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Automated Design Process of a Fixed Wing UAV Maximizing Endurance

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Abstract

In this study, we aim to reduce the time of the wing design and the optimization of the performances of unmanned aerial vehicles during the preliminary design through an automated framework using only open-source software (OpenVSP: VSPAERO with Parasite Drag Tool, and Python).

Objectives

The objectives of this work:

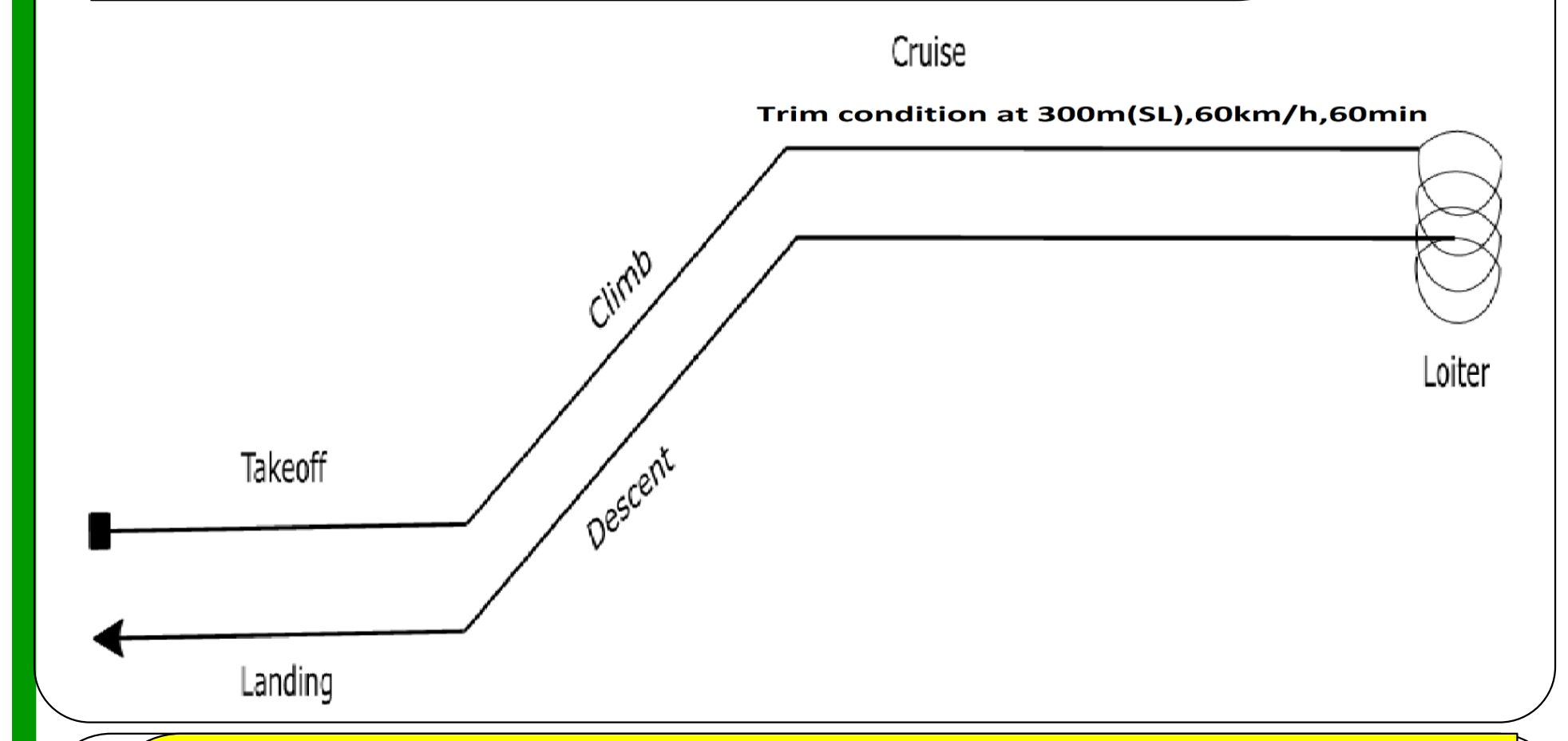
- Estimate the weight of the UAV
- Predict $C_{L,max}$ and the drag coefficient using a low - fidelity solver (VLM) and analytic expressions.
- Optimize the wing for maximum endurance.

Methodology of the Research

Requirements

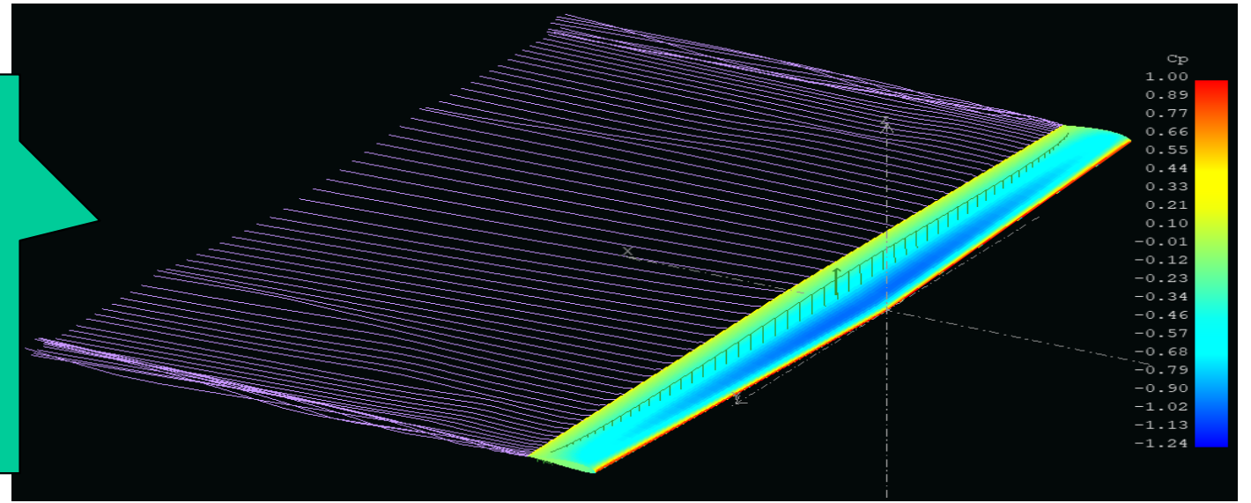
- Payload: m_{PL} = 1.5 kg
- m_{TO} <= 10 kg
- Stall speed = 10 m/s
- Maximum speed = 100 km/h
- Cruise speed = 60 km/h
- Endurance = 1 hr
- Range = 64 km
- ROC = 2.5 m/s … 5 m/s
- Altitude = 300 m (sea level)
- Equipment: camera, battery, avionics, parachute
- Electric motor

UAV Flight Mission

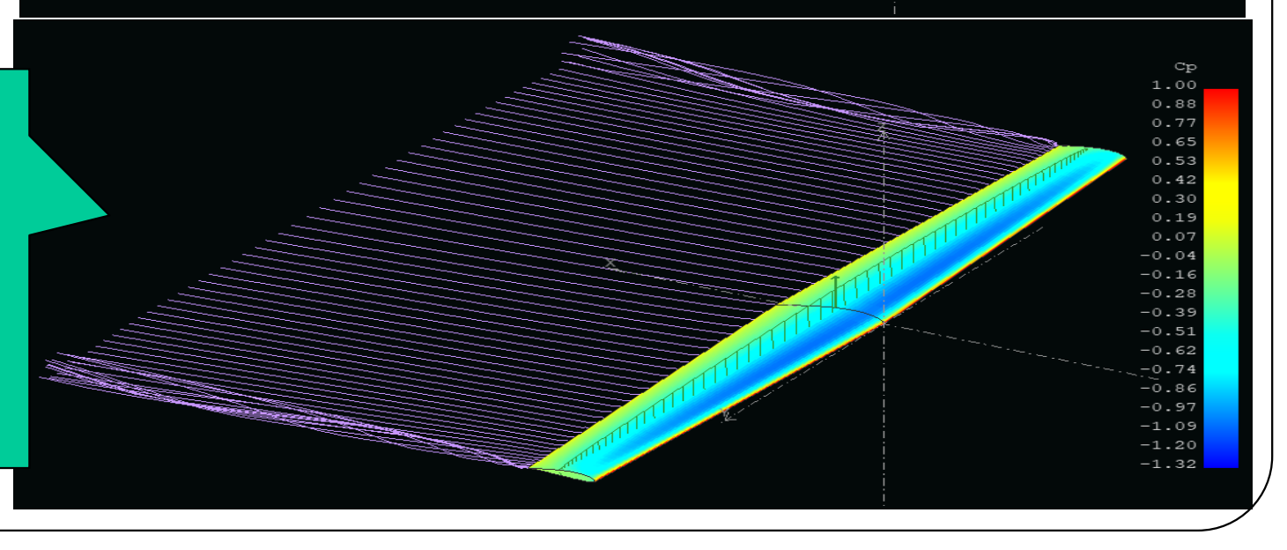


Cp and Lift Distribution

Optimized wing using: OpenVSP-API



Optimized wing using: ANN-XFLR5

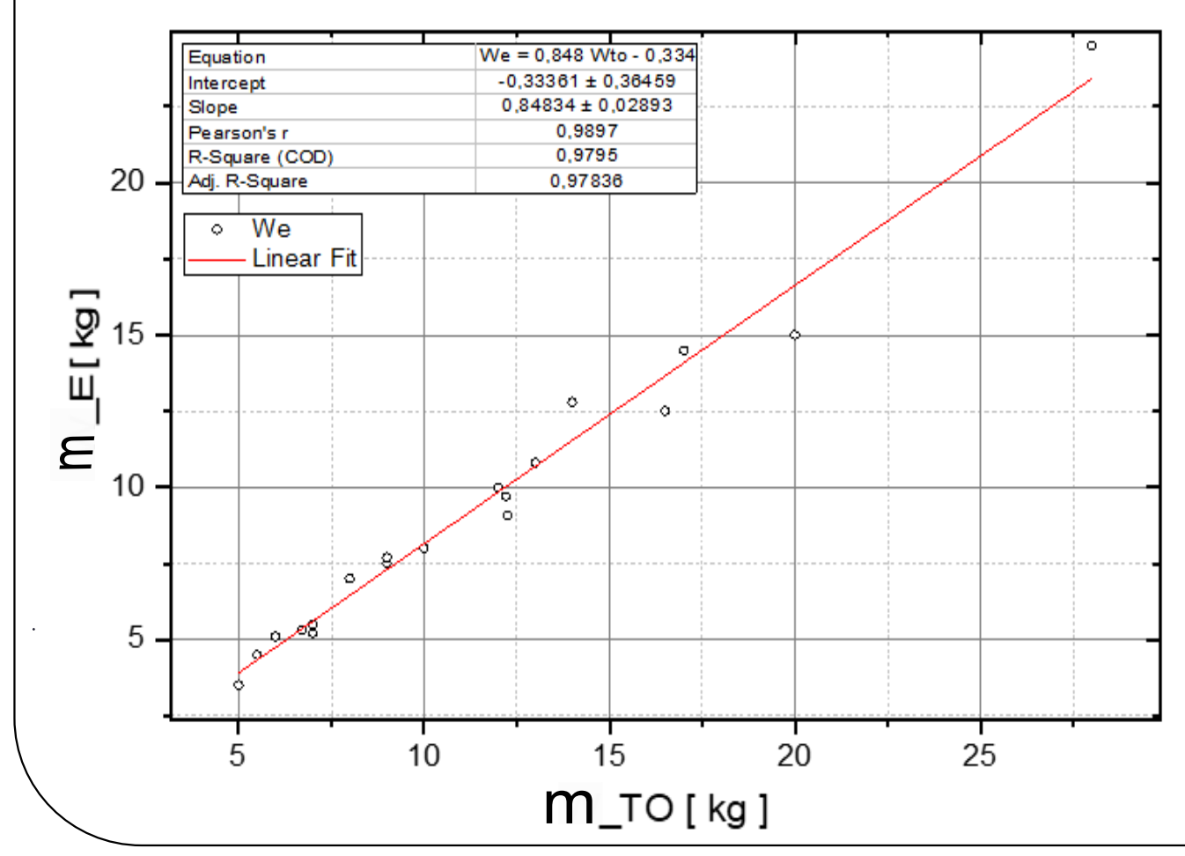


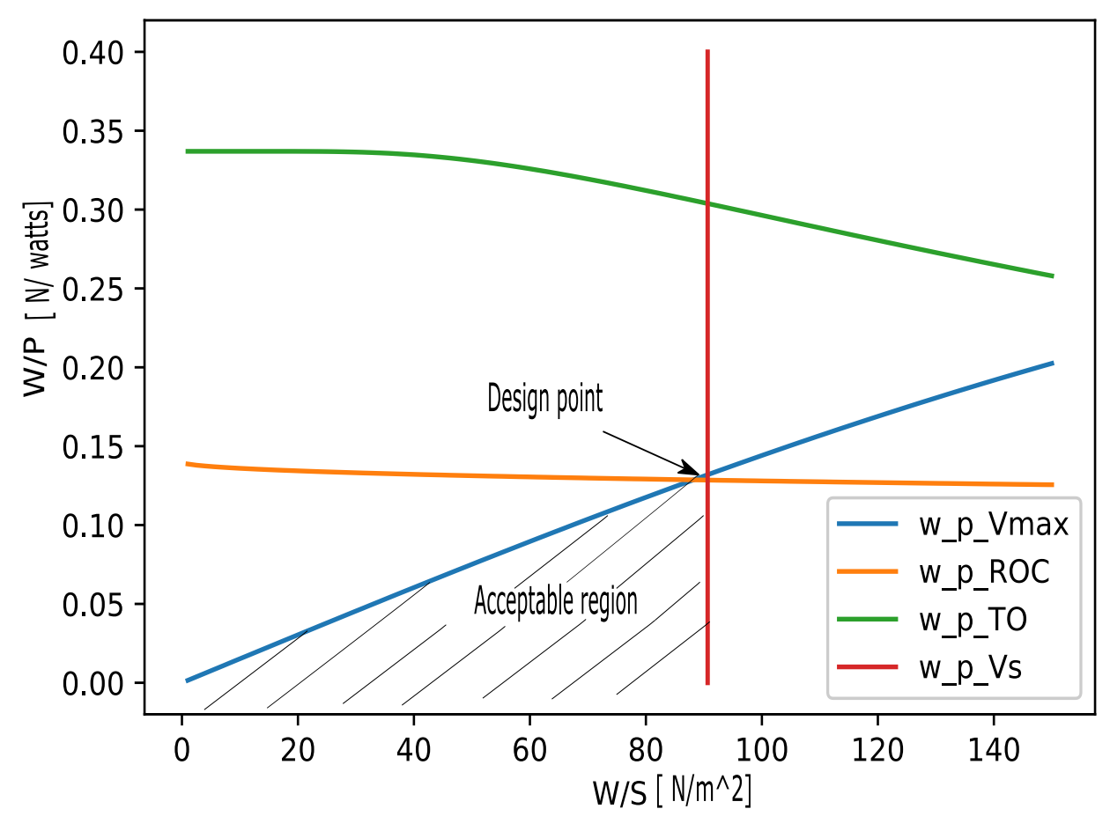
Weight Estimation

The maximum takeoff weight is given by the equation $m_{TO} = m_{PL} + m_{OE}$

We determine weight using a linear regression data from 20 existing UAVs. A matching plot technique is used to determine the wing loading and the power loading of the design point.

$$m_{TO} = 7.67\ \text{kg}, \frac{m_{TO}}{S} = 9.02\ {}^{\text{kg}}/_{\text{m}^2}, \frac{P}{m_{TO}} = 104.3\ {}^{\text{W}}/_{\text{kg}}$$





Endurance Optimization

Optimization with Genetic Algorithm (GA) is applied to the wing with:

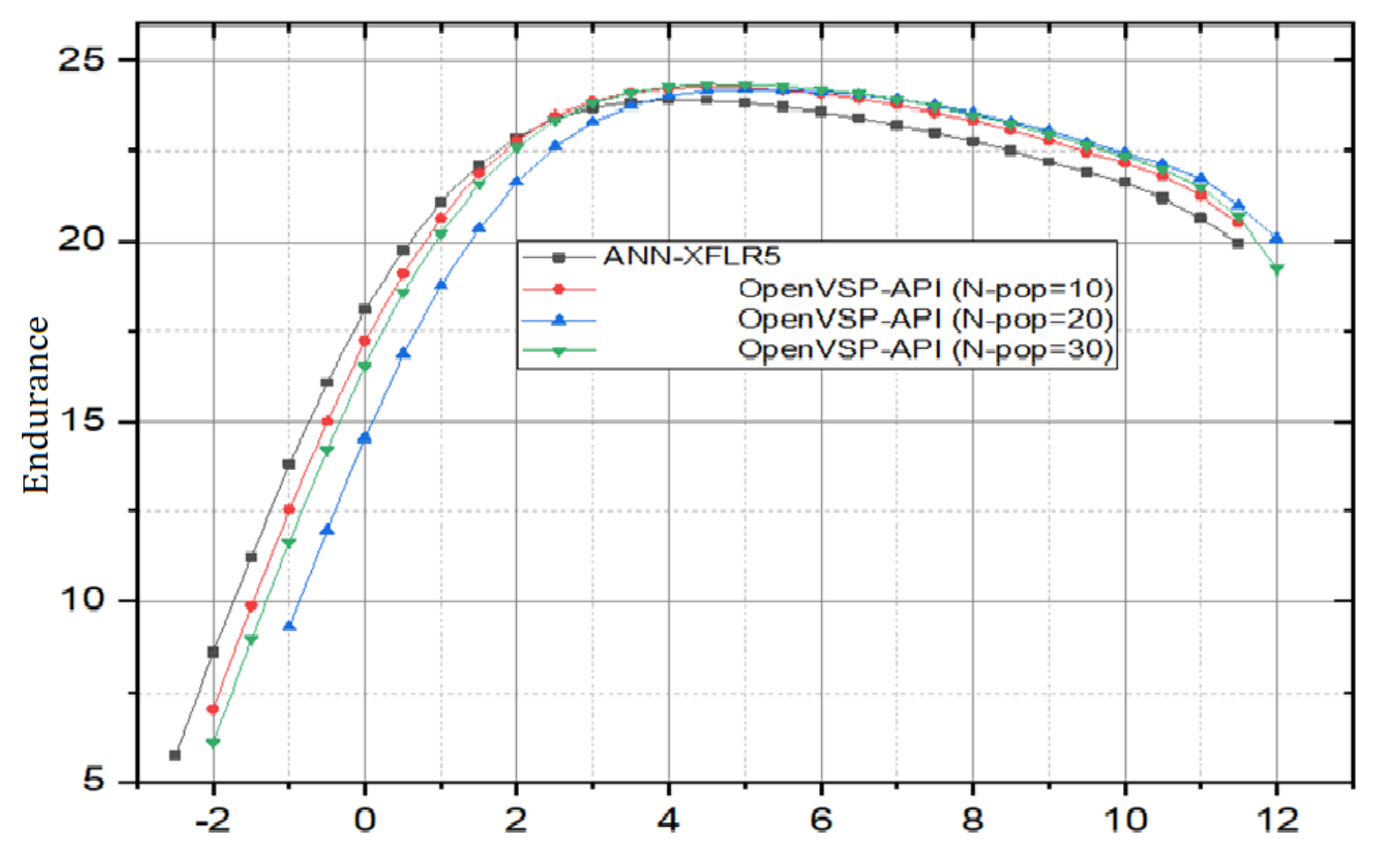
- Objective function: ${C_L}^{3/2}/_{C_D}$
-

Design Variables	Lower bound	Upper bound
WL : Wing Loading [kg/m^2]	8	10
AR : Aspect Ratio	8	11
TR : Taper Ratio	0.55	0.83
θ : Twist angle [◦]	-5	0

- Constraints: ROC , V_{max} and V_s
- Results (pop-size = 30):

Parameter	Value
WL [kg/m^2]	9.00
AR	10.90
TR	0.69
θ [◦]	-0.20
Max. of $C_L^{3/2}/C_D$	24.36
Engine (P, selected)	DC electric, 800 W
Battery	Li-Po 28 V, 8000 mAh
Wing area, S [m^2]	0.85
m_{TO} [kg]	7.67
m_{OE} [kg]	6.17

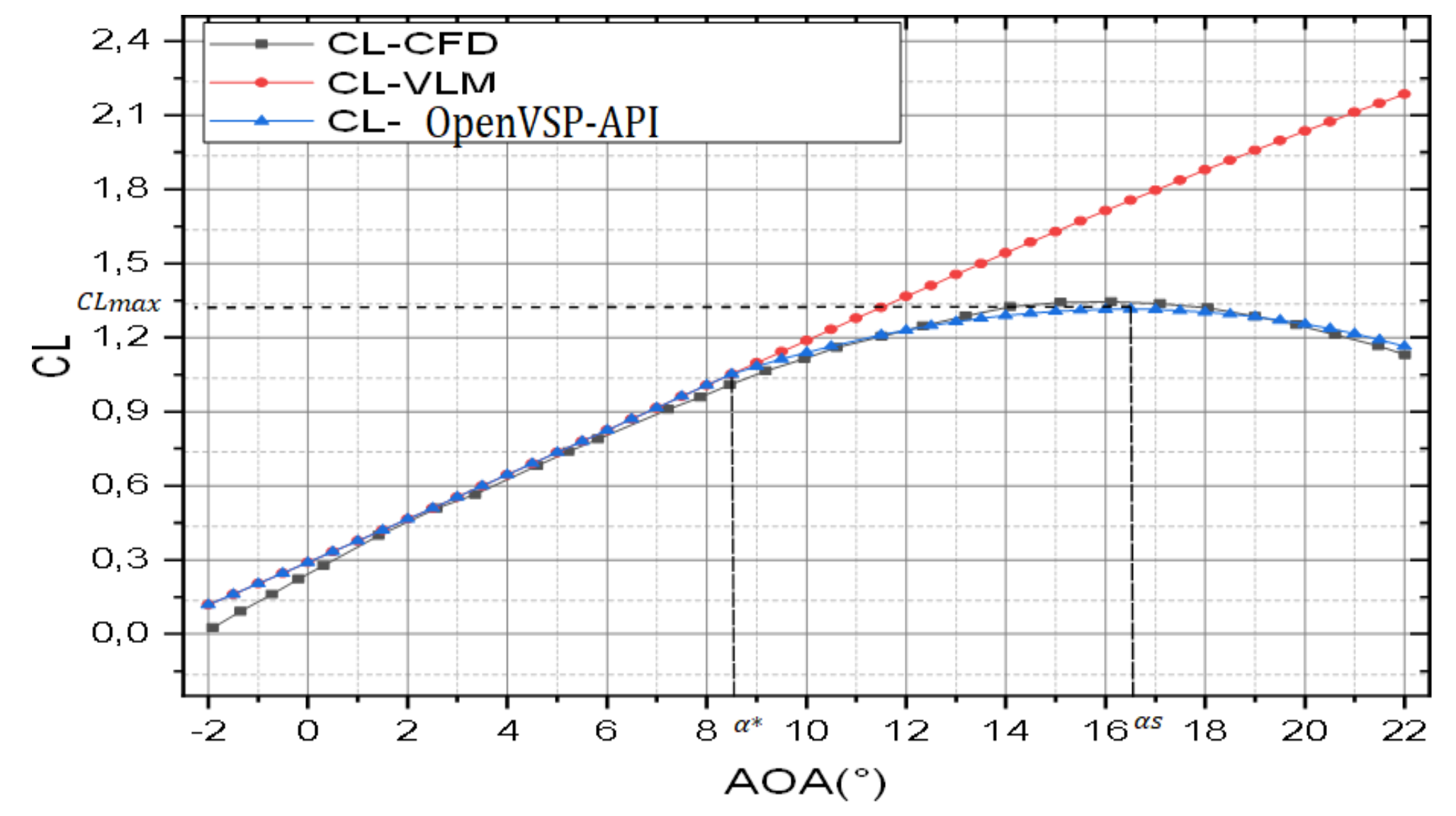
Endurance Parameter: $C_L^{3/2}/C_D$



Lift Estimation

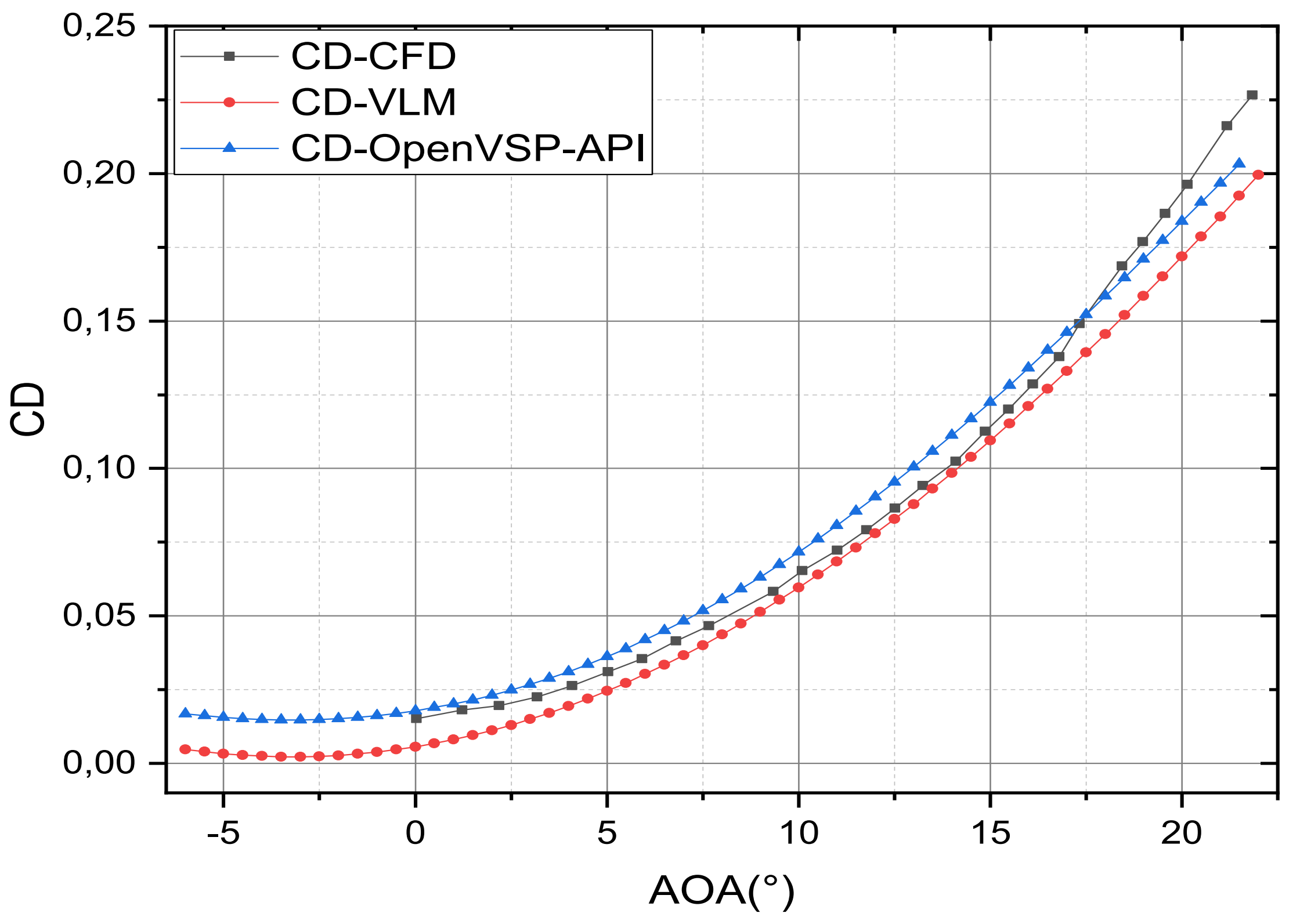
- Linear zone ($\alpha \leq \alpha_* = 8.5°$): $C_L = C_{L,VLM}$
- Nonlinear zone where ($\alpha \geq \alpha_* = 8.5°$): $C_L = f(\alpha)$ $C_{L,\max} = 1.34$ at $\alpha_s = 16.5°$

$AOA = \alpha$



Drag Estimation

It is also known that the VLM method is inaccurate in determining the total drag due to the negligence of the viscous effects. So, the parasite drag tool is coupled with VSPAERO to resolve this issue.



Conclusion

The proposed methodology provides a systematic and efficient approach to design, analyze, and optimize UAV wings for endurance. The approach can be extended to other design problems and applications, where endurance is a critical factor in achieving mission objectives. In addition, the proposed framework's main advantage is the use of open-source software, which provides a cost-effective and accessible solution for small and medium-sized startups to design and optimize UAVs. The proposed framework also reduces the time of calculation significantly, enabling quick design iterations and reducing the time to market.