – *This document presents the Matlab implementation of an algorithm to calculate the lift of a finite-span wing called the Vortex Lattice method, which is an extension of the 3D panel method. Also the simulation of a wing in software specialized in both aerodynamics and fluid dynamics such as XFLR5, which allows simulations to be performed on wing profiles and finite wings, obtaining various variables related to the wing such as lift, drag, pressure coefficients and distribution of circulation.*

ABSTRACT - *This document presents the implementation in Matlab of an algorithm to calculate the lift of a wing of finite wingspan called the Vortex Lattice method, which is an extension of the method of 3D panels, also performs the wing simulation in software specialized in aerodynamics and fluid dynamics such as XFLR5, which allows simulations in wing profiles and finite wings, obtaining various variables related to the wing such as lift, drag, pressure coefficients and distribution of the wing as the drag, pressure coefficients and the distribution of the wing as a result of various variables such as lift, drag, pressure coefficients and the distribution of the wing.*

1. INTRODUCTION

The computational analysis of fluid dynamics has allowed countless advances in the area of aerodynamics, simplifying complex calculations and allowing, in turn, greater precision and versatility when designing and selecting profiles for aircraft, whether UAV type or intercontinental aircraft [1]. On the other hand, it allows knowing the precision of the initial calculations verifying that, despite the approximations of these mathematical models, their calculations are still useful as an aircraft design principle [2]. However, fluid dynamics is still in continuous progress and there is no single way to simulate the designs made [3], specifically, if you want to obtain correct data from the simulations, it is necessary to know the regime in which they are applied. will work (subsonic, transonic or supersonic) and which turbulence model to apply, since the quality of the simulation depends on this [4].

2. OBJECTIVES

2.1 General:

Implement the Vortex Lattice method in order to calculate the lift of an airfoil for a specific angle of attack.

2.2 Specific:

- Verify the correspondence of the results of the Vortex Lattice implemented with a simulation in the XFLR5 software.
- Determine the technical reasons that justify the differences between the results of the different software, in case of different results.

3. RESULTS

Matlab

The results obtained from the Vortex Lattice method were the wing circulation, the pressure coefficients and the lift coefficients, the latter being the main comparison criterion against the results obtained with XFLR5. The implemented method was that of Hsichum Hao.

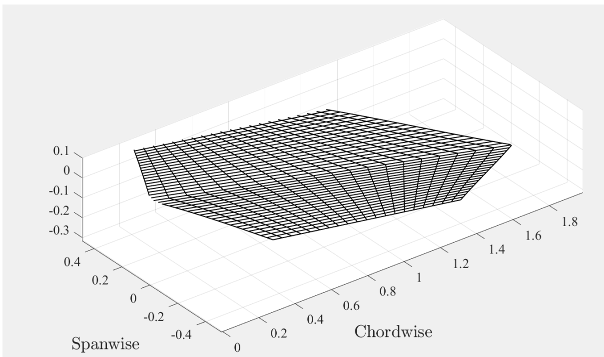


Figure 1. Division by panels

The previous figure shows the division of the panels, because the Hsichum Hao method was used, the division was made with 20 divisions on the 'X' axis and the same amount on the X axis. 'Y', giving a total of 400 panels.

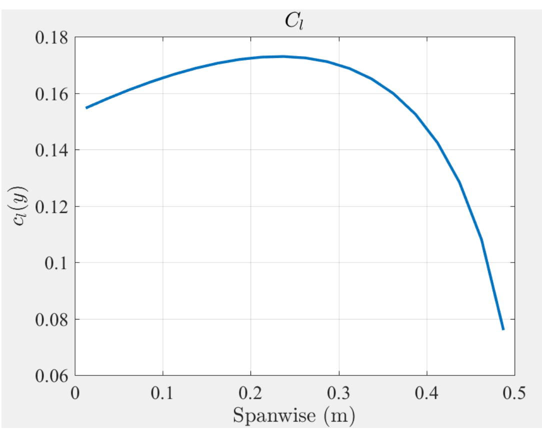


Figure 2. Cl vs. average span

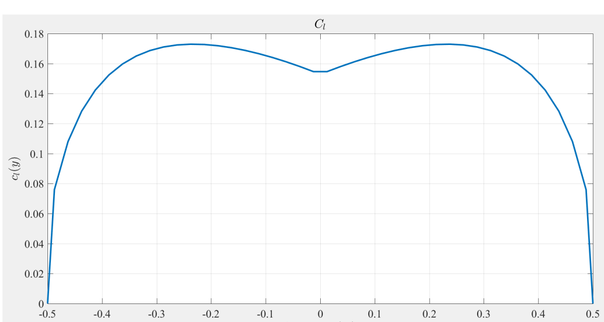


Figure 3. Cl vs. total span

The lift coefficients exerted by the wing vary between 0.08 and 0.18 along the span. Being the greatest lift exerted in the middle of the wingspan with a value of 0.17. The other results can be seen in the following figures.

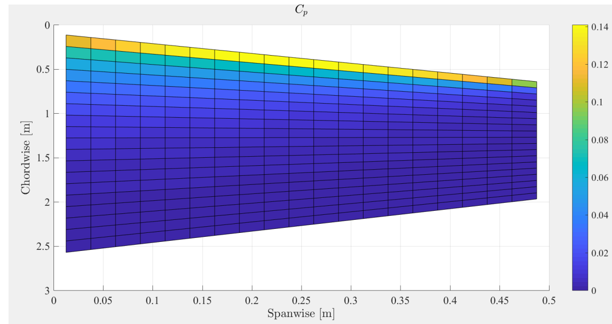


Figure 4. Cp for half wing

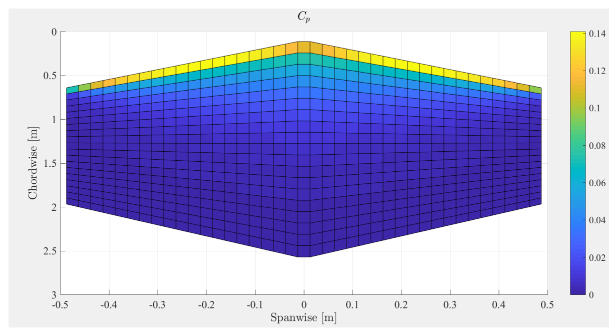


Figure 5. Cp for full wing

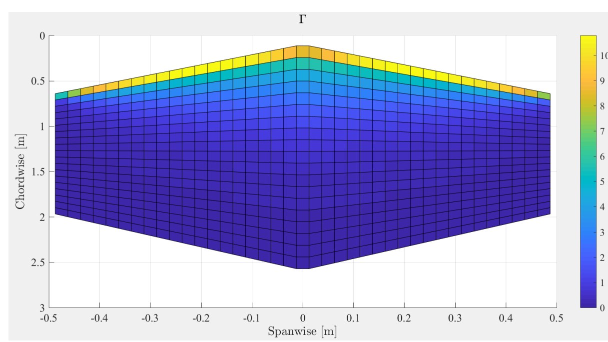


Figure 6. Circulation

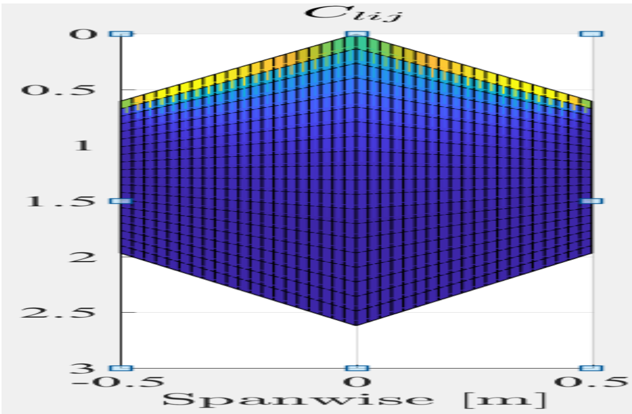


Figure 7. Lift coefficients

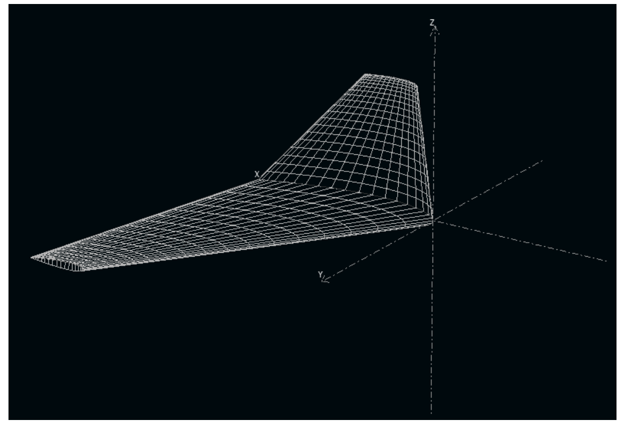


Figure 8. Distribution of panels (20x20)

XFLR5

In the XFLR5 software, the simulation of a wing with the following characteristics was developed:

- Wingspan = 3m
- Root chord = 1m
- Chord of tip = 0.3m
- Angle of arrow = 30°

In addition to this, the conditions on which the wing will be defined were defined, which are:

- Wind speed = 150 m/s
- Density = 1.225 kg/m3

Additionally, the profile NACA0012 is defined for the geometry of the wing. And a mass of 1kg is assigned to the wing since it is a necessary data to carry out the study.

For this application, as it is a wing that is symmetrical both on the X axis and on the Z axis, each half of the wing surface is divided into a number of 20x20 panels, both for the left and right sides.

Subsequently, the Horseshoe vortex VLM1 method is used to analyze the wing and the following results are obtained:

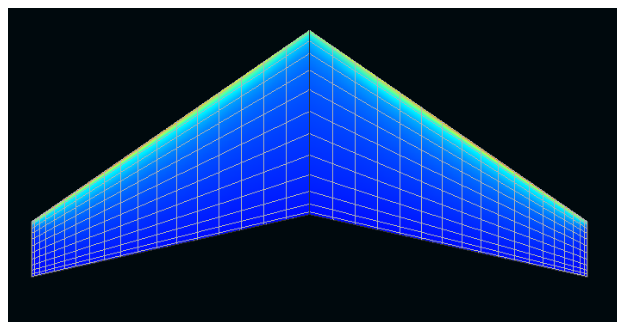


Figure 9. Cp on the wing

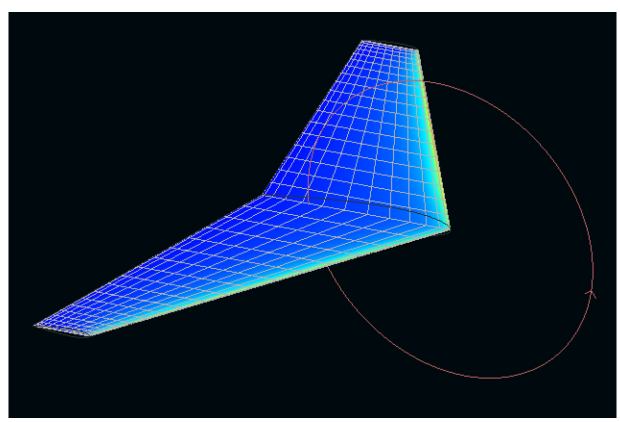


Figure 10. Moment on the wing

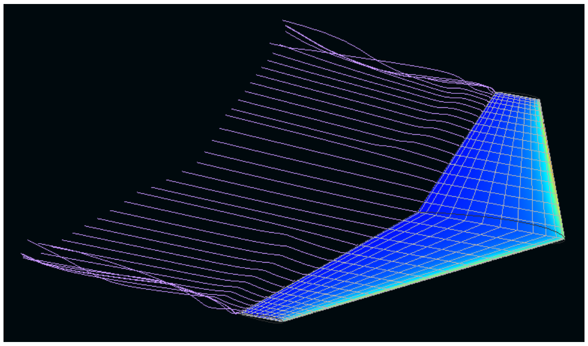


Figure 11. Stream, currentFigure

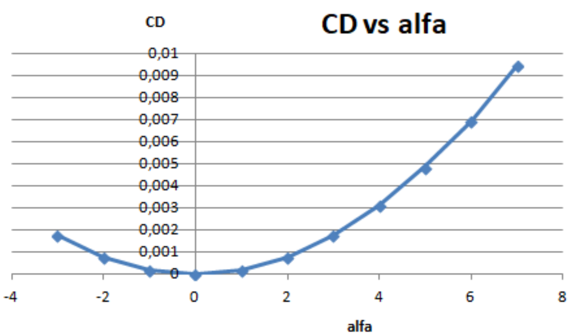
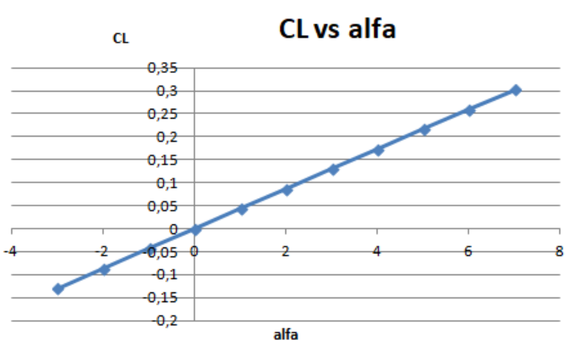


Figure 12. CD vs. Alpha, XFLR5



13. CL vs. Alpha, XFLR5

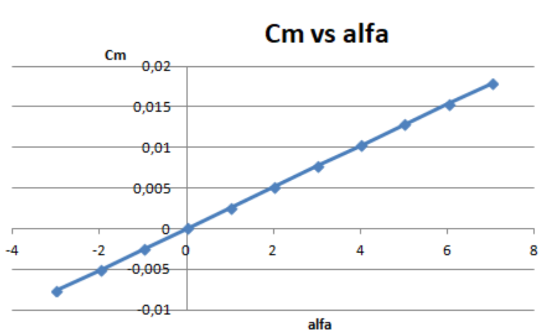


Figure 14. Cm vs. Alpha, XFLR5

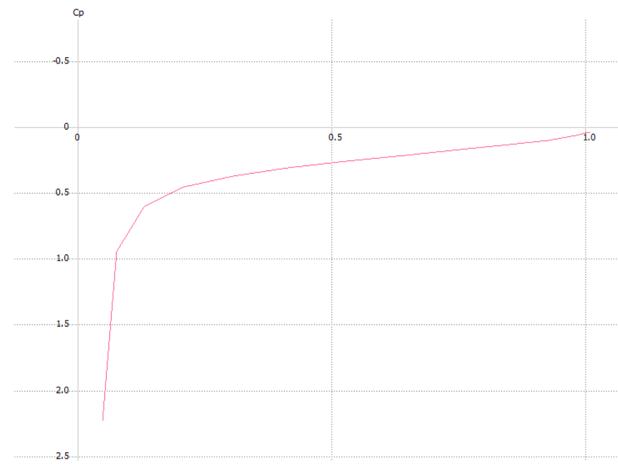


Figure 15. Cp vs. x, XFLR5

4. ANALYSIS

RESULTSThe algorithm developed in Matlab has many differences with the one proposed in XFLR5, but these differences are mainly in the wing model. In matlab the implemented wing was tapered, but in XFLR5 there were problems to exemplify the same type of wing, because the wing obtained by trying different configurations was always delta type. Based on this, making a direct comparison between both software is unfeasible. But, despite the difference in both, there is a common detail, the pressure distribution in the 3D model of the wing is similar, having a higher pressure coefficient on the leading edge of the wing. Another similar characteristic is in the lift coefficient, where being a small wing for an angle of attack of 6°, the lift coefficient is between 0.05 and 0.2 along the wing's span. In the case of Matlab, it was not possible to obtain the wake left by the wing, but in XFLR5 the effect of the induced drag can be observed mainly.

5. CONCLUSIONS

- The computational analysis of fluid dynamics allows a more detailed analysis in the area of aerodynamics, but even so, conventional methods are still useful for a first approximation of the parameters of an aircraft.

- CFD analysis of airfoils or finite wings requires knowledge about the aircraft's mission, because the selection of the turbulence model or analysis such as Vortex Lattice depends on this, which if not chosen correctly, the data generated by the simulation will be erroneous or inaccurate and are not valid for further analysis.

- The Vortex Lattice method is a very useful method for calculating lift and other parameters, and specifically in the design of an aircraft it is essential to use it to verify and better approximate the data in the finite wings.

6. REFERENCES

[1] T. Wilberforce, A. Al Makky, A. Baroutaji, R. Sambi, and AG Olabi, “Computational Fluid Dynamic simulation and modeling (CFX) of flow plate in PEM fuel cell using aluminum open cellular foam material,” in *2017 IEEE Texas Power and Energy Conference (TPEC)*, 2017, p. 1–6.

[2] Dazhuan Wu and Xinkuo Jiang, “Numerical study of the fluid forces for a whirling annular seal: CFD simulation versus experiment,” in *2014 ISFMFE - 6th International Symposium on Fluid Machinery and Fluid Engineering*, 2014, p. 118 (8.)-118 (8.).

[3] T. Wang, H. Lai, and Z. Jiang, “An algorithm study for determination of dynamic fluid level based on the state space reconstruction and BH-LSSVM,” in *2014 International Conference on Mechatronics and Control (ICMC)*, 2014, p. 132–136.

[4] Lin Peng, Lei Dong, Chongfang Song, Xiaofeng Liu, and Lin Cheng, “Simulation of flow around open storage pile based on low Reynolds number turbulence model,” in *2011 Second International Conference on Mechanic Automation and Control Engineering*, 2011, pp. 2562–2565.