# Cessna 172
# Computations Results
# and Simulation Data

Zielonka 2019

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Revision: 3

Date: 2019-08-25

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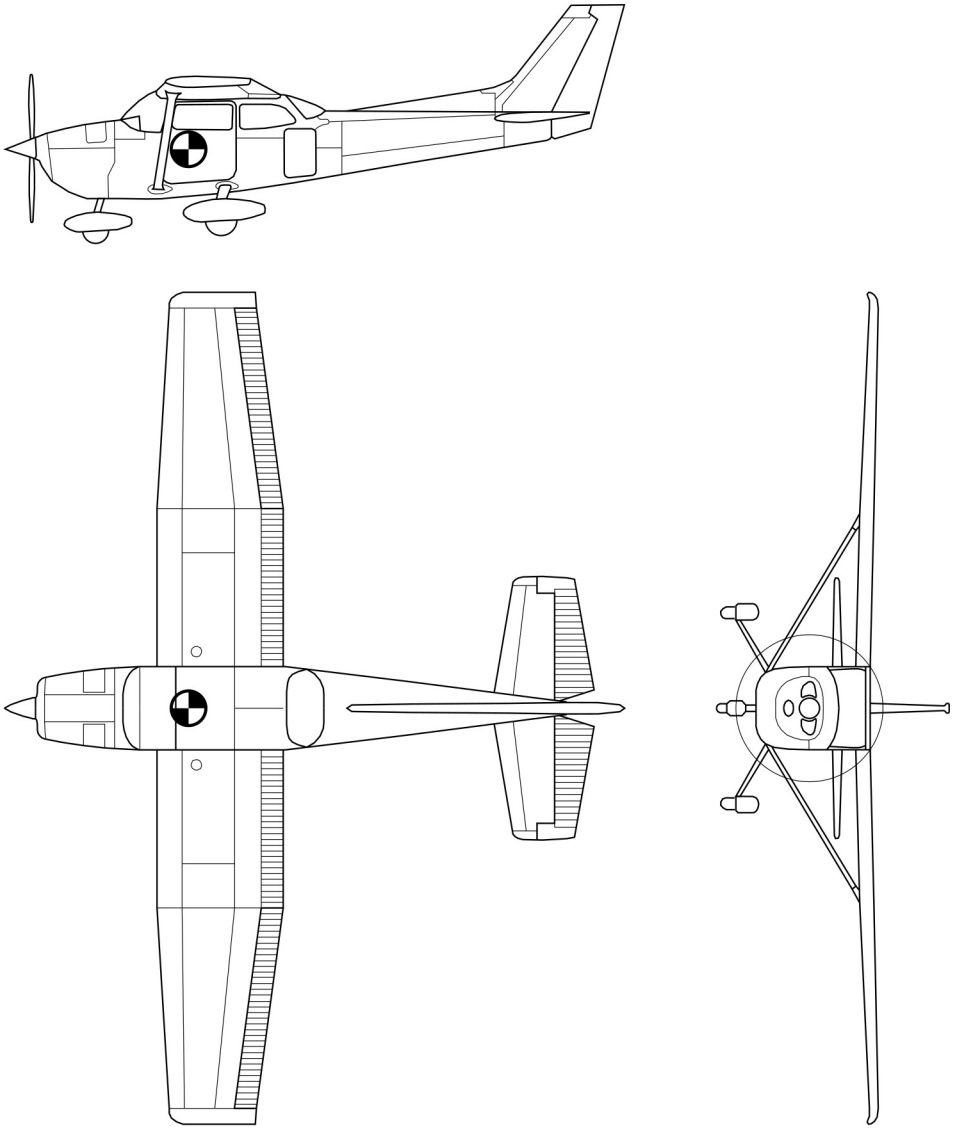

0 1 2 3 4 5 m

# 1. General Data

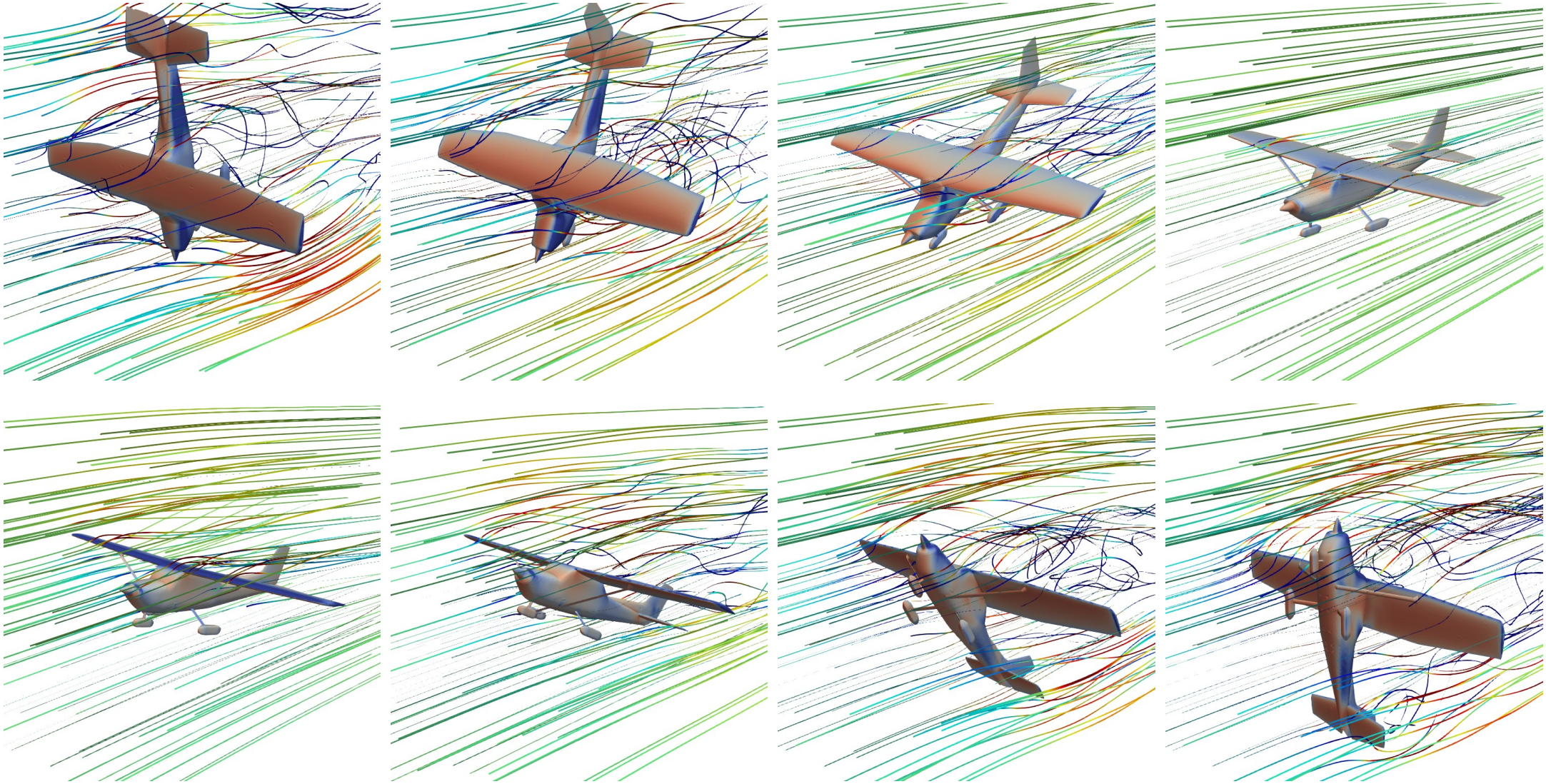
| Parameter | Value | Reference |
|---|---|---|
| Length | 8.28 m | [1, 2] |
| Wingspan | 11.00 m | [1, 2] |
| Height | 2.72 m | [1, 2] |
| Wheelbase | 1.63 m | [2] |
| Wheel track | 2.53 m | [2] |
| Wing area | 16.17 $m^2$ | [1, 2] |
| Mean aerodynamic chord | 1.49 m | [1] |
| Wing airfoil | NACA 2412 | [2] |
| Horizontal tail area | 2.00 $m^2$ | [2] |
| Horizontal tail airfoil at root (Cessna 177) | NACA 0012 | [3] |
| Horizontal tail airfoil at tip (Cessna 177) | NACA 0009 | [3] |
| Vertical tail area | 1.04 $m^2$ | [2] |
| Vertical tail airfoil at root | NACA 0009 | [4] |
| Vertical tail airfoil at tip | NACA 0006 | [4] |
| Ailerons deflection limit | up 20°, down 15° | [5] |
| Ailerons area (total) | 1.70 $m^2$ | [2] |
| Elevator deflection limit | up 28°, down 23° | [5] |
| Elevator area (including trim tab) | 1.35 $m^2$ | [2] |
| Elevator trim tab deflection limit | up 22°, down 19° | [5] |
| Rudder deflection limit | ±17.7° | [5] |
| Flaps area | 1.98 $m^2$ | [2] |
| Flaps deflection limit | 30° | [5] |
| Standard empty weight | 754 kg | [1] |
| Maximum takeoff weight (normal) | 1 157 kg | [1] |
| Maximum takeoff weight (utility) | 998 kg | [1] |
| Total fuel tanks capacity | 212 l | [1, 5] |
| Maximum weight in baggage compartments | 54 kg | [1, 5] |
| Stall speed (for weight 1,157 kg, 0° flaps) | 27.3 m/s (53 kts) | [1] |
| Cruise speed (at 75% power, at FL80) | 63.8 m/s (124 kts) | [1] |
| Maximum level speed at Sea Level | 63.3 m/s (123 kts) | [2] |

| Parameter | Value | Reference |
|---|---|---|
| Maximum rate of climb at Sea Level | 219 m/min | [2] |
| Service ceiling | 4 100 m | [2] |
| Take-off run | 288 m | [2] |
| Take-off to 15 m | 514 m | [2] |
| Landing from 15 m | 395 m | [2] |
| Landing run | 168 m | [2] |
| Range with max fuel (45 min reserves, at 80% power, at FL80) | 1 074 km | [2] |
| Range with max fuel (45 min reserves, at 60% power, at FL100) | 1 272 km | [2] |
| Endurance | 6 h 36 min | [2] |
| Downwash angle derivative with respect to the aircraft angle of attack | 0.25 | [6] |
| Engine manufacturer | Textron Lycoming | [1] |
| Engine model | IO-360-L2A | [1] |
| Engine rated horsepower (at 2,700 RPM) | 134.2 kW | [1, 7] |
| Engine height | 0.631 m | [7] |
| Engine width | 0.848 m | [7] |
| Engine length | 0.757 m | [7] |
| Engine standard dry weight | 126.1 kg | [7] |
| Fuel consumption at 2,200 RPM | 253.4 g/(kW·h) | [7] |
| Propeller manufacturer | McCauley | [1] |
| Propeller model | 1A170E/JHA7660 | [1] |
| Number of blades | 2 | [1] |
| Propeller diameter | 1.93 m | [1] |

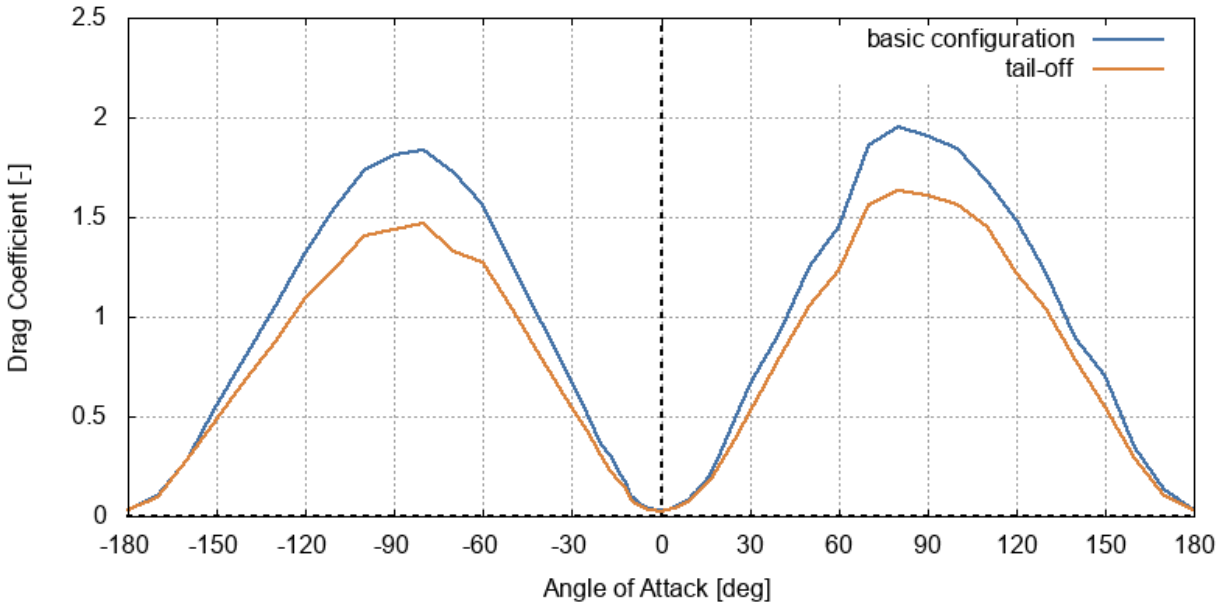
# 2. Aerodynamic Characteristics

OpenFOAM `simpleFoam` a steady-state solver for incompressible, turbulent flow was used to compute aircraft aerodynamic characteristics for the full range of angle of attack and various aircraft configurations.

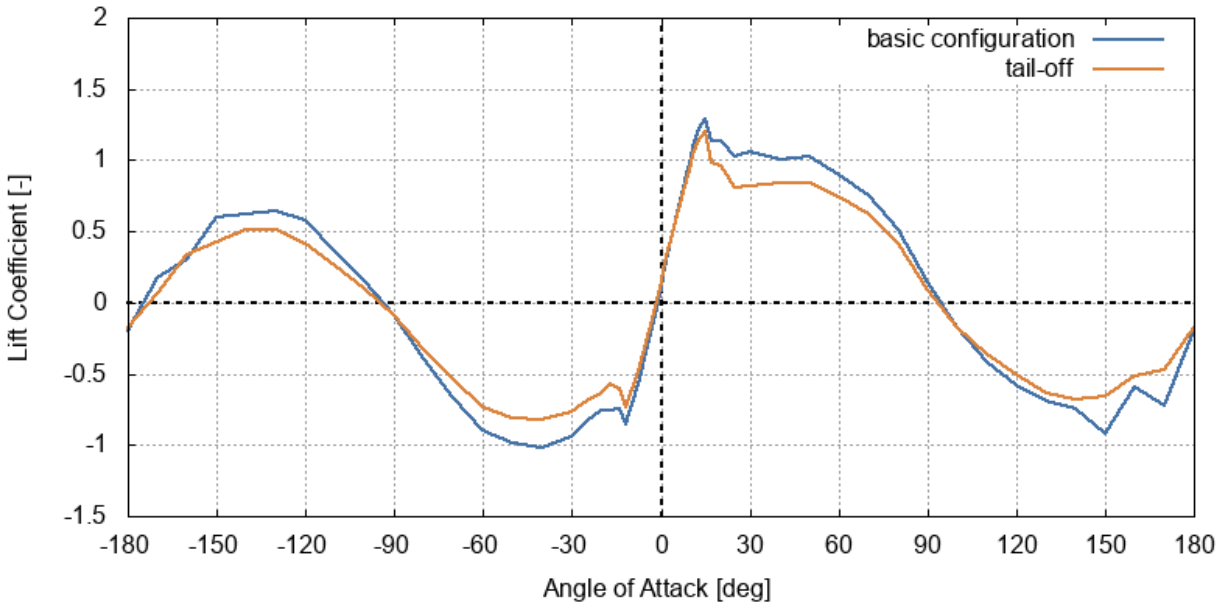
Results of basic and tail-off configurations are shown in the following figures.



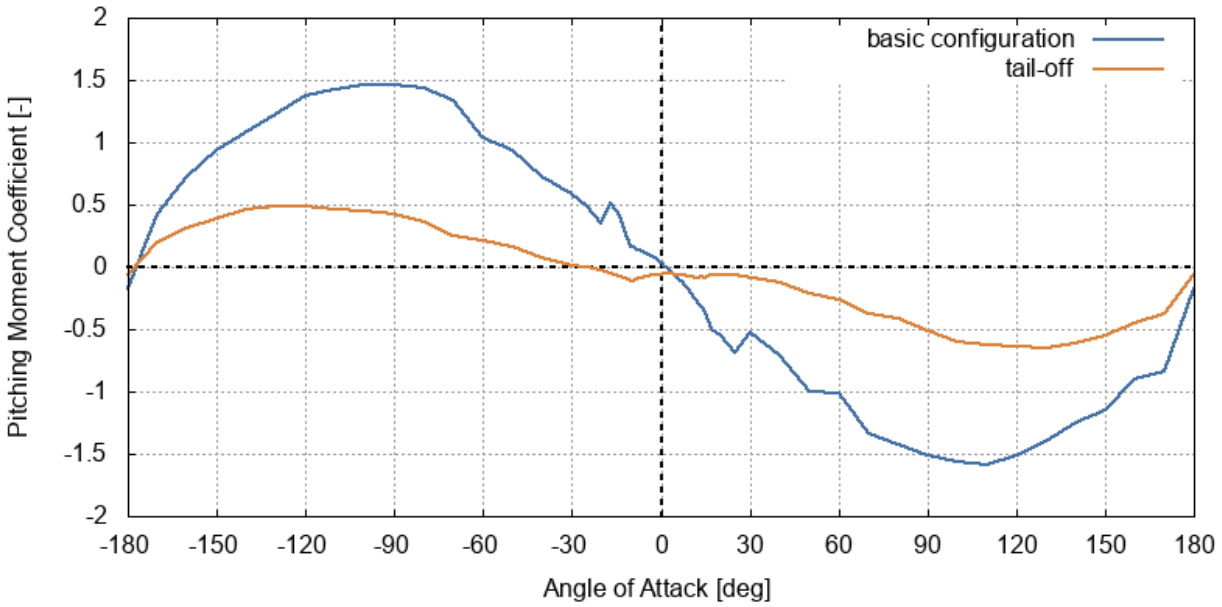
*Streamlines and kinematic pressure distribution for various angles of attack*




*Drag coefficient*

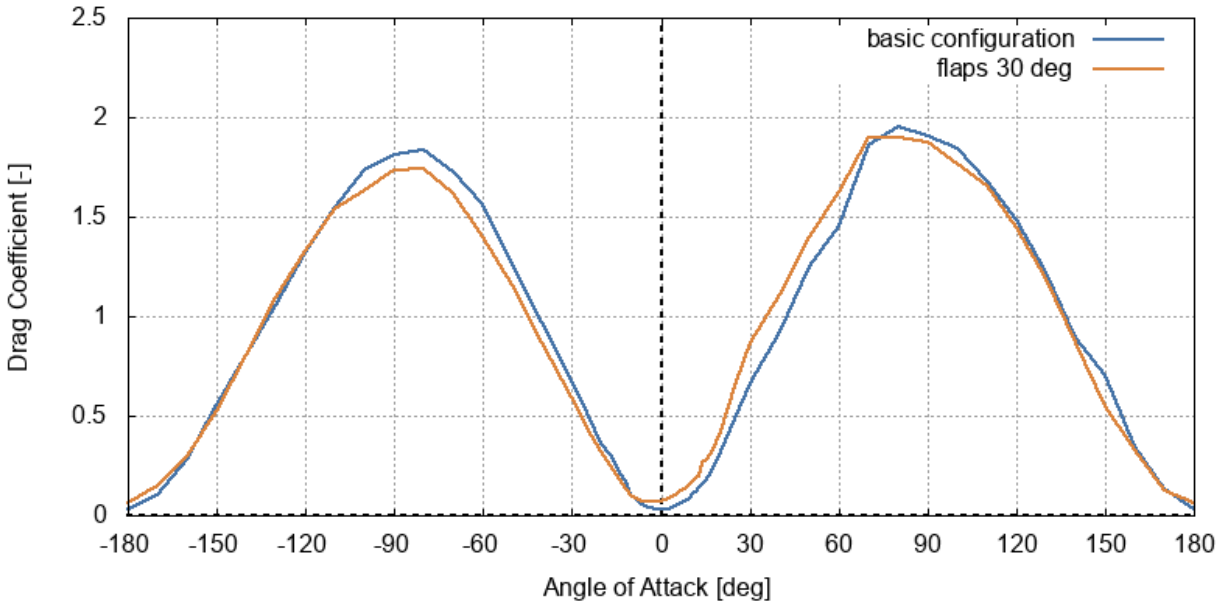



*Lift coefficient*

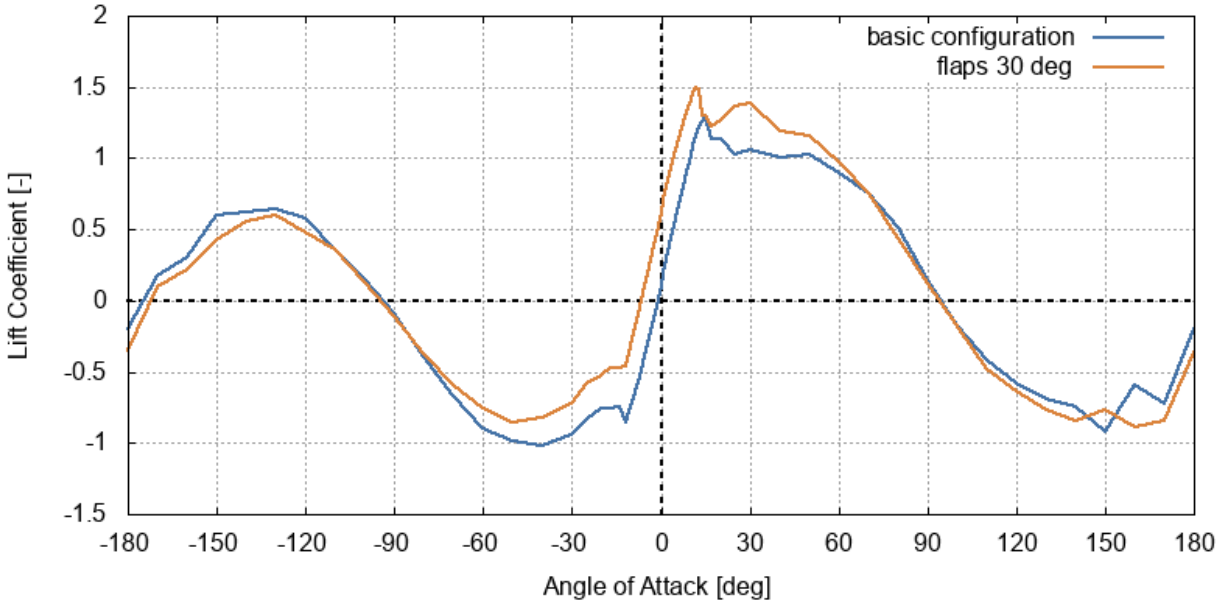



*Pitching moment coefficient*

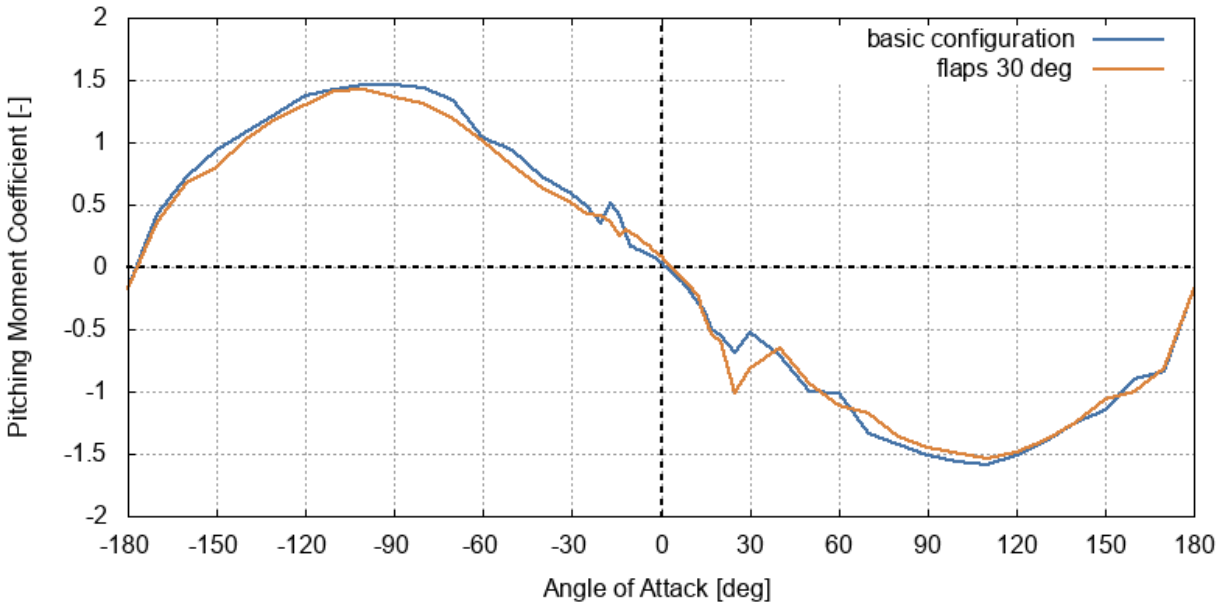
Results for basic and landing configurations (30-degree flaps deflection) are shown in the following figures.




*Drag coefficient*

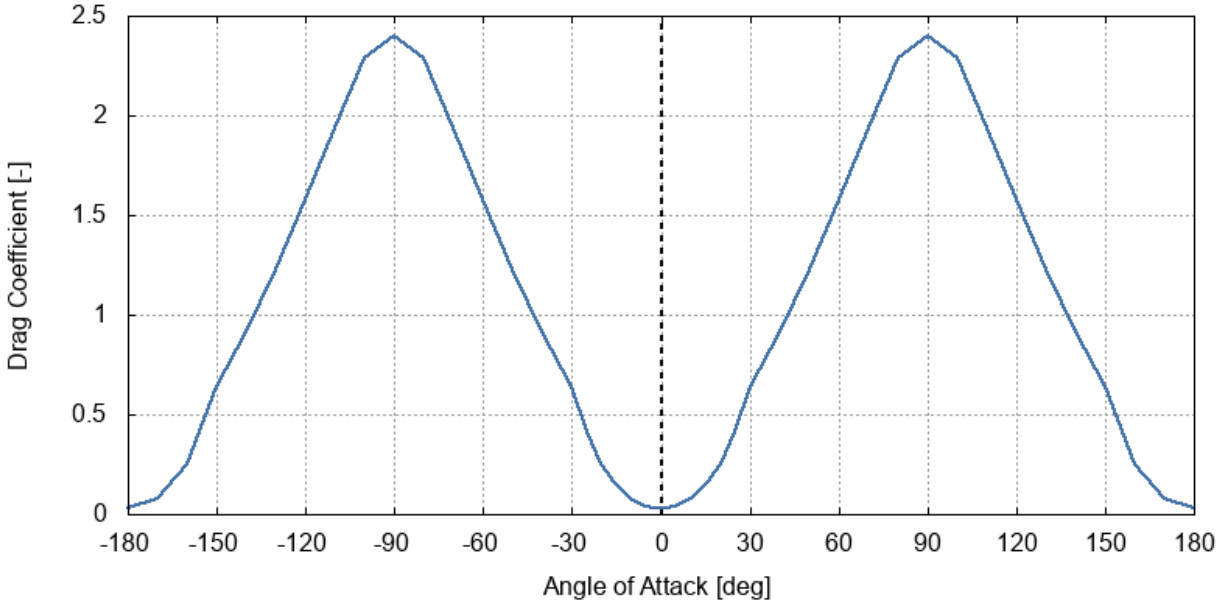



*Lift coefficient*

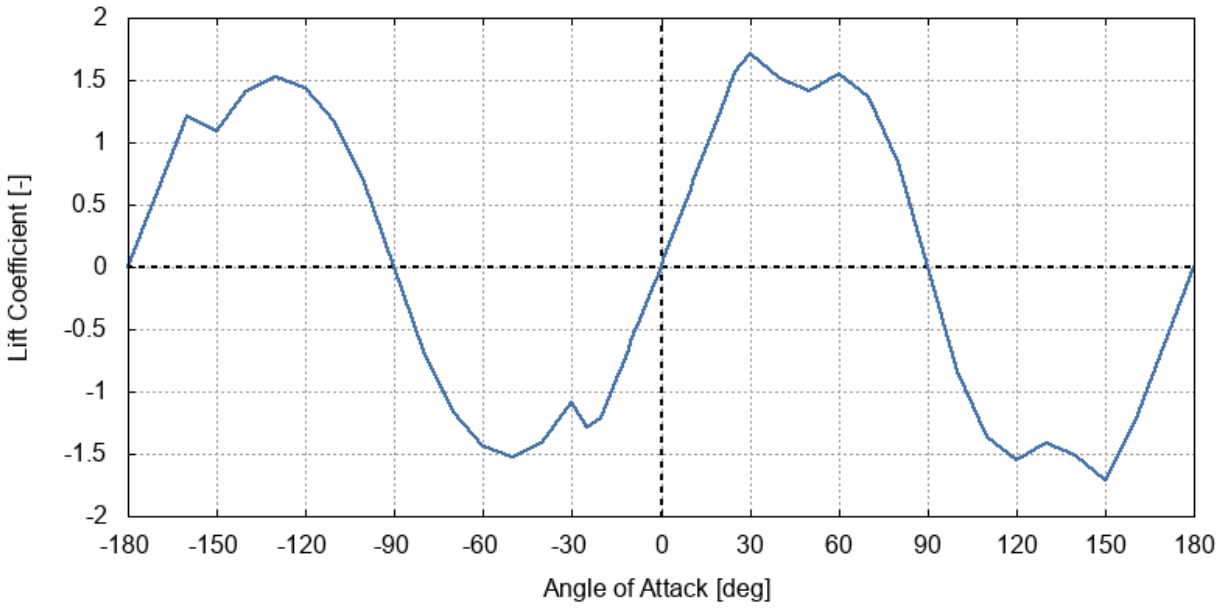



*Pitching moment coefficient*

Horizontal tail aerodynamic characteristics are shown in the following figures.

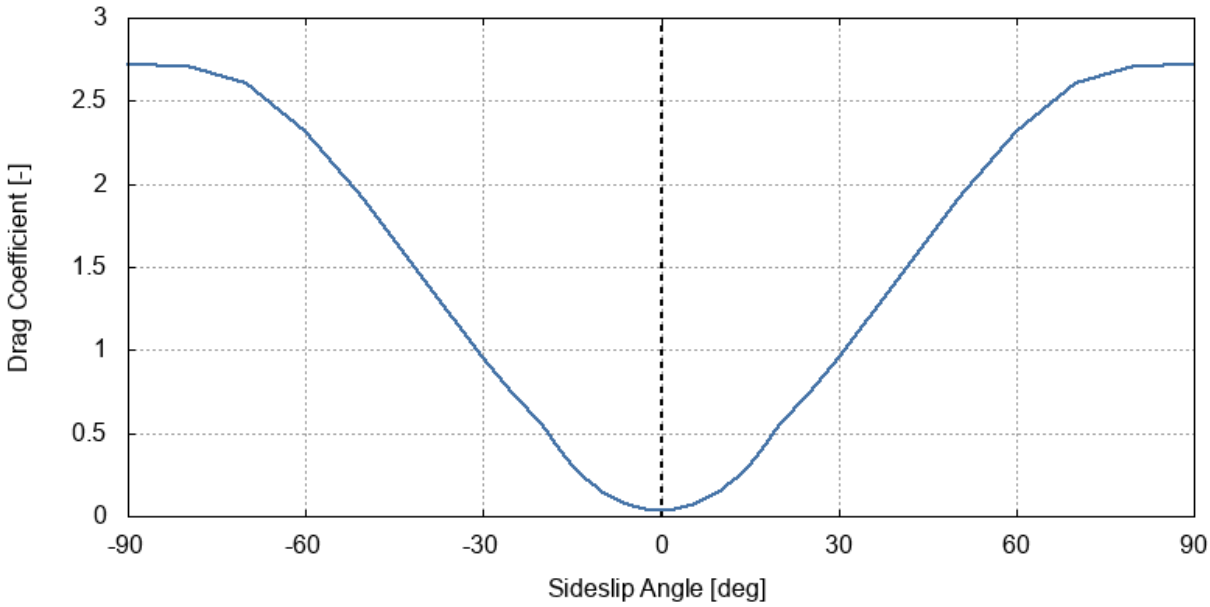



*Horizontal tail drag coefficient*

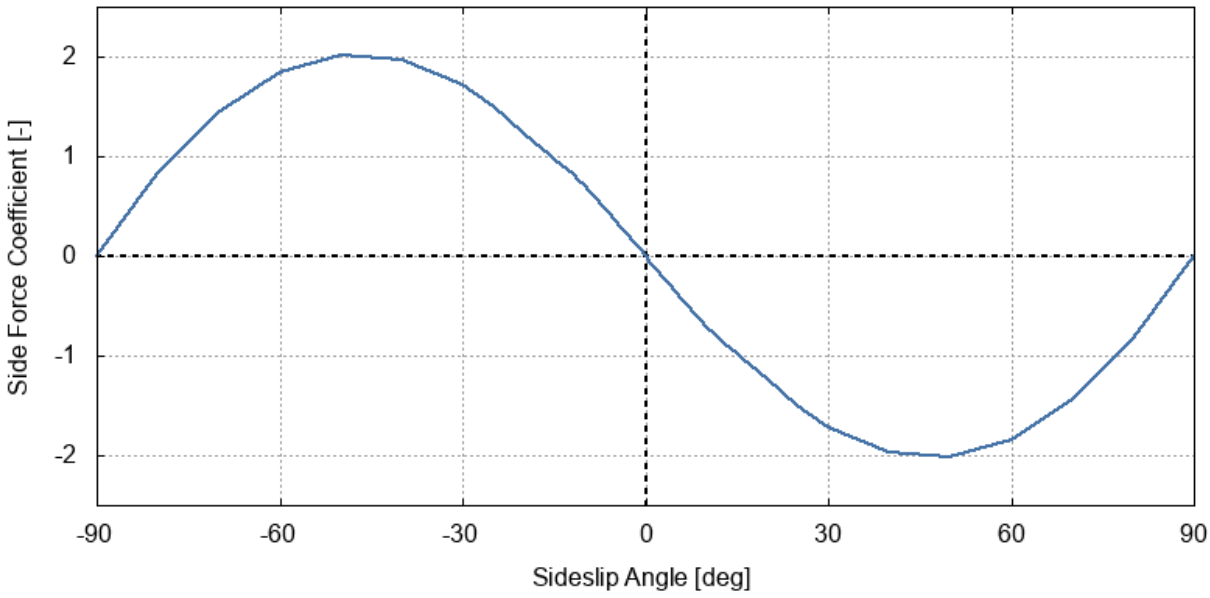



*Horizontal tail lift coefficient*

Vertical tail aerodynamic characteristics are shown in the following figures.




*Vertical tail drag coefficient*




*Vertical tail side force coefficient*

| α [deg] | Cx [-] | Cz [-] | Cm [-] |
|---|---|---|---|
| -180.0 | -0.1778 | 0.0338 | -0.2003 |
| -170.0 | 0.4214 | 0.1030 | 0.1698 |
| -160.0 | 0.7273 | 0.2816 | 0.3023 |
| -150.0 | 0.9408 | 0.5539 | 0.6037 |
| -130.0 | 1.2311 | 1.0571 | 0.6426 |
| -120.0 | 1.3786 | 1.3222 | 0.5786 |
| -110.0 | 1.4243 | 1.5438 | 0.3609 |
| -100.0 | 1.4615 | 1.7340 | 0.1532 |
| -90.0 | 1.4643 | 1.8145 | -0.0913 |
| -80.0 | 1.4349 | 1.8377 | -0.3946 |
| -70.0 | 1.3377 | 1.7304 | -0.6656 |
| -60.0 | 1.0434 | 1.5605 | -0.8998 |
| -50.0 | 0.9365 | 1.2568 | -0.9829 |
| -40.0 | 0.7292 | 0.9692 | -1.0146 |
| -30.0 | 0.5856 | 0.6722 | -0.9432 |
| -25.0 | 0.4891 | 0.5140 | -0.8370 |
| -20.0 | 0.3465 | 0.3618 | -0.7529 |
| -17.0 | 0.5161 | 0.3047 | -0.7588 |
| -14.0 | 0.4126 | 0.2144 | -0.7404 |
| -12.0 | 0.2684 | 0.1722 | -0.8554 |
| -10.0 | 0.1682 | 0.1034 | -0.7501 |
| -9.0 | 0.1571 | 0.0906 | -0.6842 |
| -8.0 | 0.1421 | 0.0783 | -0.6075 |
| -7.0 | 0.1347 | 0.0651 | -0.5321 |
| -6.0 | 0.1199 | 0.0568 | -0.4424 |
| -5.0 | 0.1090 | 0.0489 | -0.3557 |
| -4.0 | 0.0992 | 0.0418 | -0.2679 |
| -3.0 | 0.0830 | 0.0372 | -0.1789 |
| -2.0 | 0.0691 | 0.0336 | -0.0889 |
| -1.0 | 0.0513 | 0.0314 | 0.0049 |
| 0.0 | 0.0315 | 0.0306 | 0.0998 |
| 1.0 | 0.0126 | 0.0311 | 0.1944 |
| 2.0 | -0.0026 | 0.0329 | 0.2898 |

| α [deg] | Cx [-] | Cz [-] | Cm [-] |
|---|---|---|---|
| 3.0 | -0.0282 | 0.0349 | 0.3881 |
| 4.0 | -0.0551 | 0.0398 | 0.4839 |
| 5.0 | -0.0741 | 0.0449 | 0.5799 |
| 6.0 | -0.0982 | 0.0521 | 0.6679 |
| 7.0 | -0.1174 | 0.0607 | 0.7532 |
| 8.0 | -0.1509 | 0.0694 | 0.8487 |
| 9.0 | -0.1773 | 0.0807 | 0.9357 |
| 10.0 | -0.2064 | 0.0925 | 1.0151 |
| 11.0 | -0.2390 | 0.1063 | 1.0895 |
| 12.0 | -0.2639 | 0.1206 | 1.1607 |
| 13.0 | -0.2971 | 0.1369 | 1.2240 |
| 14.0 | -0.3254 | 0.1525 | 1.2558 |
| 15.0 | -0.3631 | 0.1726 | 1.2930 |
| 17.0 | -0.5042 | 0.2169 | 1.1411 |
| 20.0 | -0.5533 | 0.3184 | 1.1328 |
| 25.0 | -0.6826 | 0.4824 | 1.0309 |
| 40.0 | -0.7076 | 0.9254 | 1.0062 |
| 50.0 | -0.9984 | 1.2527 | 1.0285 |
| 60.0 | -1.0141 | 1.4544 | 0.8901 |
| 70.0 | -1.3370 | 1.8579 | 0.7527 |
| 80.0 | -1.4293 | 1.9547 | 0.5114 |
| 90.0 | -1.5130 | 1.9055 | 0.1421 |
| 100.0 | -1.5670 | 1.8449 | -0.1712 |
| 110.0 | -1.5886 | 1.6785 | -0.4155 |
| 120.0 | -1.5085 | 1.4831 | -0.5821 |
| 130.0 | -1.3977 | 1.2191 | -0.6926 |
| 140.0 | -1.2469 | 0.8872 | -0.7399 |
| 150.0 | -1.1508 | 0.7052 | -0.9188 |
| 160.0 | -0.8942 | 0.3447 | -0.5876 |
| 170.0 | -0.8425 | 0.1365 | -0.7211 |
| 180.0 | -0.1756 | 0.0339 | -0.1950 |

*Table 2-1: Cessna 172 basic configuration aerodynamic characteristics*

| α [deg] | Cx [-] | Cz [-] | Cm [-] |
|---|---|---|---|
| -180.0 | 0.0298 | -0.1710 | -0.0570 |
| -170.0 | 0.0967 | 0.0630 | 0.2040 |
| -160.0 | 0.2776 | 0.3320 | 0.3080 |
| -140.0 | 0.6842 | 0.5100 | 0.4580 |
| -130.0 | 0.8782 | 0.5090 | 0.4850 |
| -120.0 | 1.0930 | 0.4170 | 0.4880 |
| -110.0 | 1.2410 | 0.2640 | 0.4620 |
| -100.0 | 1.4079 | 0.1010 | 0.4480 |
| -90.0 | 1.4391 | -0.0870 | 0.4240 |
| -80.0 | 1.4722 | -0.3260 | 0.3560 |
| -70.0 | 1.3311 | -0.5330 | 0.2440 |
| -60.0 | 1.2737 | -0.7370 | 0.2170 |
| -50.0 | 1.0418 | -0.8160 | 0.1610 |
| -40.0 | 0.7928 | -0.8270 | 0.0740 |
| -30.0 | 0.5500 | -0.7710 | 0.0110 |
| -25.0 | 0.4280 | -0.6900 | -0.0030 |
| -20.0 | 0.3060 | -0.6330 | -0.0240 |
| -17.0 | 0.2303 | -0.5750 | -0.0560 |
| -14.0 | 0.1721 | -0.6010 | -0.0690 |
| -12.0 | 0.1383 | -0.7340 | -0.0840 |
| -10.0 | 0.0835 | -0.6390 | -0.1170 |
| -9.0 | 0.0718 | -0.5840 | -0.1090 |
| -8.0 | 0.0631 | -0.5170 | -0.0990 |
| -7.0 | 0.0520 | -0.4450 | -0.0920 |
| -6.0 | 0.0452 | -0.3640 | -0.0860 |
| -5.0 | 0.0391 | -0.2830 | -0.0790 |
| -4.0 | 0.0341 | -0.2000 | -0.0750 |
| -3.0 | 0.0299 | -0.1190 | -0.0680 |
| -2.0 | 0.0274 | -0.0360 | -0.0630 |
| -1.0 | 0.0260 | 0.0500 | -0.0600 |
| 0.0 | 0.0268 | 0.1370 | -0.0580 |
| 1.0 | 0.0267 | 0.2240 | -0.0550 |
| 2.0 | 0.0291 | 0.3130 | -0.0550 |

| α [deg] | Cx [-] | Cz [-] | Cm [-] |
|---|---|---|---|
| 3.0 | 0.0319 | 0.4010 | -0.0550 |
| 4.0 | 0.0366 | 0.4850 | -0.0560 |
| 5.0 | 0.0417 | 0.5760 | -0.0580 |
| 6.0 | 0.0486 | 0.6540 | -0.0590 |
| 7.0 | 0.0562 | 0.7350 | -0.0620 |
| 8.0 | 0.0644 | 0.8200 | -0.0660 |
| 9.0 | 0.0740 | 0.8980 | -0.0700 |
| 10.0 | 0.0851 | 0.9680 | -0.0740 |
| 11.0 | 0.0969 | 1.0320 | -0.0760 |
| 12.0 | 0.1097 | 1.0960 | -0.0820 |
| 13.0 | 0.1235 | 1.1500 | -0.0840 |
| 14.0 | 0.1368 | 1.1660 | -0.0790 |
| 15.0 | 0.1545 | 1.1960 | -0.0850 |
| 17.0 | 0.1863 | 0.9820 | -0.0570 |
| 20.0 | 0.2641 | 0.9600 | -0.0650 |
| 25.0 | 0.3856 | 0.8130 | -0.0610 |
| 40.0 | 0.7971 | 0.8380 | -0.1300 |
| 50.0 | 1.0567 | 0.8370 | -0.2130 |
| 60.0 | 1.2355 | 0.7410 | -0.2630 |
| 70.0 | 1.5629 | 0.6210 | -0.3740 |
| 80.0 | 1.6306 | 0.4160 | -0.4100 |
| 90.0 | 1.6088 | 0.0850 | -0.5150 |
| 100.0 | 1.5656 | -0.1780 | -0.6040 |
| 110.0 | 1.4494 | -0.3640 | -0.6300 |
| 120.0 | 1.2192 | -0.5000 | -0.6320 |
| 130.0 | 1.0382 | -0.6320 | -0.6440 |
| 140.0 | 0.7815 | -0.6770 | -0.6090 |
| 150.0 | 0.5442 | -0.6570 | -0.5460 |
| 160.0 | 0.2884 | -0.5130 | -0.4510 |
| 170.0 | 0.0986 | -0.4690 | -0.3780 |
| 180.0 | 0.0299 | -0.1720 | -0.0570 |

*Table 2-2: Cessna 172 tail-off aerodynamic characteristics*

# 3. Mass Data

Data given in [3], data from chapter 1. and coordinates of structure groups estimated using aircraft drawing were used to calculate empty aircraft inertia tensor and center of mass coordinates. Results are given in the following table.

| **Parameter** | **Value** |
|---|---|
| Center of mass x-coordinate | -0.20 m |
| Center of mass y-coordinate | 0.00 m |
| Center of mass z-coordinate | -0.10 m |
| Moment of inertia $I_x$ | 2 424.2 kg·m$^2$ |
| Moment of inertia $I_y$ | 2 427.3 kg·m$^2$ |
| Moment of inertia $I_z$ | 4 372.5 kg·m$^2$ |
| Cross product of inertia $I_{xy}$ | 0.0 kg·m$^2$ |
| Cross product of inertia $I_{xz}$ | -161.5 kg·m$^2$ |
| Cross product of inertia $I_{yz}$ | 0.0 kg·m$^2$ |

*Cessna 172 empty aircraft inertia tensor and center of mass coordinates*

| **Structure group** | **Weight [kg]** | **Coordinates [m]** | | | **First moment of mass [kg·m]** | | | **Moment of inertia [kg·m$^2$]** | | | **Moment of inertia (Body Axis System) [kg·m$^2$]** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $x$ | $y$ | $z$ | $S_X$ | $S_Y$ | $S_Z$ | $I_{x,0}$ | $I_{y,0}$ | $I_{z,0}$ | $I_x$ | $I_y$ | $I_z$ | $I_{xy}$ | $I_{xz}$ | $I_{yz}$ |
| Wing | 201.9 | -0.10 | 0.00 | -0.73 | -20.2 | 0.0 | -147.4 | 2 037.2 | 38.9 | 2 073.0 | 2 144.8 | 148.5 | 2 075.1 | 0.0 | -14.7 | 0.0 |
| Tail | 52.2 | -4.70 | 0.00 | -0.34 | -245.3 | 0.0 | -17.7 | 53.3 | 10.4 | 58.1 | 59.4 | 1 169.1 | 1 210.9 | 0.0 | -83.4 | 0.0 |
| Fuselage | 216.4 | -0.70 | 0.00 | -0.13 | -151.5 | 0.0 | -28.1 | 39.4 | 473.6 | 474.8 | 43.1 | 583.3 | 580.8 | 0.0 | -19.7 | 0.0 |
| Landing gear | 104.4 | 0.10 | 0.00 | 0.90 | 10.4 | 0.0 | 93.9 | 69.9 | 39.9 | 102.4 | 154.5 | 125.4 | 103.5 | 0.0 | -9.4 | 0.0 |
| Surface controls | 26.5 | 0.60 | 0.00 | 0.06 | 15.9 | 0.0 | 1.6 | 3.1 | 2.4 | 3.7 | 3.2 | 12.1 | 13.2 | 0.0 | -1.0 | 0.0 |
| Nacelle | 26.5 | 1.60 | 0.00 | 0.14 | 42.4 | 0.0 | 3.7 | 4.6 | 4.8 | 4.6 | 5.1 | 73.2 | 72.5 | 0.0 | -5.9 | 0.0 |
| Engine | 126.1 | 1.55 | 0.00 | 0.14 | 195.5 | 0.0 | 17.7 | 11.7 | 10.2 | 13.6 | 14.2 | 315.6 | 316.5 | 0.0 | -27.4 | 0.0 |

*Cessna 172 structure groups breakdown*

# Bibliography

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[4] Belsterling C.: Design and Test of the 172K Fluidic Rudder. National Aeronautics and Space Administration, CR-158974, 1978

[5] Type-Certificate Data Sheet for Cessna 172 Series (Skyhawk). European Aviation Safety Agency, EASA.IM.A.051, 2018

[6] Roesch P., Harlan R.: A Passive Gust Alleviation System for a Light Aircraft. National Aeronautics and Space Administration, CR-2605, 1975

[7] Operator's Manual Textron Lycoming Aircraft Engines Series O-360, HO-360, IO-360, AIO-360, HIO-360 & TIO-360. Textron Lycoming, 2005