ezaero Documentation

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CONTENTS:

Under construction

ezaero (easy-aero) is an open source Python package oriented to implement numerical methods for Aerodynamics, such as the Vortex lattice Method for lifting surfaces.

CHAPTER

ONE

STEADY VLM MODULE

The *ezaero.vlm.steady* module includes a Vortex Lattice Method implementation for lifting surfaces.

References

class ezaero.vlm.steady.**FlightConditions**(*ui: float = 100, aoa: float = 3.141592653589793, rho: float = 1*)

Container for the flight conditions.

ui

Free-stream flow velocity.

Type float

angle_of_attack

Angle of attack of the wing, expressed in radians.

Type float

rho

Free-stream flow density.

Type float

class ezaero.vlm.steady.**MeshParameters**(*m: int = 4, n: int = 16*)

Container for the wing mesh parameters.

m

Number of chordwise panels.

Type int

n

Number of spanwise panels.

Type int

class ezaero.vlm.steady.**Simulation**(*wing: ezaero.vlm.steady.WingParameters, mesh: ezaero.vlm.steady.MeshParameters, flight_conditions: ezaero.vlm.steady.FlightConditions*)

Simulation runner.

wing

Wing geometry definition.

Type *WingParameters*

mesh

Mesh specification for the wing.

Type *MeshParameters*

flight_conditions
Flight conditions for the simulation.

Type *FlightConditions*

plot_cl()
Plot lift coefficient distribution on the wing.

plot_wing(***kwargs*)
Generate 3D plot of wing panels, vortex panels, and panel control points.

run()
Run end-to-end steady VLM simulation.

Returns Object containing the results of the steady VLM simulation.

Return type *SimulationResults*

class ezaero.vlm.steady.**SimulationResults**(*dp: numpy.ndarray*, *dL: numpy.ndarray*, *cl: numpy.ndarray*, *cl_wing: float*, *cl_span: numpy.ndarray*)
Container for the resulting distributions from the steady VLM simulation.

dp
Distribution of pressure difference between lower and upper surfaces.

Type np.ndarray, shape (m, n)

dL
Lift distribution.

Type np.ndarray, shape (m, n)

cl
Lift coefficient distribution.

Type np.ndarray, shape (m, n)

cl_wing
Wing lift coefficient.

Type float

cl_span
Spanwise lift coefficient distribution.

Type np.ndarray, shape (n,)

class ezaero.vlm.steady.**WingParameters**(*root_chord: float = 1*, *tip_chord: float = 1*, *planform_wingspan: float = 4*, *sweep_angle: float = 0*, *dihedral_angle: float = 0*)
Container for the geometric parameters of the wing.

root_chord
Chord at root of the wing.

Type float

tip_chord
Chord at tip of the wing.

Type float

planform_wingspan
Wingspan of the planform.

Type float

sweep_angle
Sweep angle of the 1/4 chord line, expressed in radians.

Type float

dihedral_angle
Dihedral angle, expressed in radians.

Type float

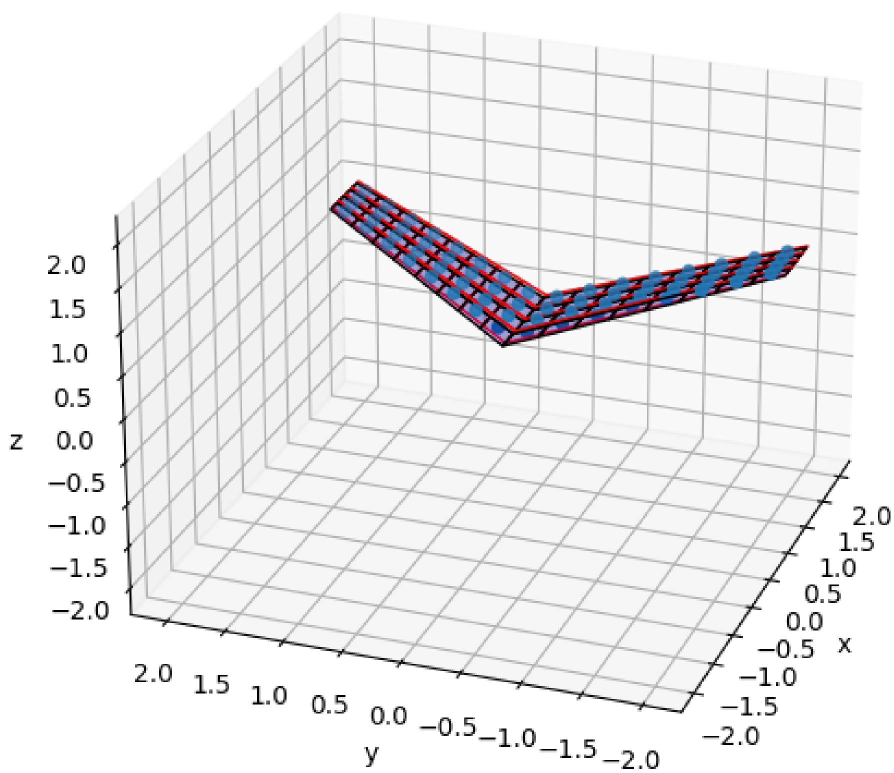
CHAPTER

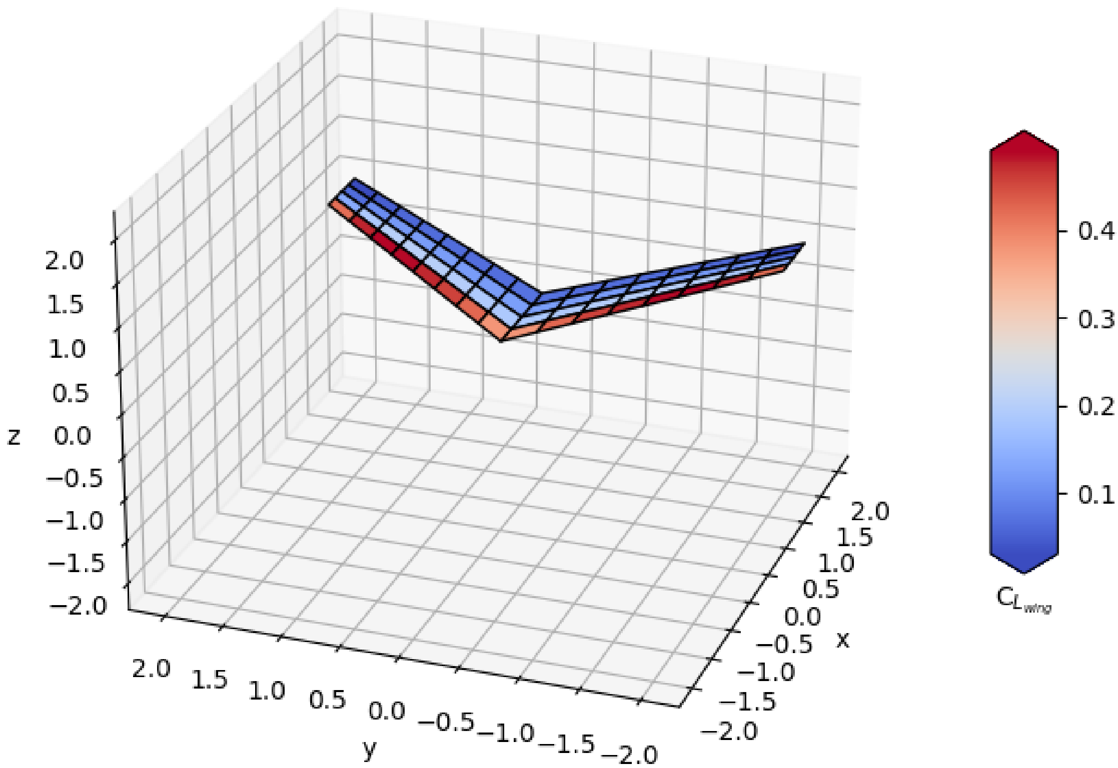
TWO

EXAMPLES

2.1 Simple steady VLM demo

Minimal example of simulation execution.

- 



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Out:

```
Wing lift coefficient: 0.20335518605804598
Elapsed time: 0.010985136032104492 s
```

```
import time

import matplotlib.pyplot as plt
import numpy as np

import ezaero.vlm.steady as vlm

# definition of wing, mesh and flight condition parameters
wing = vlm.WingParameters(
    root_chord=1,
    tip_chord=0.6,
    planform_wingspan=4,
    sweep_angle=30 * np.pi / 180,
    dihedral_angle=15 * np.pi / 180,
)
mesh = vlm.MeshParameters(m=4, n=16)
flcond = vlm.FlightConditions(ui=100, aoa=3 * np.pi / 180, rho=1.0)
```

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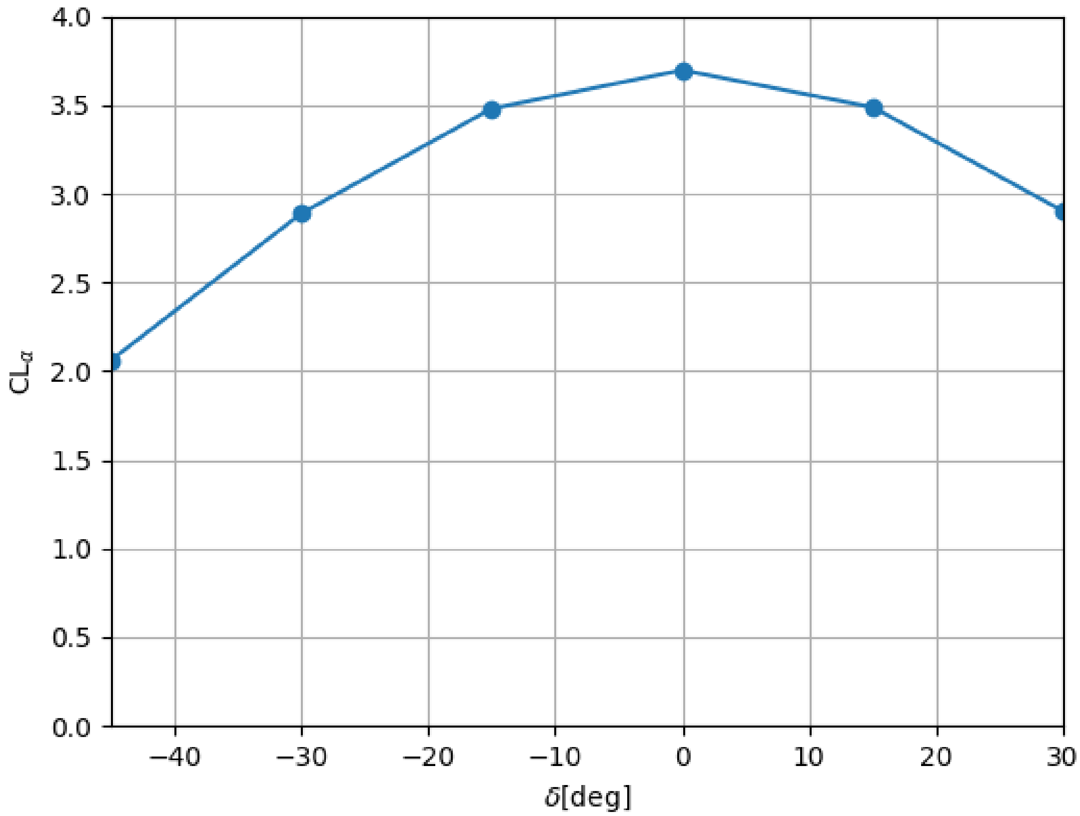
```
sim = vlm.Simulation(wing=wing, mesh=mesh, flight_conditions=flcond)

start = time.time()
res = sim.run()
print(f"Wing lift coefficient: {res.cl_wing}")
print(f"Elapsed time: {time.time() - start} s")

# plot wing panels, vortex panels, and collocation points
sim.plot_wing()
plt.show()

# plot cl distribution on wing
sim.plot_cl()
plt.show()
```

Total running time of the script: (0 minutes 0.880 seconds)

2.2 Dihedral angle effect

Effect of dihedral on the lift coefficient slope of rectangular wings.

2.2.1 References



Out:

```
Elapsed time: 1.1316943168640137 s
```

```
import time

import matplotlib.pyplot as plt
import numpy as np

import ezaero.vlm.steady as vlm

start = time.time()

# dihedral angles grid
deltas = np.array([-45, -30, -15, 0, 15, 30]) * np.pi / 180

# define mesh parameters and flight conditions
mesh = vlm.MeshParameters(m=8, n=30)
```

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```
# slope for each dihedral calculated using two flight conditions
flcond_0 = vlm.FlightConditions(ui=100.0, aoa=0.0, rho=1.0)
flcond_1 = vlm.FlightConditions(ui=100.0, aoa=np.pi / 180, rho=1.0)
cla_list = []  # container for the lift coefficient slope
for delta in deltas:
    # The figure in the book uses an aspect ratio of 4. It does not
    # correspond to the planform, but the "real" wingspan, hence we project
    # the wingspan with the dihedral angle
    bp = 4 * np.cos(delta)
    # define rectangular wing (same cr and ct), with no sweep (theta).
    wing = vlm.WingParameters(
        root_chord=1.0,
        tip_chord=1.0,
        planform_wingspan=bp,
        sweep_angle=0,
        dihedral_angle=delta,
    )
    res_0 = vlm.Simulation(wing=wing, mesh=mesh, flight_conditions=flcond_0).run()
    res_1 = vlm.Simulation(wing=wing, mesh=mesh, flight_conditions=flcond_1).run()
    d_cl = res_1.cl_wing - res_0.cl_wing
    d_alpha = flcond_1.aoa - flcond_0.aoa
    slope = d_cl / d_alpha * np.cos(delta)  # project load
    cla_list.append(slope)

end = time.time()
elapsed = end - start

print("Elapsed time: {} s".format(elapsed))

fig = plt.figure()
plt.plot(deltas * 180 / np.pi, cla_list, "o-")
plt.xlabel(r"$\delta$[deg]")
plt.ylabel(r"CL$_\alpha$")
plt.ylim(0, 4)
plt.grid()
plt.xlim(deltas.min() * 180 / np.pi, deltas.max() * 180 / np.pi)
plt.show()
```

Total running time of the script: (0 minutes 1.261 seconds)

PYTHON MODULE INDEX

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INDEX