

# Flight Loads: DroneVLA aircraft



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# Table of Contents

|  |    |
|--|----|
| <a href="#">Chapter 1. Introduction</a>  | 1  |
| <a href="#">Chapter 2. References</a>  | 2  |
| <a href="#">Chapter 3. List of Abbreviations</a>   | 3  |
| <a href="#">Chapter 4. Aircraft data</a>   | 4  |
| <a href="#">4.1. Geometry</a>  | 4  |
| <a href="#">4.2. Masses and inertia</a>  | 7  |
| <a href="#">4.3. Aerodynamic</a>   | 8  |
| <a href="#">Chapter 5. Design Airspeeds</a>  | 9  |
| <a href="#">5.1. Maximum speed in level flight <math>V_H</math></a>                          | 9  |
| <a href="#">5.2. Stall speeds <math>V_S</math>, <math>V_{S0}</math>, <math>V_{S1}</math></a> | 9  |
| <a href="#">5.3. Design manoeuvring speed <math>V_A</math></a>                               | 9  |
| <a href="#">5.4. Flaps maximum operating speed <math>V_F</math></a>                          | 10 |
| <a href="#">5.5. Flaps maximum extension speed <math>V_{FE}</math></a>                       | 10 |
| <a href="#">5.6. Design cruising speed <math>V_C</math></a>                                  | 10 |
| <a href="#">5.7. Design dive speed <math>V_D</math></a>                                      | 10 |
| <a href="#">5.8. Demonstrated dive speed <math>V_{DF}</math></a>                             | 11 |
| <a href="#">5.9. Never exceed speed <math>V_{NE}</math></a>                                  | 11 |
| <a href="#">5.10. Design Airspeeds summary</a>   | 11 |
| <a href="#">Chapter 6. Altitude</a>  | 12 |
| <a href="#">Chapter 7. Manoeuvring and Gust load factors <math>n</math></a>                  | 13 |
| <a href="#">7.1. Gust envelope</a>   | 13 |
| <a href="#">Chapter 8. V-n Envelope</a>  | 16 |
| <a href="#">Chapter 9. Loads on the aeroplane</a>  | 18 |
| <a href="#">9.1. Reference axes and sign convention</a>                                      | 18 |
| <a href="#">9.1.1. aaaaa</a>   | 18 |
| <a href="#">9.2. Symmetrical flight conditions</a>   | 18 |
| <a href="#">9.3. Aerodynamic centre</a>  | 18 |
| <a href="#">9.4. Pitching moment of the wing</a>   | 18 |
| <a href="#">Chapter 10. Loads on the wing</a>  | 20 |
| <a href="#">10.1. Influence of the fuselage</a>  | 20 |
| <a href="#">10.2. Forces and moments acting on the wings</a>                                 | 20 |
| <a href="#">10.2.1. SpanWise Airloads Distribution</a>                                       | 20 |
| <a href="#">10.2.2. Normal and parallel component</a>  | 22 |
| <a href="#">10.2.3. Shear, Bending and Torsion</a>   | 22 |
| <a href="#">10.2.4. Critical load condition</a>  | 25 |
| <a href="#">10.3. Unsymmetrical loads</a>  | 27 |
| <a href="#">10.3.1. Rolling condition</a>  | 27 |
| <a href="#">10.3.2. Effect of aileron displacement on the wing torsion</a>                   | 29 |
| <a href="#">Chapter 11. Loads on the horizontal tail</a>                                     | 32 |
| <a href="#">11.1. Balancing loads</a>  | 32 |
| <a href="#">11.2. Manoeuvring loads</a>  | 32 |
| <a href="#">11.2.1. Unchecked manoeuvre</a>  | 32 |
| <a href="#">11.2.2. Checked manoeuvre</a>  | 32 |

|  |    |
|--|----|
| 11.2.3. Gust loads.....                        | 32 |
| 11.3. Horizontal tail loads summary.....       | 32 |
| 11.4. Unsymmetrical loads.....                 | 32 |
| Chapter 12. Loads on the vertical tail.....    | 33 |
| 12.1. Manoeuvring loads .....                  | 33 |
| 12.1.1. a(1).....                              | 33 |
| 12.1.2. a(2).....                              | 33 |
| 12.1.3. a(3).....                              | 33 |
| 12.1.4. Gust loads.....                        | 33 |
| 12.2. Vertical tail loads summary.....         | 33 |
| 12.3. Combined loads.....                      | 33 |
| Chapter 13. Loads on the wing flaps.....       | 34 |
| 13.1. Manoeuvring and gust envelope .....      | 34 |
| Chapter 14. Loads on the control surfaces..... | 35 |
| 14.1. Ailerons.....                            | 35 |
| 14.2. Elevator.....                            | 35 |
| 14.3. Rudder .....                             | 35 |
| Chapter 15. Power plant .....                  | 36 |
| 15.1. Engine torque .....                      | 36 |
| 15.2. Side load on engine mount.....           | 36 |
| 15.3. Intertia load on engine mount .....      | 36 |
| 15.4. Gyroscopic loads.....                    | 36 |

## List of Figures

|   |    |
|---|----|
| <a href="#">Figure 7.1. V-n diagram</a>   | 14 |
| <a href="#">Figure 7.2. Gust diagram</a>  | 15 |
| <a href="#">Figure 8.1. Maneuver and Gust load factors and diagram</a>                        | 16 |
| <a href="#">Figure 8.2. Maneuver and Gust load factors and diagram</a>                        | 17 |
| <a href="#">Figure 9.1. Wing airloads</a>   | 18 |
| <a href="#">Figure 9.2. Balancing loads</a>   | 19 |
| <a href="#">Figure 10.1. Wing lift coefficient spanwise distribution</a>                      | 20 |
| <a href="#">Figure 10.2. Wing drag coefficient spanwise distribution</a>                      | 21 |
| <a href="#">Figure 10.3. Wing pitching moment coefficient (0.25mac) spanwise distribution</a> | 21 |
| <a href="#">Figure 10.4. Shear, Bending and Torsion due to airloads - POINT A</a>             | 22 |
| <a href="#">Figure 10.5. Shear, Bending and Torsion due to airloads - POINT C</a>             | 23 |
| <a href="#">Figure 10.6. Shear, Bending and Torsion due to airloads - POINT D</a>             | 24 |
| <a href="#">Figure 10.7. Shear comparison</a>   | 25 |
| <a href="#">Figure 10.8. Bending comparison</a>   | 26 |
| <a href="#">Figure 10.9. Torsion comparison</a>   | 26 |
| <a href="#">Figure 10.10. Pitching moment coefficient - POINT A</a>                           | 27 |
| <a href="#">Figure 10.11. Pitching moment coefficient - POINT C</a>                           | 28 |
| <a href="#">Figure 10.12. Pitching moment coefficient - POINT D</a>                           | 28 |
| <a href="#">Figure 10.13. Torsion distribution full loads - POINT A</a>                       | 29 |
| <a href="#">Figure 10.14. Torsion distribution full loads - POINT C</a>                       | 30 |
| <a href="#">Figure 10.15. Torsion distribution full loads - POINT D</a>                       | 31 |
| <a href="#">Figure 11.1. Balancing loads</a>  | 32 |

## List of Tables

|  |    |
|--|----|
| <a href="#">Table 4.1. Wing parameters</a> .....                                 | 4  |
| <a href="#">Table 4.2. Horizontal Tail parameters</a> .....                      | 5  |
| <a href="#">Table 4.3. Vertical Tail parameters</a> .....                        | 5  |
| <a href="#">Table 4.4. Fuselage parameters</a> .....                             | 6  |
| <a href="#">Table 4.5. Elevator parameters</a> .....                             | 6  |
| <a href="#">Table 4.6. Rudder parameters</a> .....                               | 6  |
| <a href="#">Table 4.7. Aileron parameters</a> .....                              | 7  |
| <a href="#">Table 4.8. Weight parameters</a> .....                               | 7  |
| <a href="#">Table 5.1. Design airspeeds</a> .....                                | 11 |
| <a href="#">Table 7.1. Gust load factor, different Speeds and Altitude</a> ..... | 14 |

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## Chapter 1. Introduction

This document defines the SUBPART C - Structure - Flight Loads of the:DroneVLA.The boundaries of the flight envelope will be defined within this document. All speeds are calibrated airspeeds (CAS) (requirement 4.4 [1])and given in knots if not stated otherwise.All other units used are metric (SI units).The weights are given in mass units (kg) but the formulas require force units as input,therefore these are calculated in place wherever they are used.Note: The speeds defined within this document should be used for the placards,speed markings, aeroplane flight manual (limitations), load calculations and need to be verified by flight test.

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## Chapter 2. References

1. ASTM F2245-12d," ASTM."ASTM F2245-12d, ASTM.
2. ABCD-FL-57-00 Wing Load Calculation, EASA.
3. ISO 2533:1975, International Standardization Organization, 1975.
4. CS-LSA Certification Specifications and Acceptable Means of Compliance, Amnd.1 29.Jul.2013, EASA, 2013.
5. "ABCD-FTR-01-00 Flight Test Report," EASA.
6. L. Smith, "NACA technical note 1945, 'Aerodynamic characteristics of 15 NACA airfoil sections at seven Reynolds numbers from  $0.7 \times 10^6$  to  $9 \times 10^6$ ," 1949.
7. ABCD-WB-08-00 Weight and Balance Report, EASA.

HERE BELOW AN EXAMPLE OF REFERENCES TO BE EDITED

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## Chapter 3. List of Abbreviations

- CL = lift coefficient
- CD....
- ...
- ...
- ...
- ...
- ...

ADD HERE list of abbreviations as a formatted table....to be created



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## Chapter 4. Aircraft data

The aircraft geometrical, masses, inertial and aerodynamic data, useful for flight loads estimation are summarized in this chapter.

### 4.1. Geometry

The aircraft reference geometrical characteristics are summarized in the following tables.[Wing parameters](#)

**Table 4.1. Wing parameters**

| Wing parameters          | Value       | Measure unit        |
|--------------------------|-------------|---------------------|
| b                        | 5.2         | m                   |
| S                        | 2.589       | m <sup>2</sup>      |
| AR                       | 10.446      | -                   |
| taper                    | NaN         | -                   |
| sweep                    | 0           | deg                 |
| sweep_location           | 0           | percentage          |
| secondary_sweep_location | 0           | percentage          |
| croot                    | 0.498       | m                   |
| ctip                     | 0.498       | m                   |
| xle                      | 1.638       | m                   |
| yle                      | 0           | m                   |
| zle                      | 0.165       | m                   |
| xtip_le                  | NaN         | % fuselage length   |
| dihedral                 | 0           | deg                 |
| mac                      | 0.498       | m                   |
| xmac                     | NaN         | % fuselage length   |
| ymac                     | NaN         | % semispan          |
| ypos                     | NaN         | % semispan          |
| zpos                     | NaN         | % fuselage diameter |
| camberloc                | 0.15        | Percentage          |
| thickchord               | 0.18        | Percentage          |
| type                     | Rectangular | flag                |
| twist_angle              | 3           | deg                 |
| mgc                      | 0.49788     | m                   |
| taper_ratio              | 1           | Non dimensional     |

**Table 4.2. Horizontal Tail parameters**

| Horizontal parameters    | Value  | Measure unit    |
|--------------------------|--------|-----------------|
| S                        | 0.529  | m <sup>2</sup>  |
| l                        | 1.492  | m               |
| camber                   | 0      | percentage      |
| camberloc                | NaN    | percentage      |
| thickchord               | 0.12   | percentage      |
| twist                    | 0      | deg             |
| twistloc                 | 0.25   | percentage      |
| xloc0                    | 1.49   | m               |
| xloc                     | 3.128  | m               |
| yloc                     | 0      | m               |
| zloc                     | 0.15   | m               |
| xrot                     | 0      | m               |
| yrot                     | 0      | m               |
| zrot                     | 0      | m               |
| b                        | 1.496  | m               |
| ctip                     | 0.3136 | m               |
| croot                    | 0.3929 | m               |
| sweep                    | 15     | deg             |
| sweeploc                 | 0      | percentage      |
| secsweeploc              | 1      | percentage      |
| dihedral                 | 0      | deg             |
| location_of_camber       | 0.2    | percentage      |
| secondary_sweep_location | 1      | percentage      |
| ce_c_root                | 0.34   | Non dimensional |
| ce_c_tip                 | 0.36   | Non dimensional |

**Table 4.3. Vertical Tail parameters**

| Vertical parameters | Value   | Measure unit         |
|---------------------|---------|----------------------|
| xle                 | 0.95    | % of fuselage length |
| croot               | 0.3136  | m                    |
| ctip                | 0.15347 | m                    |
| xtip_le             | 1       | % of fuselage length |
| b                   | 0.4375  | m                    |
| zpos                | 1       | % of df              |
| S                   | 0.1022  | m <sup>2</sup>       |

| Vertical parameters | Value   | Measure unit |
|---------------------|---------|--------------|
| chord               | 0.3136  | m            |
| MAC                 | 0.23354 | m            |
| l_vt                | 1.65    | m            |

**Table 4.4. Fuselage parameters**

| Fuselage parameters        | Value | Measure unit    |
|----------------------------|-------|-----------------|
| length                     | 3.64  | Non dimensional |
| diameter                   | 0.42  | Non dimensional |
| Non_dim_radius_of_gyration | 0.34  | Non dimensional |
| Radius_of_gyration         | NaN   | m               |

**Table 4.5. Elevator parameters**

| Elevator parameters | Value    | Measure unit    |
|---------------------|----------|-----------------|
| S                   | 0.14749  | m <sup>2</sup>  |
| chord               | 0.12324  | m               |
| chord_ratio_ce_c    | 0.35     | Non dimensional |
| overhang            | 0.12     | Non dimensional |
| span_ratio          | 0.8      | Non dimensional |
| S_hinge             | 0.126    | m <sup>2</sup>  |
| eta_inner           | 0.1      | percentage      |
| eta_outer           | 0.9      | percentage      |
| cf_c_inner          | 0.3      | percentage      |
| cf_c_outer          | 0.3      | percentage      |
| y_inner             | 0.0748   | m               |
| y_outer             | 0.6732   | m               |
| cf                  | 0.10845  | m               |
| moment_arm          | 0.016021 | m               |

**Table 4.6. Rudder parameters**

| Rudder parameters | Value    | Measure unit    |
|-------------------|----------|-----------------|
| S                 | 0.019062 | m <sup>2</sup>  |
| chord             | 0.10893  | m               |
| chord_ratio_cf_c  | 0.35     | Non dimensional |
| overhang          | 0.12     | Non dimensional |
| span_ratio        | 0.8      | Non dimensional |
| cr_c_root         | 0.45     | Non dimensional |
| cr_c_tip          | 0.5      | Non dimensional |

| Rudder parameters | Value    | Measure unit    |
|-------------------|----------|-----------------|
| eta_inner         | 0.1      | Non dimensional |
| eta_outer         | 0.9      | Non dimensional |
| croot             | 0.14112  | m               |
| ctip              | 0.076735 | m               |
| y_inner           | 0.021875 | m               |
| y_outer           | 0.19688  | m               |
| moment_arm        | 0.014161 | m               |

**Table 4.7. Aileron parameters**

| Aileron parameters | Value    | Measure unit    |
|--------------------|----------|-----------------|
| S                  | 0.14018  | m <sup>2</sup>  |
| b                  | 0.908    | m               |
| ca                 | 0.15438  | m               |
| cb                 | 0.019    | m               |
| y_inner            | 1.63     | m               |
| y_outer            | 2.538    | m               |
| eta_inner          | 0.627    | Non dimensional |
| eta_outer          | 0.976    | Non dimensional |
| ca_c_inner         | 0.31     | Non dimensional |
| ca_c_outer         | 0.31     | Non dimensional |
| croot              | 0.15438  | m               |
| ctip               | 0.15438  | m               |
| cf                 | 0.13538  | m               |
| moment_arm         | 0.016928 | m               |

## 4.2. Masses and inertia

The aircraft reference masses and inertia are summarized in this subsection

The Aircraft masses and inertia are summarized in Table: [Weight parameters](#)

**Table 4.8. Weight parameters**

| Weight           | Value | Measure unit        |
|------------------|-------|---------------------|
| W_maxTakeOff     | 100   | kg                  |
| W_OperativeEmpty | NaN   | kg                  |
| W_Payload        | NaN   | kg                  |
| W_Fuel           | NaN   | kg                  |
| W_Crew           | NaN   | kg                  |
| IY               | 100   | kg * m <sup>2</sup> |

### 4.3. Aerodynamic

The aircraft reference aerodynamic is in figure: [Wing-Body reference Aerodynamics](#)

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## Chapter 5. Design Airspeeds

This chapter defines the operating and design airspeeds as required for certification-CSVLA

### 5.1. Maximum speed in level flight VH

Data not yet available...to be added Available and Required Power.

### 5.2. Stall speeds VS, VS0, VS1

These speeds will be verified by flight test according to certification requirements. In order to calculate the stall speed, the maximum lift coefficient of the aeroplane as a whole is determined first. The maximum lift coefficient of the aeroplane has been calculated from high fidelity CFD. In landing configuration computed with full flap,  $CL_{MAX\text{ landing}} = 2.1$  in take-off configuration leading to  $CL_{MAX\text{ takeoff}} = 1.9$ , and in clean configuration, leading to  $CL_{MAX\text{ clean}} = 1.58$ , also considering the horizontal tail balancing force.

Flaps retracted(clean configuration):

$$V_S = \sqrt{\frac{2 W_{MTOM}}{\rho_0 C_{L_{MAX\text{Clean}}} S}} = \sqrt{\frac{2 * 981}{1.225 * 1.58 * 2.589}} = 19.7839 m/s$$

Flaps extended(Landing configuration):

$$V_{S_0} = \sqrt{\frac{2 W_{MTOM}}{\rho_0 C_{L_{MAX\text{Landing}}} S}} = \sqrt{\frac{2 * 981}{1.225 * 2.1 * 2.589}} = 17.1606 m/s$$

Flaps extended(Take-off configuration):

$$V_{S_1} = \sqrt{\frac{2 W_{MTOM}}{\rho_0 C_{L_{MAX\text{Takeoff}}} S}} = \sqrt{\frac{2 * 981}{1.225 * 1.9 * 2.589}} = 18.0412 m/s$$

Add here comments if necessary

Note: These speeds are estimates. The methods for the estimation can be various. It is important that these estimations are as precise as possible. Flight tests will be used to validate the stall speeds. In case the flight tests show different values, this might have an impact on the speeds used for design and ultimately might impair the compliance to the CSVLA

### 5.3. Design manoeuvring speed VA

According to requirement-CSVLA-335,

the maneuvering speed VA cannot be less than:

$$V_A \geq V_S \sqrt{n_{max}} = 19.7839 * \sqrt{3.8} = 38.566m/s$$

Add here comments if necessary

#### 5.4. Flaps maximum operating speed VF

According to requirement-CSVLA -345,

such speed shall be not less than the greater of 1.4VS and 1.8VS0

The speed has been selected as the greater between 1.4VS =27.6975m/s and 1.8 VSF =24.0248m/s, where VSF is the computed stalling speed with flaps fully extended at the design weight.

The flaps operating speeds is:

$$V_F = 27.6975m/s$$

#### 5.5. Flaps maximum extension speed VFE

On this aeroplane the maximum flap extension speed is identical to the flap operating speed VF. This speed is the maximum speed for flaps in take-off and landing configuration.

$$V_{FE} = 27.6975m/s$$

#### 5.6. Design cruising speed VC

According to requirement-CSVLA-335.

- VC (in m/s) may not be less than -

$$2.4 \sqrt{\frac{Mg}{S}} \left( V_C(kt) = 4.7 \sqrt{\frac{Mg}{S}} \right) \rightarrow 2.4 * \sqrt{\frac{100 * 9.8066}{2.589}} = 46.7095m/s$$

where M/S is the wing loading in kg/m2 and g is the acceleration due to gravity in m/s2.

- VC need not be more than 0.9 VH at sea level.

VH must be available. Otherwise previous value is considered!!!

$$V_C = 46.7095m/s$$

#### 5.7. Design dive speed VD

According to requirement-CSVLA-335.

(1) VD may not be less than 1.25 VC; and (2) with VCmin, the required minimum design cruising speed, VD may not be less than 1.40 VCmin.

$$(1) 1.25VC = 58.3869m/s$$

(2)  $1.4V_{Cmin} = 40\text{m/s}$

$$V_C = 1.25 * 46.7095 = 58.3869\text{m/s}$$

### 5.8. Demonstrated dive speed VDF

VDF is not a design airspeeds for this category.

### 5.9. Never exceed speed VNE

VNE is not a design airspeeds. It must be checked into sec. CS-VLA 1505 Airspeed limitations.

### 5.10. Design Airspeeds summary

Design airspeeds summary is resumed in Table: [Design airspeeds](#)

**Table 5.1. Design airspeeds**

| Design airspeeds | Value | Measure unit |
|------------------|-------|--------------|
| VS               | 19.78 | m/s          |
| VS0              | 17.16 | m/s          |
| VS1              | 18.04 | m/s          |
| VA               | 38.57 | m/s          |
| VC               | 46.71 | m/s          |
| VD               | 58.39 | m/s          |
| VE               | 58.39 | m/s          |
| VG               | 30.46 | m/s          |
| VS_inv           | 24.87 | m/s          |
| VF               | 30.89 | m/s          |



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## Chapter 6. Altitude

The maximum permissible operational altitude for the aircraft is 1300m. Despite the CSVLA requirements do not require to account for the effects of altitude, such effects have been considered up to 1300m. In fact the gust load factor have been calculated at such altitude. This is considered acceptable since it covers the operational range within which the aeroplane will fly most of the time.

(Note: the CSVLA requirement does not require to account for the effects of altitude. Calculating the loads at sea level would be acceptable. In this case, the choice to consider such effect up to 1300m is a decision of a designer, which would be accepted by the team.)

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## Chapter 7. Manoeuvring and Gust load factors n

According to CSVLA - 337(a) , the positive limit manoeuvring load factor n may not be less than 3.8, while, according to CSVLA - 337(b) the negative limit manoeuvring load factor may not be less than -1.5.

The following value will be considered:

1.  $n_{max} = 3.8$
2.  $n_{min} = -1.5$

### 7.1. Gust envelope

Gust load factors need to be considered because they can exceed the prescribed maximum load factors at different weights and altitudes. Since gust loads depend on air density and aircraft mass they will be calculated for Compliance with the flight load requirements of this subpart to show:

(1) At each critical altitude within the range in which the aeroplane may be expected to operate, from sea level up to maximum operative altitude equal to:1300m.

(2) At each practicable combination of weight and disposable load within the operating limitations specified in the Flight Manual according to requirement CSVLA-321 and fully extended (requirement CSVLA-345 at  $V_F$ ).

The calculation is based on CSVLA-341. To calculate the gust loads at altitudes other than at sea level the following equation is altered to include the density at any altitude.

$$n = 1 + \frac{1/2 \rho_0 V a K_g U_{de}}{Mg/S}$$

where:

- $K_g = \frac{0.88\mu_g}{5.3 + \mu_g}$
- $\mu_g = \frac{2(M/S)}{\rho \bar{C} a}$
- $U_{de}$  = derived gust velocities referred to in CSVLA 333(c) (m/s)
- $\rho_0$  = density of air at sea level (kg/m<sup>3</sup>)
- $\rho$  = density of air (kg/m<sup>3</sup>)
- $M/S$  = wing loading (kg/m<sup>2</sup>)
- $\bar{c}$  = mean geometric chord (m);  $g$  = acceleration due to gravity (m/s<sup>2</sup>);
- $a$  = slope of the aeroplane normal force coefficient curve  $C_{NA}$  per radian

Since the gust loads on the wing and tail have been chosen to be treated together,  $a$  is the slope of the lift-curve of the aeroplane is equal to  $a = 5.2341/\text{rad}$  and  $0.09131/\text{deg}$ .

The gust speed at VC is equal to: 15.24m/s

The gust speed at VD is equal to: 7.62m/s

TABLE TO BE CHECKED!!!

**Table 7.1. Gust load factor, different Speeds and Altitude**

| ID | V(m/s) | M(kg) | M/S(kg/m <sup>2</sup> ) | Altitude(m) | rho(kg/m <sup>3</sup> ) | mug   | Kg     | Ude(m/s) | n     |
|----|--------|-------|-------------------------|-------------|-------------------------|-------|--------|----------|-------|
| 1  | 46.71  | 100   | 38.62                   | 1300        | 1.079                   | 27.47 | 0.7377 | 15.24    | 5.444 |

(Note: the applicant should provide the method for the calculation of the slope of the lift-curve of the aeroplane)



Figure 7.1. V-n diagram



Figure 7.2. Gust diagram

## Chapter 8. V-n Envelope



Figure 8.1. Maneuver and Gust load factors and diagram



Figure 8.2. Maneuver and Gust load factors and diagram

ADD HERE V-n Envelope

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## Chapter 9. Loads on the aeroplane

ADD HERE details for balancing Equation

ADD HERE details for balancing Equation

### 9.1. Reference axes and sign convention

#### 9.1.1. aaaaaa

ADD HERE details for balancing Equation

### 9.2. Symmetrical flight conditions

ADD HERE details for balancing Equation

### 9.3. Aerodynamic centre

ADD HERE details for balancing Equation

### 9.4. Pitching moment of the wing

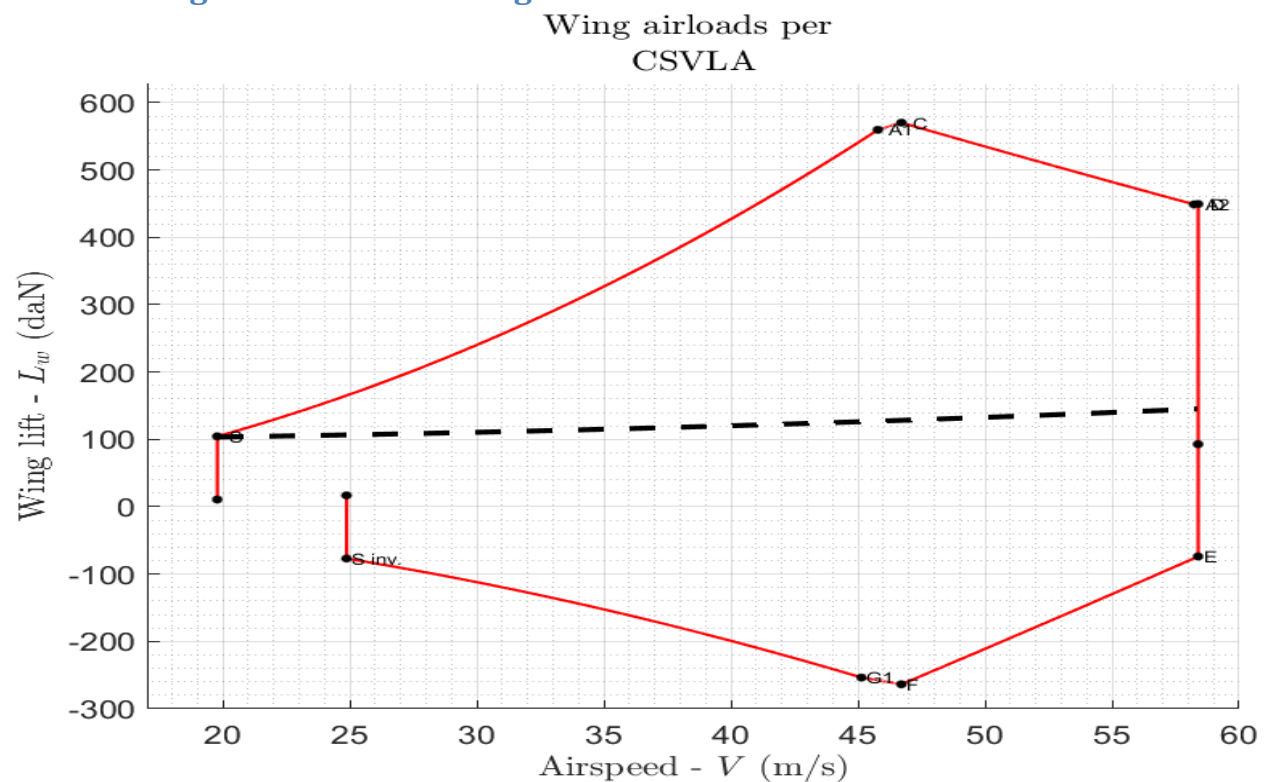


Figure 9.1. Wing airloads

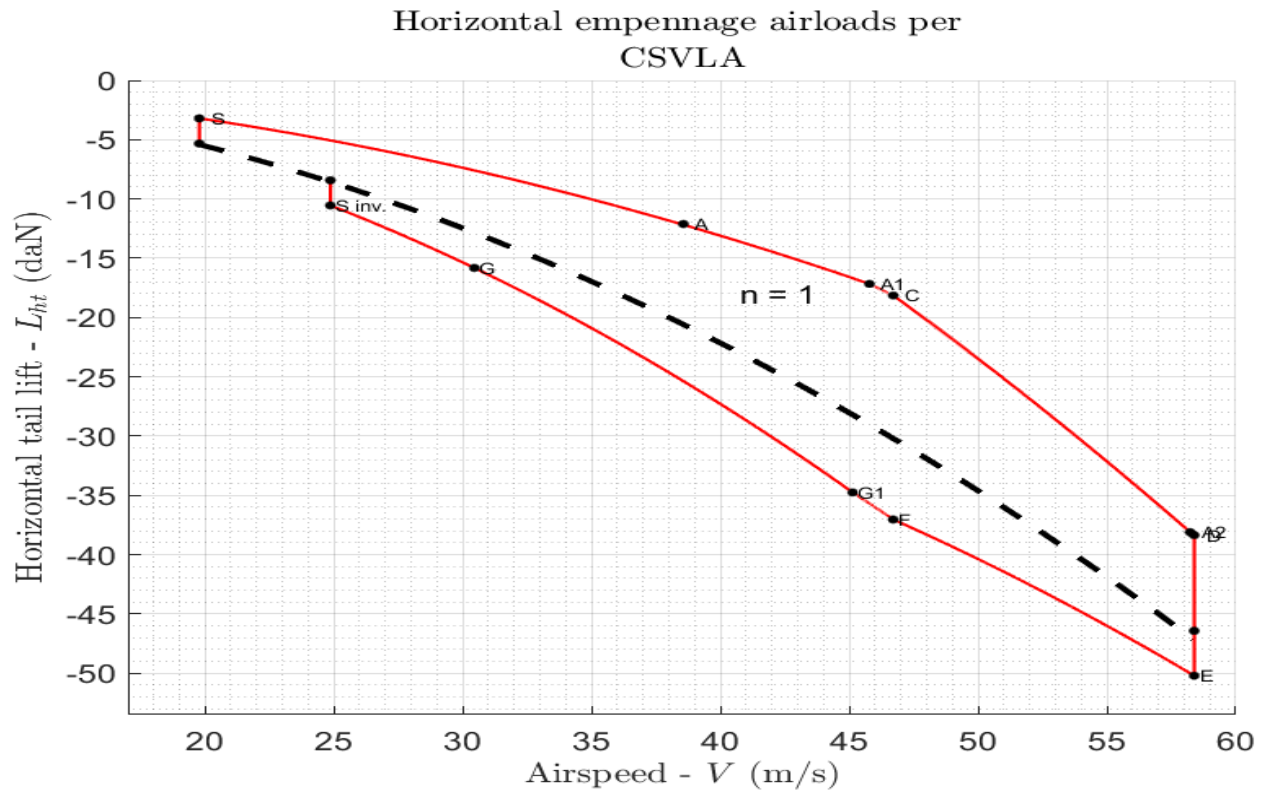


Figure 9.2. Balancing loads



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## Chapter 10. Loads on the wing

ADD HERE details for balancing Equation

ADD HERE details for fuselage effect how are they accounted?

### 10.1. Influence of the fuselage

ADD HERE details for balancing Equation

### 10.2. Forces and moments acting on the wings

#### 10.2.1. SpanWise Airloads Distribution

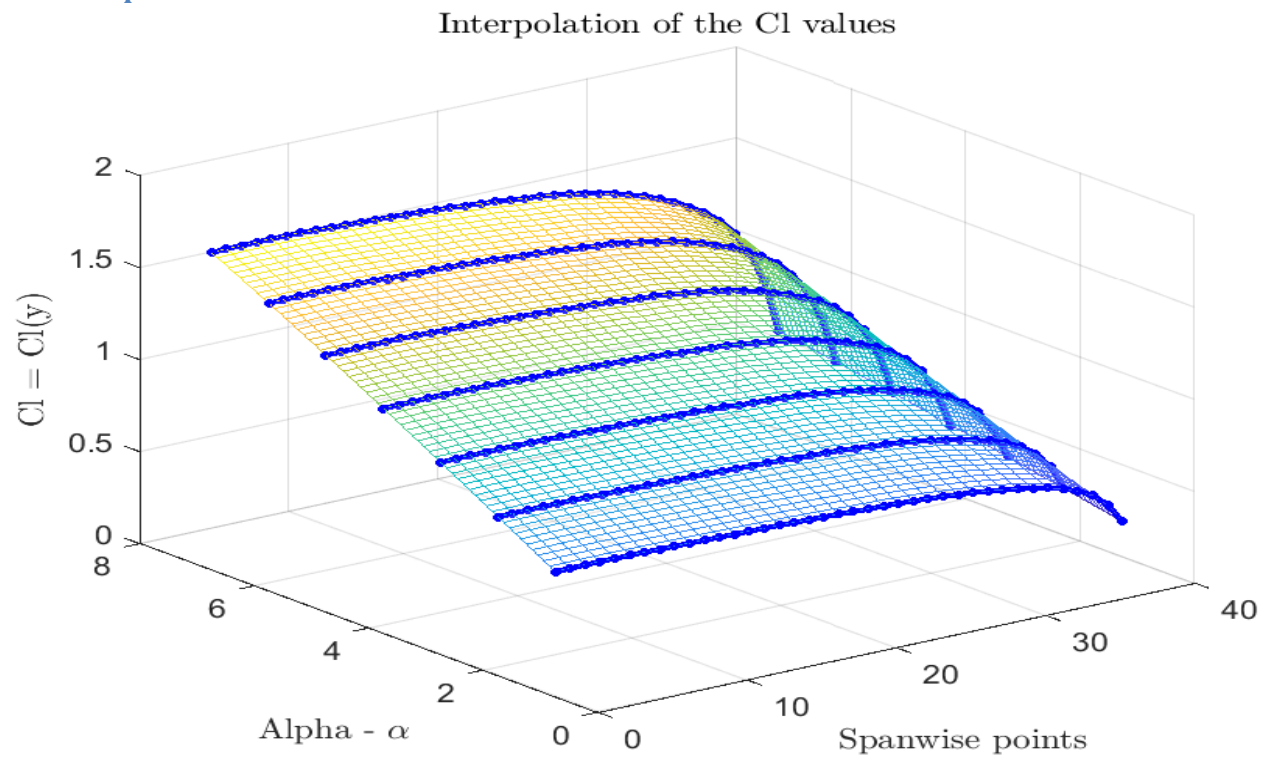


Figure 10.1. Wing lift coefficient spanwise distribution

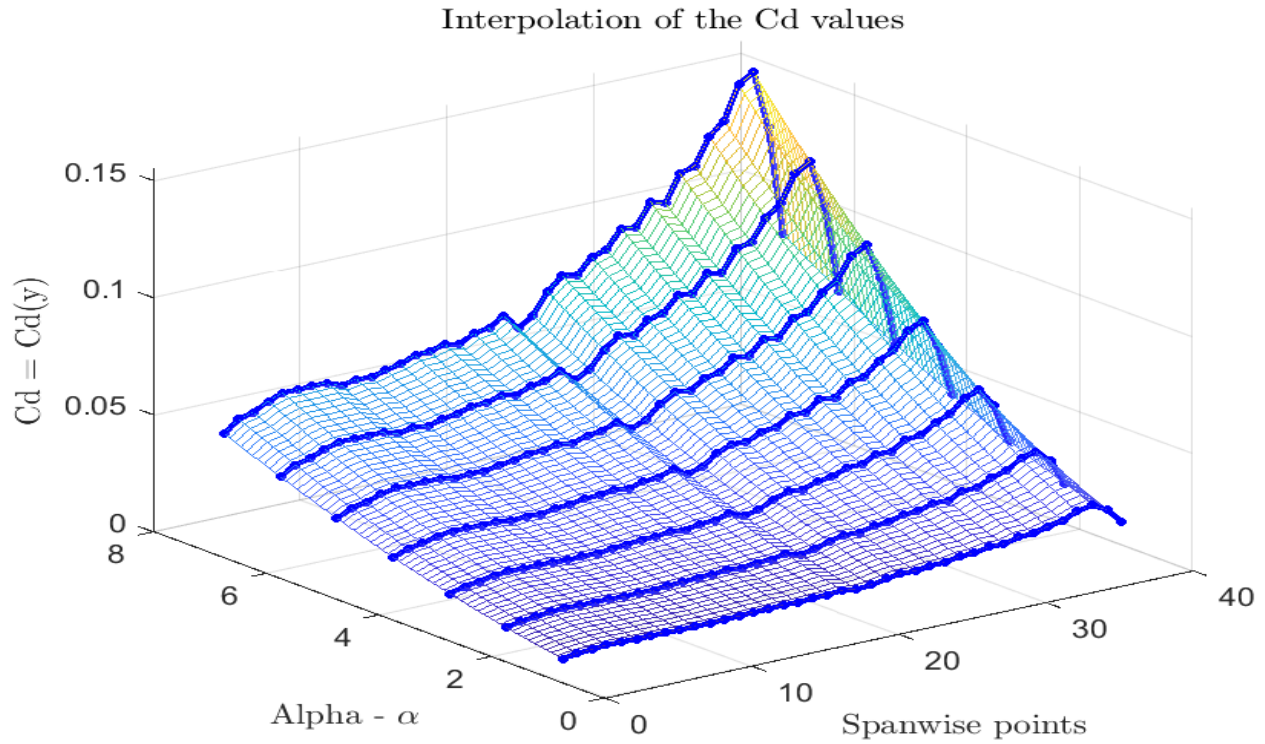


Figure 10.2. Wing drag coefficient spanwise distribution

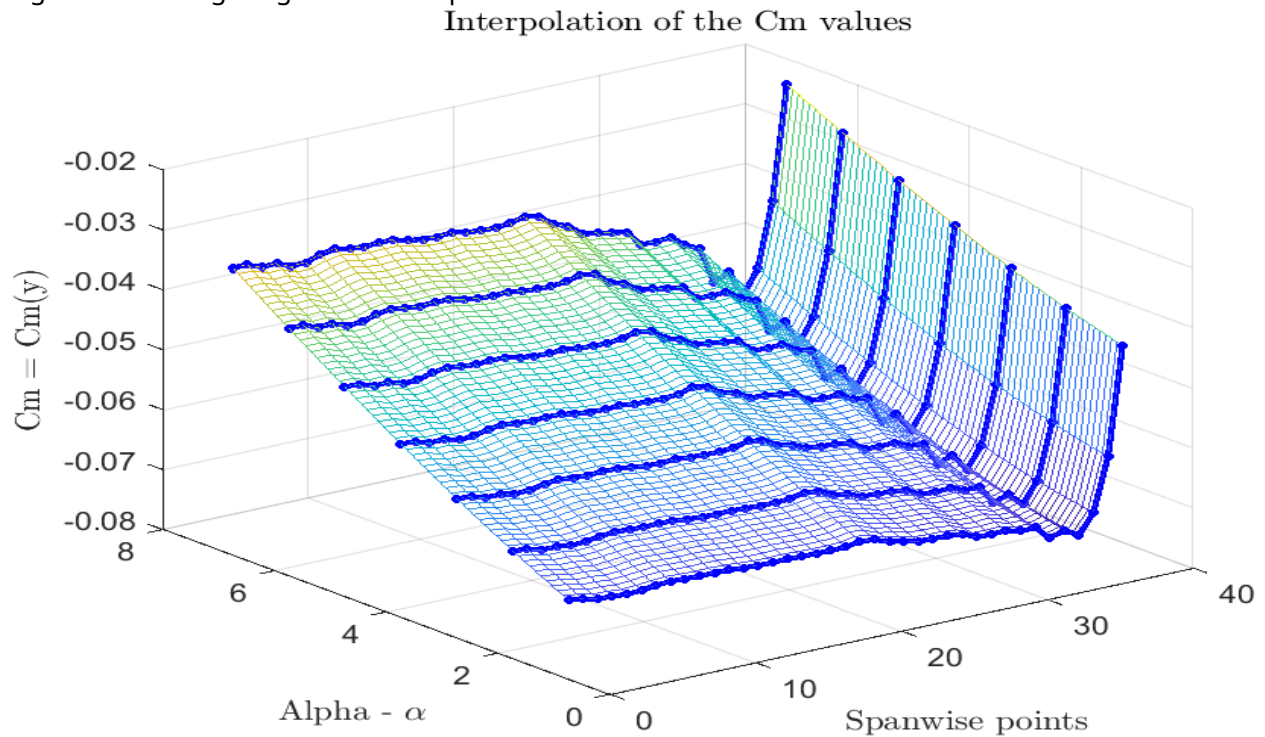


Figure 10.3. Wing pitching moment coefficient (0.25mac) spanwise distribution

### 10.2.2. Normal and parallel component

### 10.2.3. Shear, Bending and Torsion

## Point A

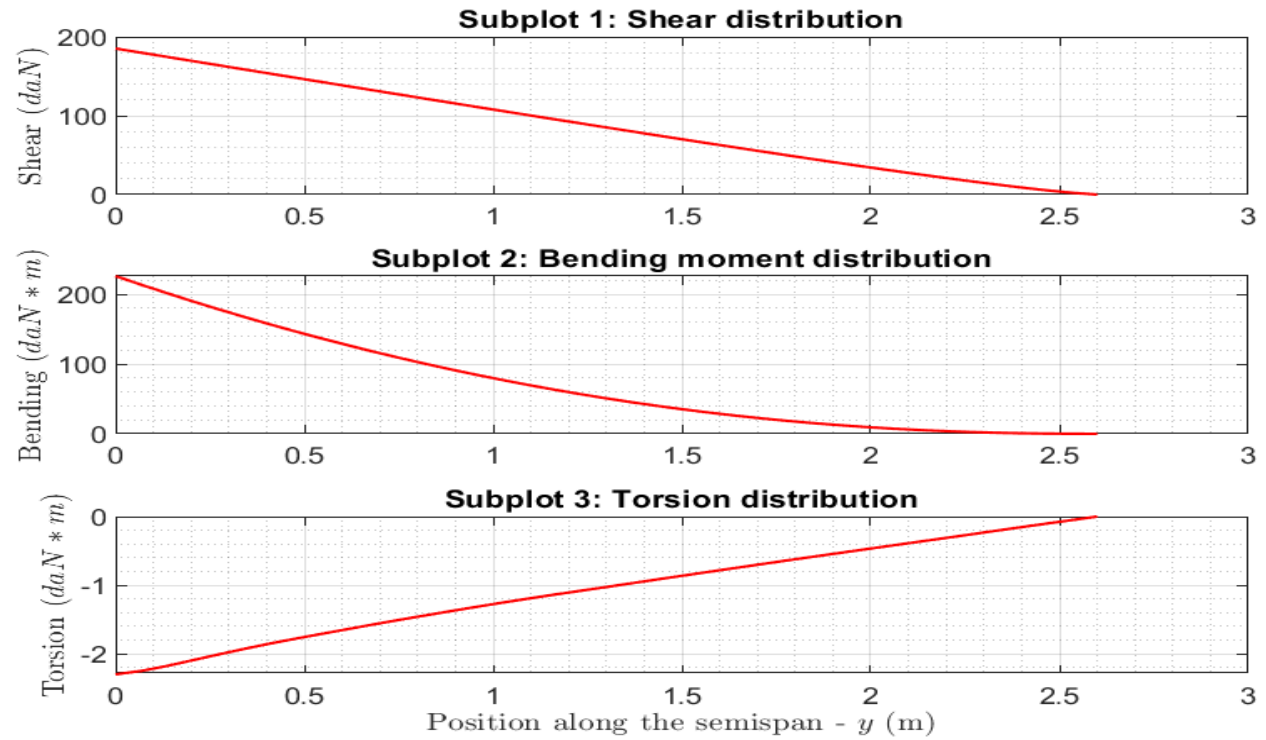


Figure 10.4. Shear, Bending and Torsion due to airloads - POINT A

## Point C

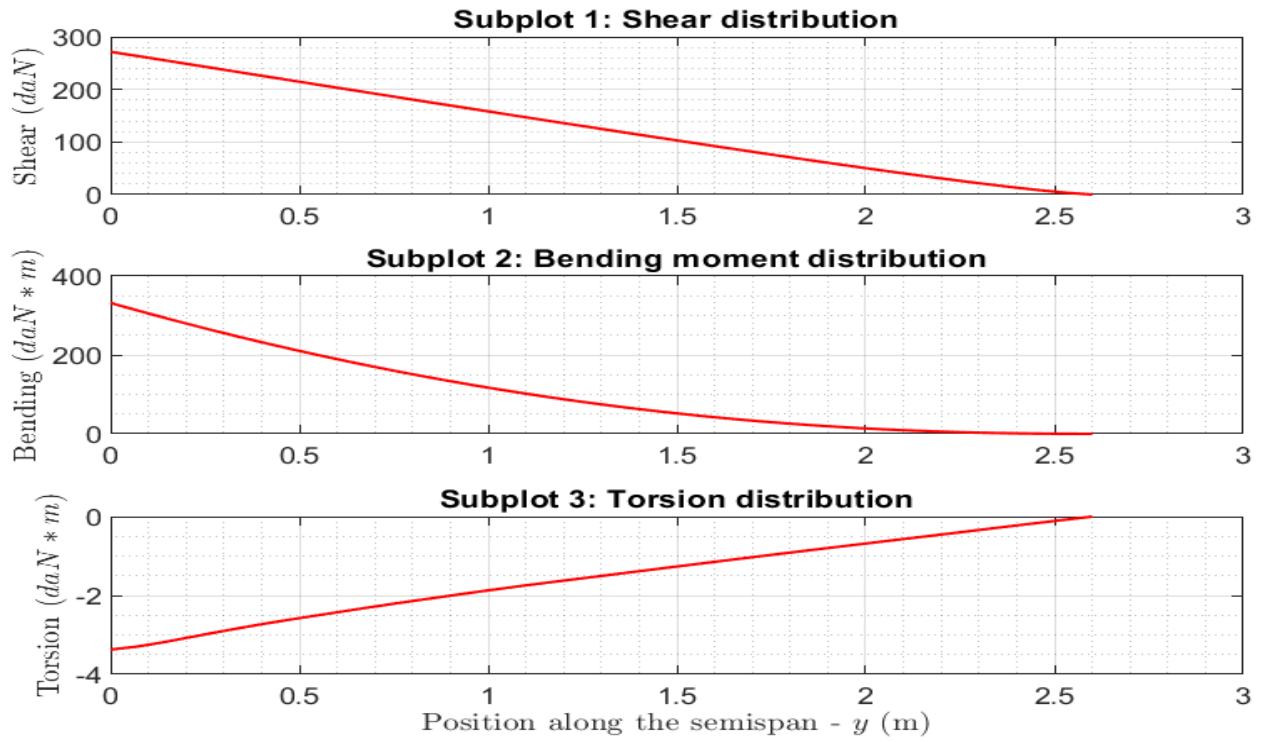


Figure 10.5. Shear, Bending and Torsion due to airloads - POINT C

## Point D

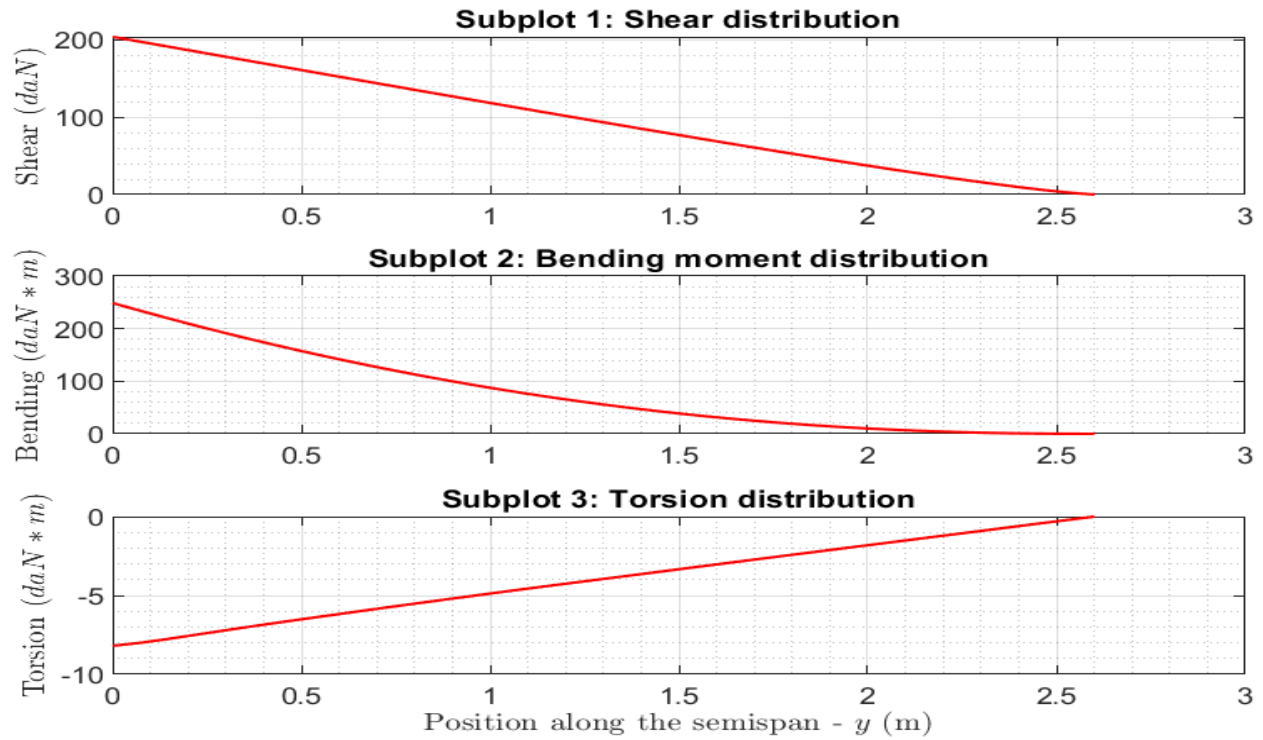


Figure 10.6. Shear, Bending and Torsion due to airloads - POINT D

## 10.2.4. Critical load condition

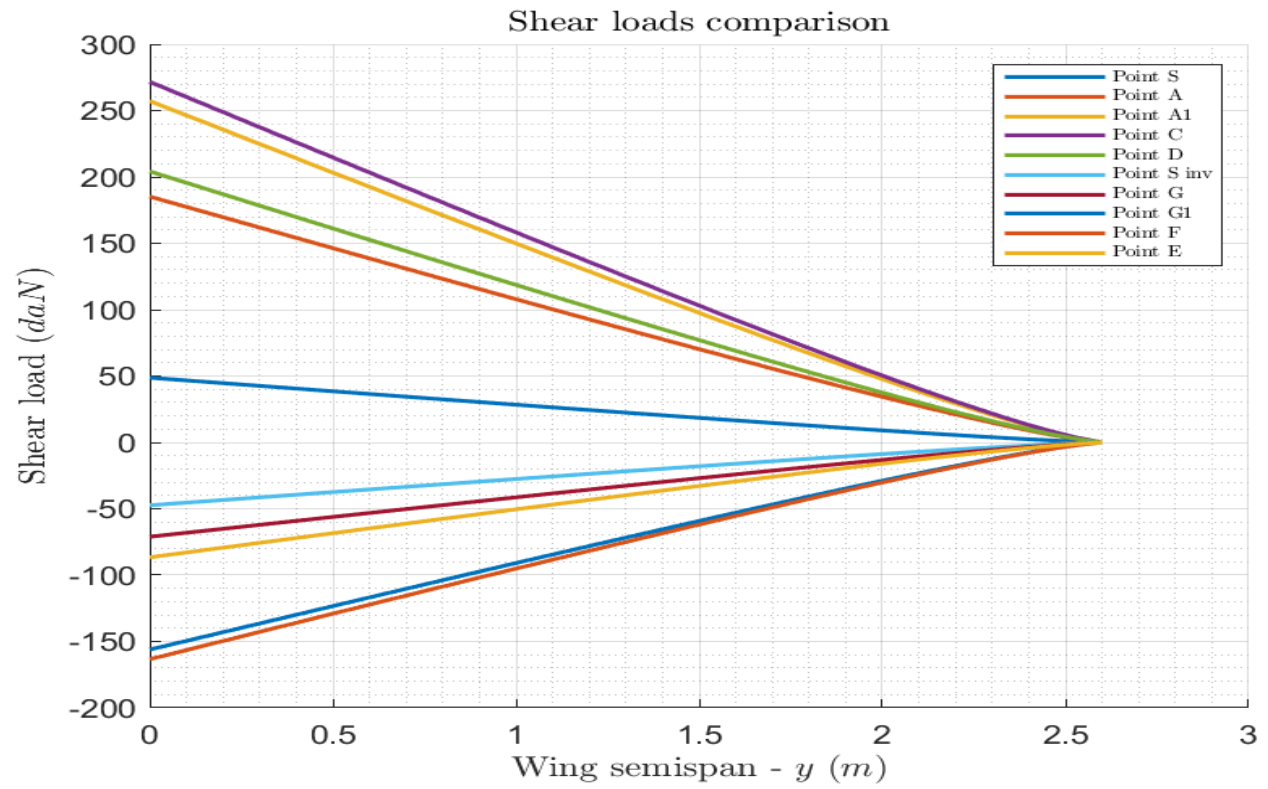


Figure 10.7. Shear comparison

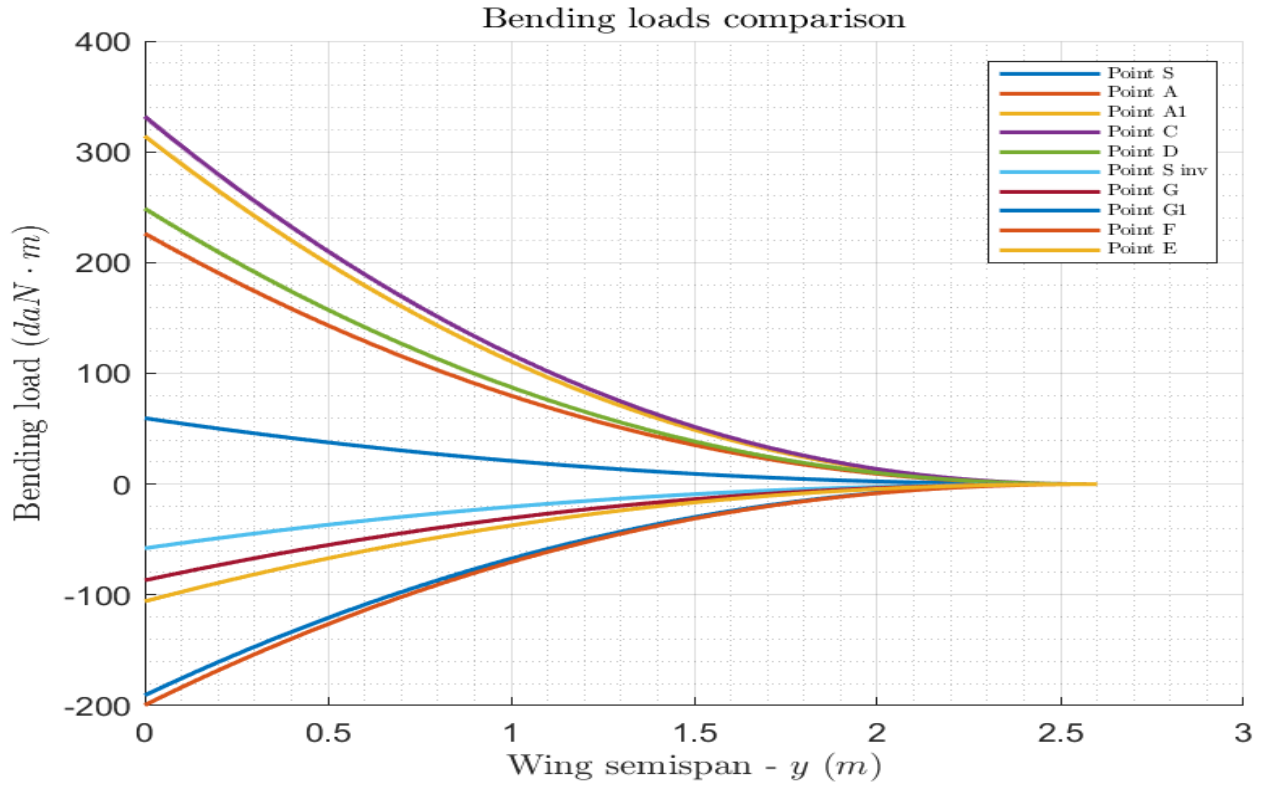


Figure 10.8. Bending comparison

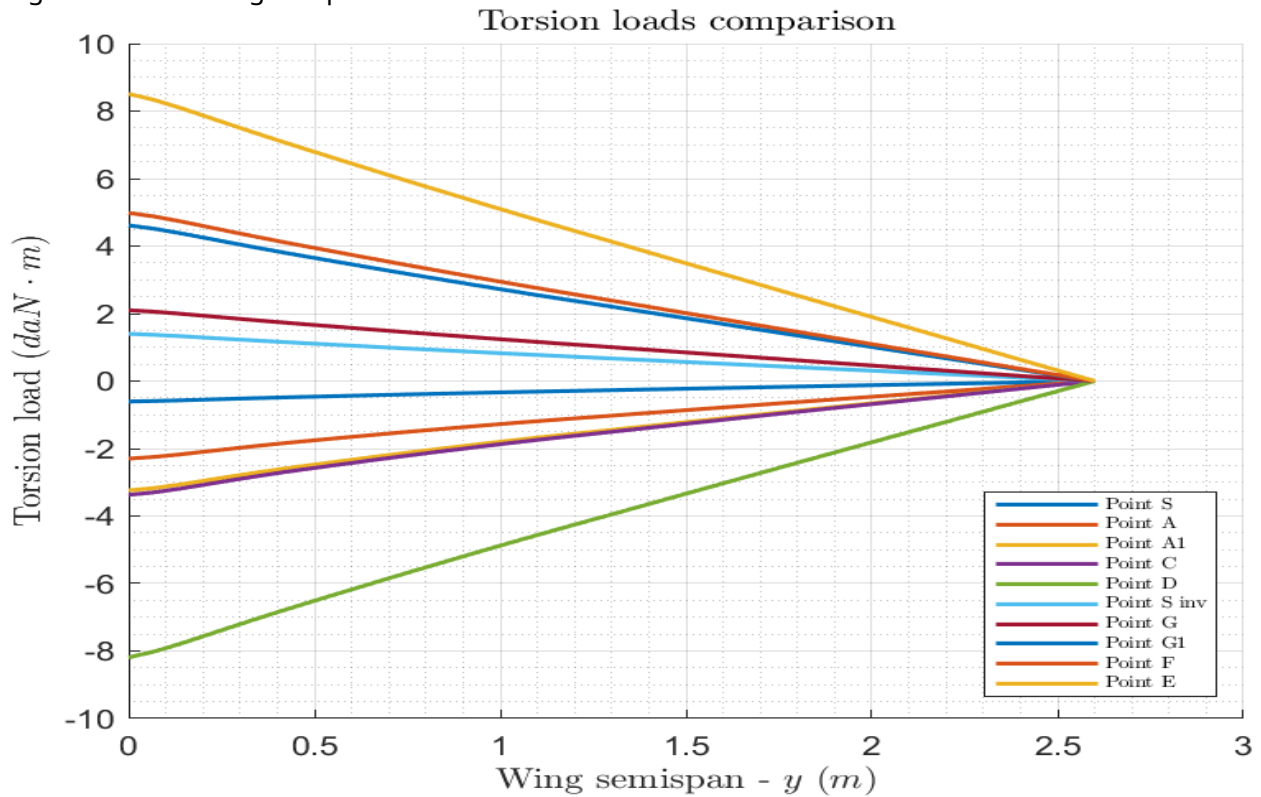


Figure 10.9. Torsion comparison

ADD HERE details for uns loads

### 10.3. Unsymmetrical loads

#### 10.3.1. Rolling condition

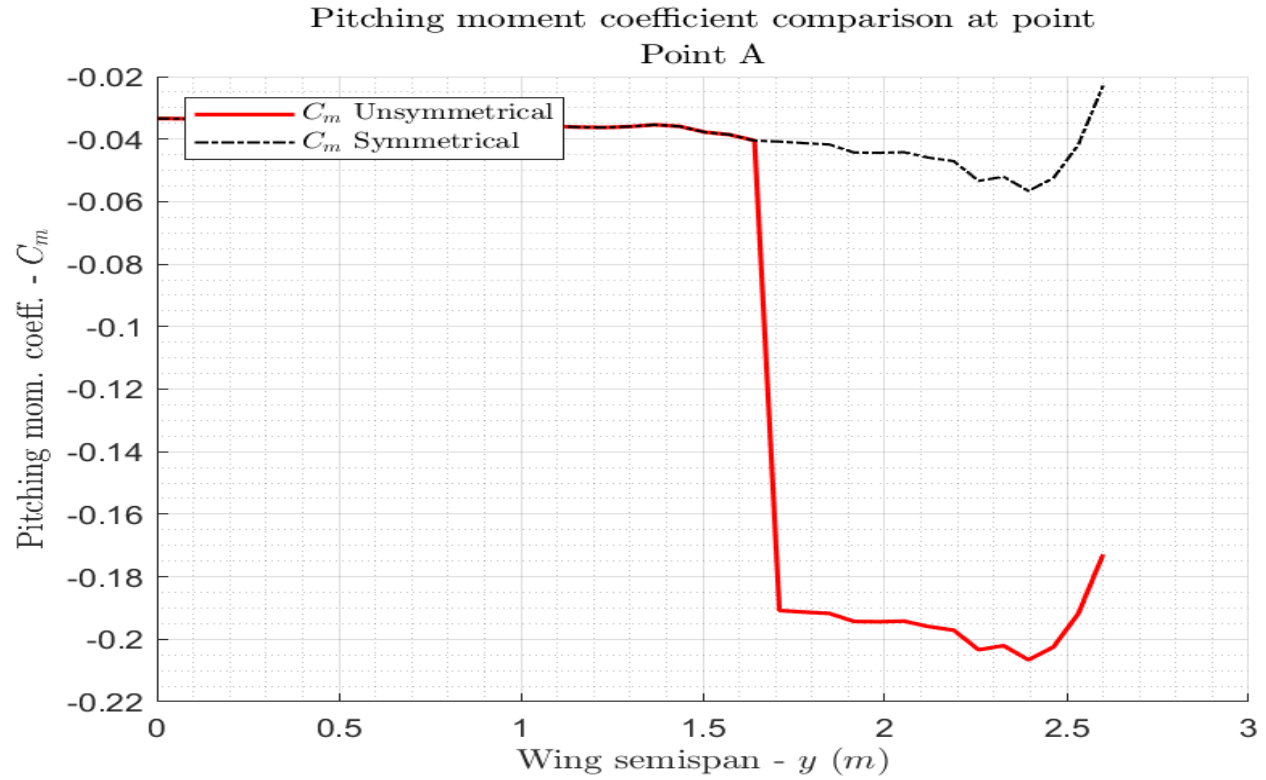


Figure 10.10. Pitching moment coefficient - POINT A



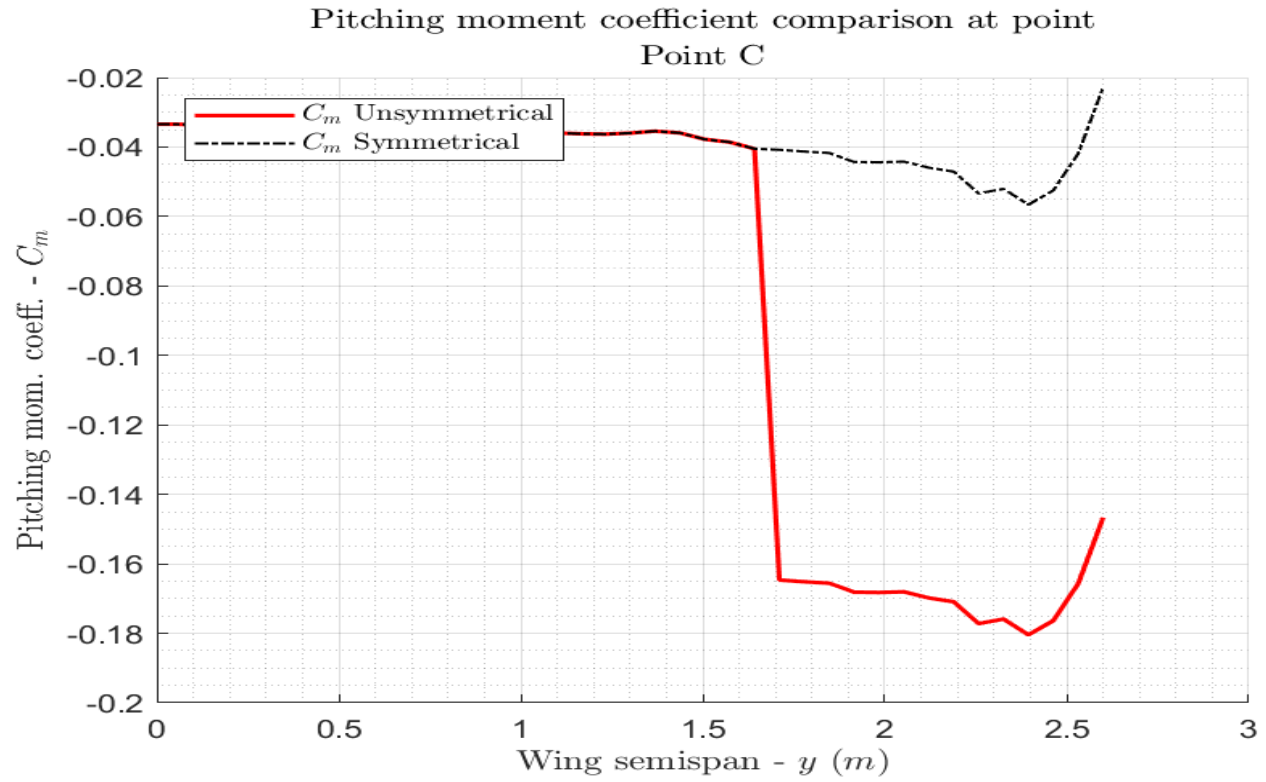


Figure 10.11. Pitching moment coefficient - POINT C

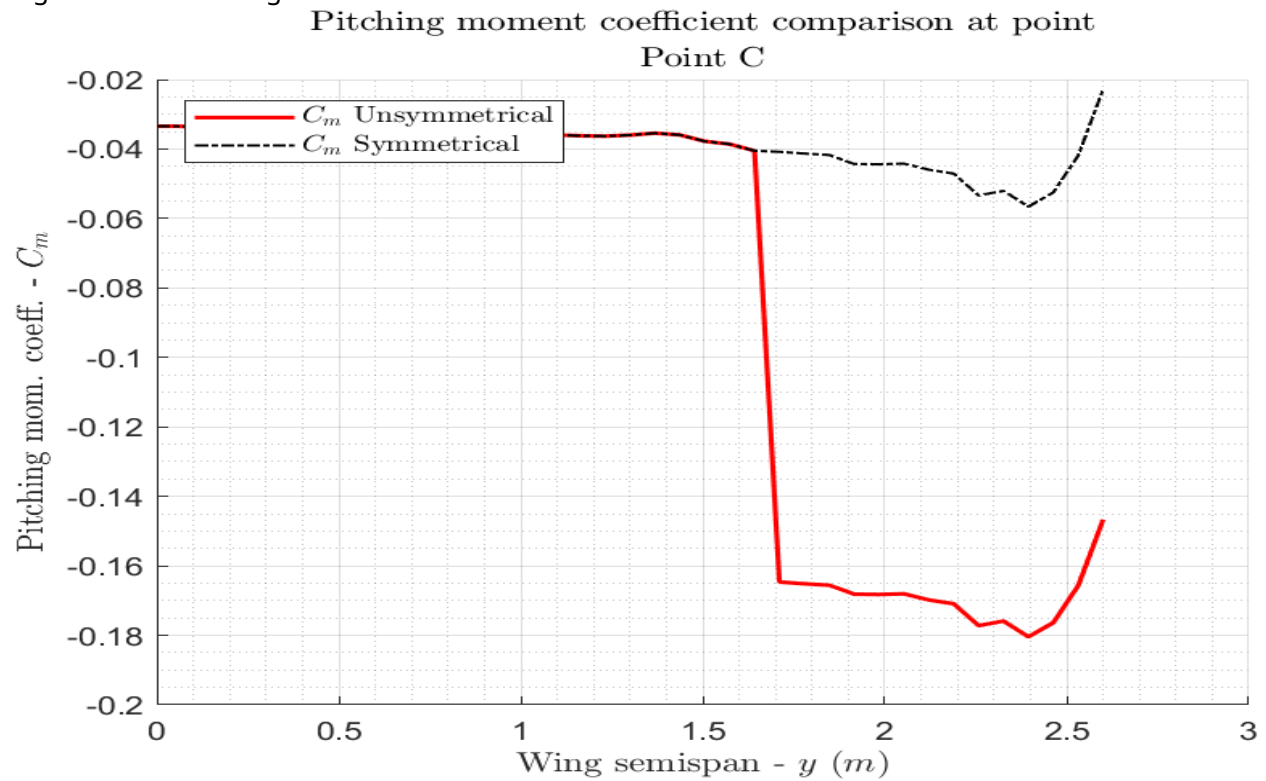


Figure 10.12. Pitching moment coefficient - POINT D

**10.3.2. Effect of aileron displacement on the wing torsion**

Unsymmetrical Torsion load due to aileron deflection at  
Point A

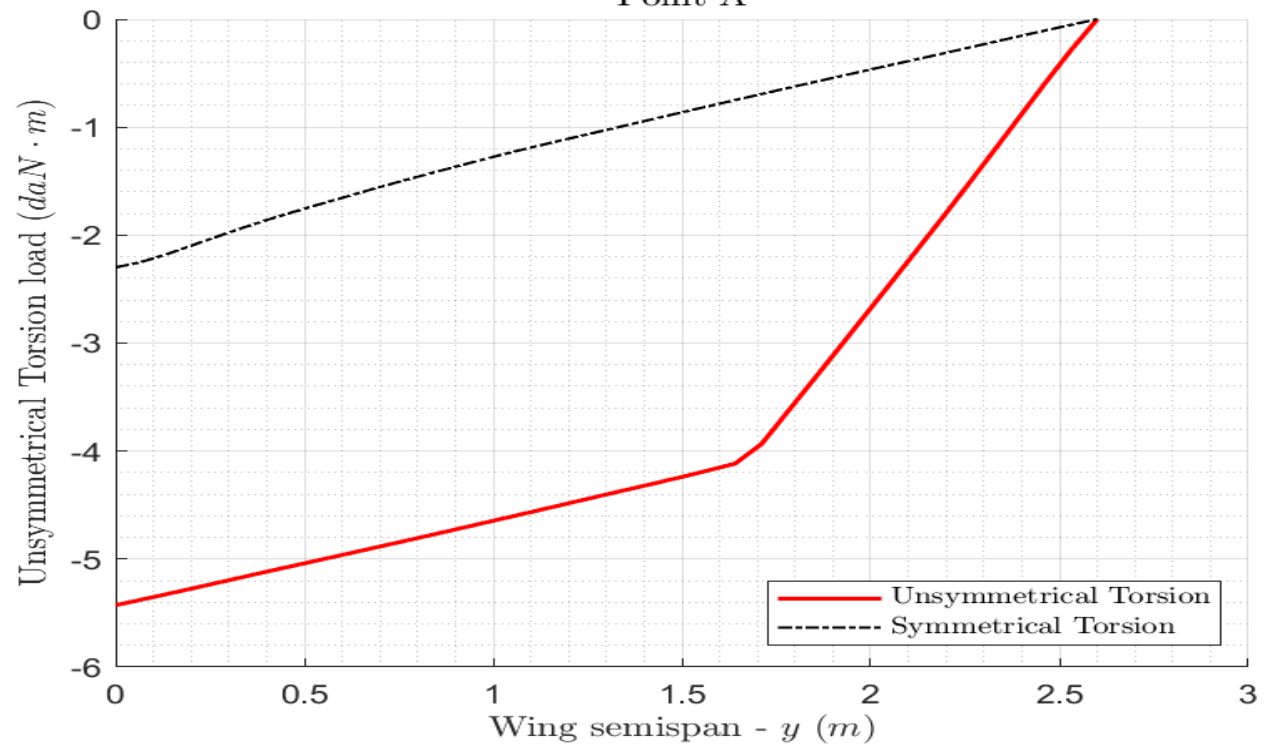


Figure 10.13. Torsion distribution full loads - POINT A

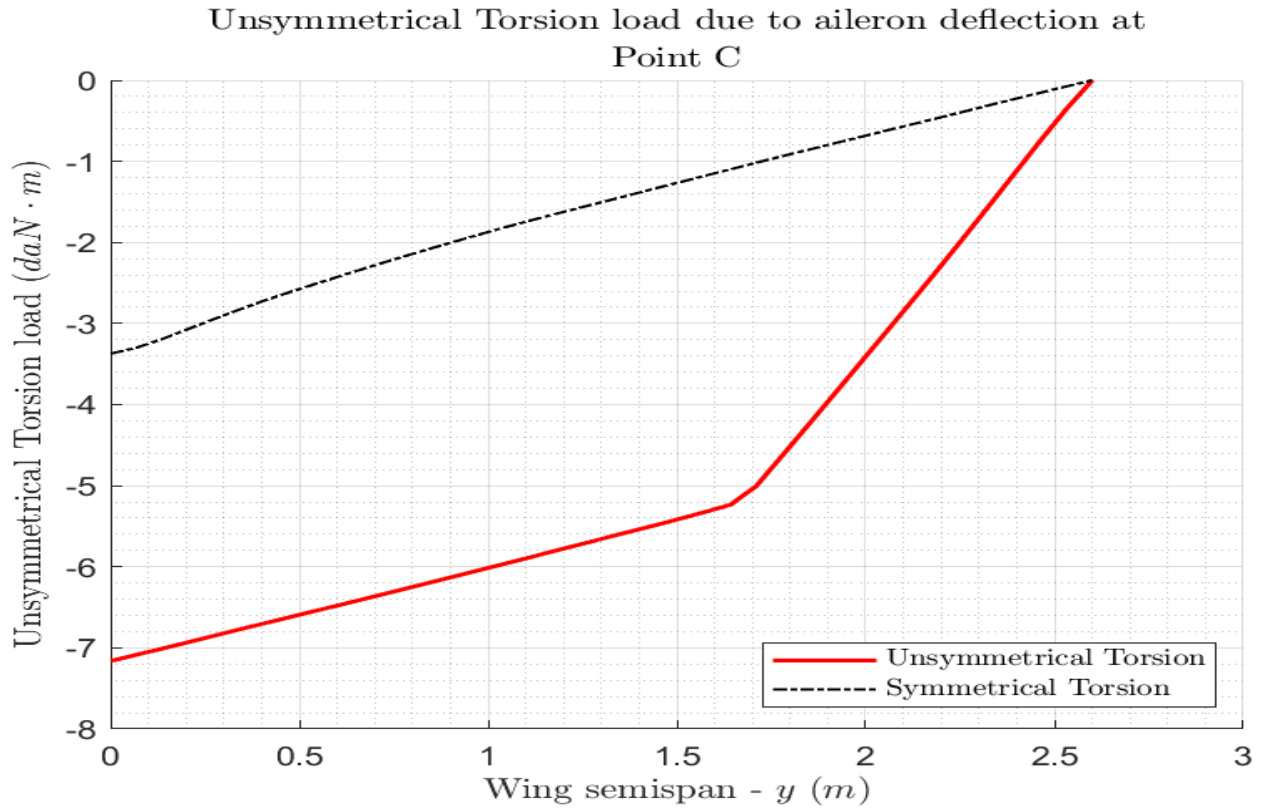


Figure 10.14. Torsion distribution full loads - POINT C

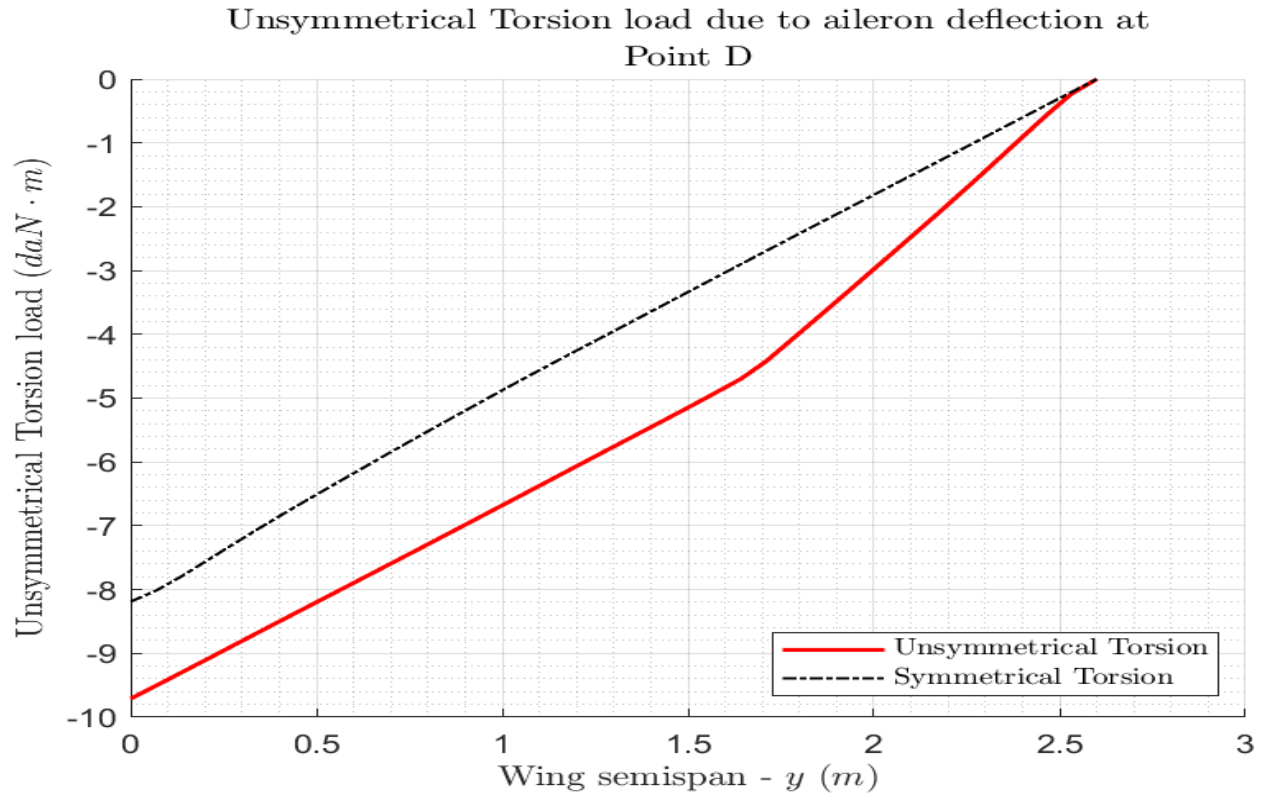


Figure 10.15. Torsion distribution full loads - POINT D

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## Chapter 11. Loads on the horizontal tail

ADD HERE details

ADD HERE details

### 11.1. Balancing loads

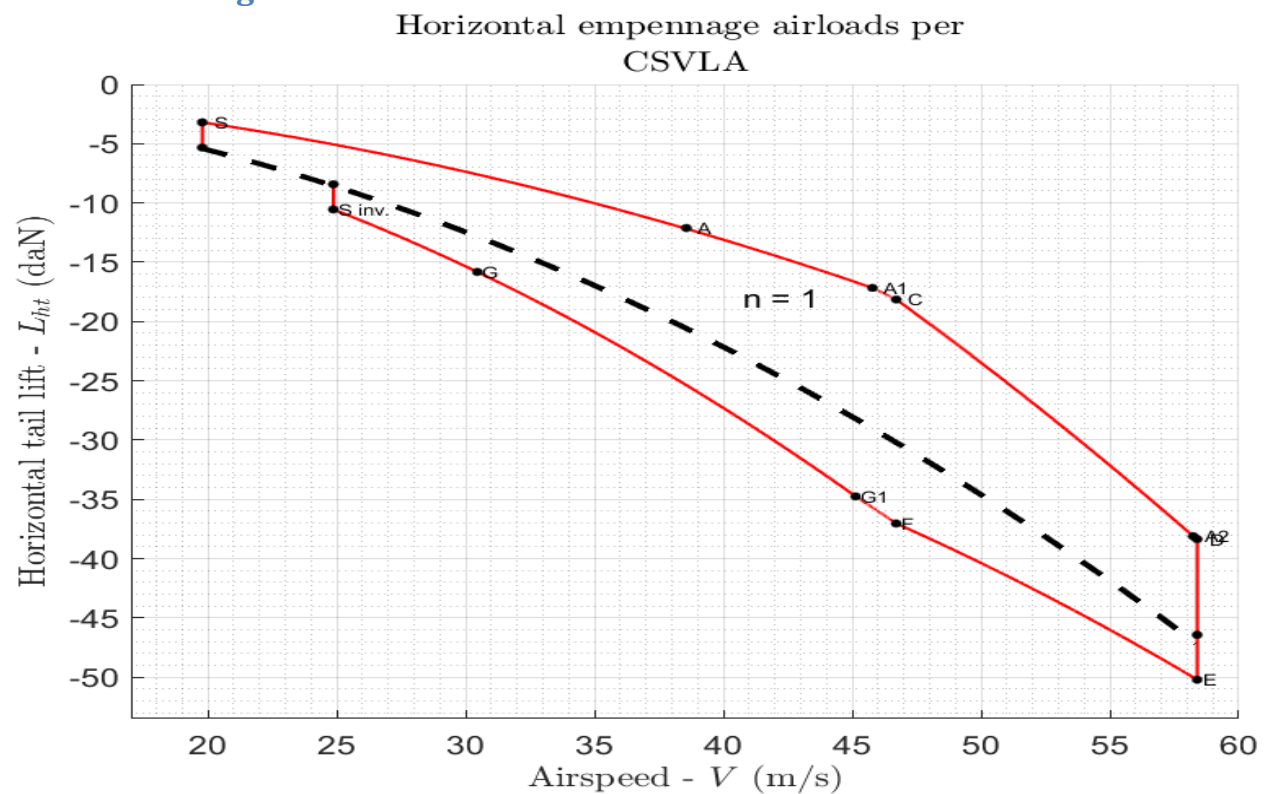


Figure 11.1. Balancing loads

ADD HERE details

### 11.2. Manoeuvring loads

#### 11.2.1. Unchecked manoeuvre

#### 11.2.2. Checked manoeuvre

#### 11.2.3. Gust loads

ADD HERE details

### 11.3. Horizontal tail loads summary

ADD HERE details

### 11.4. Unsymmetrical loads

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## **Chapter 12. Loads on the vertical tail**

ADD HERE details

ADD HERE details

### **12.1. Manoeuvring loads**

**12.1.1. a(1)**

**12.1.2. a(2)**

**12.1.3. a(3)**

**12.1.4. Gust loads**

ADD HERE details

### **12.2. Vertical tail loads summary**

ADD HERE details on h-v combined loads

### **12.3. Combined loads**

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## **Chapter 13. Loads on the wing flaps**

ADD HERE details

ADD HERE details

### **13.1. Manoeuvring and gust envelope**

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## **Chapter 14. Loads on the control surfaces**

ADD HERE details

ADD HERE details

### **14.1. Ailerons**

ADD HERE details

### **14.2. Elevator**

ADD HERE details

### **14.3. Rudder**



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## Chapter 15. Power plant

ADD HERE details

### 15.1. Engine torque

$$MT_{continuous} = P_{continuous} * \frac{1000}{\frac{2\pi * RPM_{prop}}{60}} = 9.321 * \frac{1000}{\frac{2 * 3.14 * 2388}{60}} = 39.3042 N * m$$

$$LT_{continuous} = RR_{prop} * MT_{continuous} = 2.429 * 39.3 = 78.6084 N * m$$

$$MT_{takeoff} = P_{takeoff} * \frac{1000}{\frac{2\pi * RPM_{prop}}{60}} = 11.19 * \frac{1000}{\frac{2 * 3.14 * 2388}{60}} = 44.7255 N * m$$

$$LT_{takeoff} = RR_{prop} * MT_{takeoff} = 2.429 * 44.73 = 89.4509 N * m$$

The engine takeoff power is -11.19kW at -5800RPM. The rotational speed of the propeller is -5800/2.429 =2388RPM. The maximum continuous power is -9.321kW. The mean engine torque is -44.73N \* m. Using a factor of -2 for a four cylinder engine, the limit torque will be -89.45N \* m. This limit torque acts simultaneously with the 75 % of the inertia limit load. The mean engine torque at max continuous power is -39.3N \* m. Using a factor of -2 for a four cylinder engine, the limit torque will be -78.61N \* m which acts simultaneously with the 100 % of the inertia limit load.

### 15.2. Side load on engine mount

The limit load factor in a lateral direction is 1.33. The mass of the engine group is 24.4kg. The side load results is  $1.33 * 24.4 * 9.807 * (1/10) = 31.82 \text{ daN}$

### 15.3. Inertia load on engine mount

The inertia load is equal to the maximum limit load factor times the engine group weight:  $5.357 * 24.4 * 9.807 * (1/10) = 170.5 \text{ daN}$

ADD HERE details

### 15.4. Gyroscopic loads