Structures assignment AE3212 SVV 2019

The aileron of an aircraft is located close to the tip of the wing as indicated in Figure 1. Correct operation of the aileron is critical to flight safety. A critical loading scenario ensues when the aileron is at maximum upward deflection: the aerodynamic loading on the wing is at its limit load and one of the two actuators of the aileron is jammed. Under these conditions, the aileron will be subjected to torsion, bending and shear.

The cross-section of the aileron under consideration consists of a semi-circular leading edge, a spar and a triangular trailing edge (see Figure 2). The aileron is symmetric about the z-axis. Stiffeners are uniformly distributed along the circumference of the aileron and run over its full length. Regarding the material, the aileron is made out of aluminium 2024-T3.

The aileron is hinged at three points as shown in Figure 3. The hinges are numbered 1 to 3. In the middle, two actuators are attached to the aileron, numbered I and II. The aileron has four ribs, A, B, C and D.

The aileron is placed in a test fixture to simulate the critical loading condition described earlier. In the test fixture, the middle hinge point is kept fixed. The two other hinge points are subjected to a vertical displacement that corresponds with the bending displacement of the wing under limit load (Figure 4).

Actuator I is kept fixed in the z-direction. A force P acts on actuator II in the negative z-direction. At a quarter of its chord length, the aileron is loaded by a uniformly distributed load acting in the negative y-direction. This load represents the net aerodynamic force on the aileron. Furthermore, the aileron is loaded in its maximum upward deflected position (see Figure 5).

As a group of stress engineers, you will create a preliminary numerical structural analysis tool to compute the maximum deflection of the leading and trailing edges of the aileron as well as the maximum shear flow in the ribs that introduce the loads from the hinges and the actuators into the aileron.

During the analysis, the following assumptions hold:

- The aileron can be modelled as a beam.
- Net aerodynamic load as a uniformly distributed load *q*.
- Reaction loads at the hinges and actuators can be modelled as point loads.
- The hinges only restrict translations but allow rotations.
- Attachments of the stiffeners to the skin of the aileron do not have to be analysed.

Load case

- Hinge 1 is fixed in the z-direction and displaced in the y-direction by a predefined amount.
- Hinge 2 is fixed in the x, y and z-directions.
- Hinges 3 is fixed in the z-direction and displaced in the y-direction by a predefined amount.
- Actuator I is kept fixed in the z-direction.
- **Discrete load P** acts in negative the z-direction at actuator II.
- **Distributed load *q*** due to aerodynamic forces on aileron, points in the negative y-direction and remains constant irrespective of any aileron deformation.
- **No other than the aforementioned loads are acting on the aileron.**

Reference aircraft

Boeing 737

Boeing 737

Data Boeing 737 (Refer to the drawings)

Property	Symbol	Value	Unit
Chord length aileron	C_a	0.605	m
Span of the aileron	l_a	2.661	m
x-location of hinge 1	x_1	0.172	m
x-location of hinge 2	x_2	1.211	m
x-location of hinge 3	x_3	2.591	m
Distance between actuator 1 and 2	x_a	35.0	cm
Aileron height	h	20.5	cm
Skin thickness	t_{sk}	1.1	mm
Spar thickness	t_{sp}	2.8	mm
Thickness of stiffener	t_{st}	1.2	mm
Height of stiffener	h_{st}	1.6	cm
Width of stiffener	w_{st}	1.9	cm
Number of stiffeners (equally spaced along the periphery of the cross-section)	n_{st}	15	-
Vertical displacement hinge 1	d_1	1.154	cm
Vertical displacement hinge 3	d_3	1.840	cm
Maximum upward deflection	θ	28	deg
Load in actuator 2	P	97.4	kN
Net aerodynamic load	q	5.54	kN/m

Analytical model

An analytical model of the aileron will be provided. The provided analytical model may be used to verify the numerical model that is to be developed by you and your team. Please note, that the provided model is just one of several ways in which the aileron can be modelled analytically.

Numerical model

The mechanical behaviour of a complex structure can only be described in approximation by an analytical model. A *numerical model* is required for a more accurate description. A numerical model is constructed by dividing the complex structure into simpler parts, which can be described accurately using an analytical model. The models of the simpler parts are then linked back together numerically. The accuracy of the numerical model will depend on the discretization chosen when dividing the complex structure into simpler parts.

As a group of stress engineers, it is your task to create a numerical model to analyse the maximum deflection of the leading and trailing edges of the aileron and the maximum shear flow in the ribs that introduce the loads from the hinges and the actuators into the aileron. To construct this model, you may only resort to courses that are taught in the Aerospace Engineering Bachelor. For the structures assignment, the books of Megson and Hibbeler are a good start. Please note, that the use of a Finite Element (FE) model is prohibited.

Your numerical model must be verified using the provided analytical model, and validated using the provided test-data.

Test Data

At the start of week 3.2, test data of the aileron will be provided. The format in which the data will be given is not known yet. It will be your responsibility to interpret the test data correctly.

Deliverables

- Simulation plan (see lecture notes on Brightspace).
- A final technical report (see lecture notes Brightspace).

Reference Material

- Megson, 'Aircraft Structures for Engineering Students' 4th or 5th edition.
- 2nd year Structural Analysis & Design course (AE2135-I), lectures + lecture notes.

Important guidelines

- Be consistent with the use of your coordinate systems!
- The aileron cross-section can be assumed to be constant throughout its length, and the *xz*-plane in the undeflected position may be considered a symmetry plane of the aileron.
- The reaction force in actuator I and the force in actuator II are parallel to the z-axis at all time.
- The point of application of both actuators in a plane parallel to the global y-z plane is shown in figure 5. This point can be considered fixed in the local coordinate system of the aileron.
- Actuators I and II are placed at the same x-distance from hinge 2.
- See paragraph 24.3 of Megson on how to compute the analyse the shear flow in wing ribs.

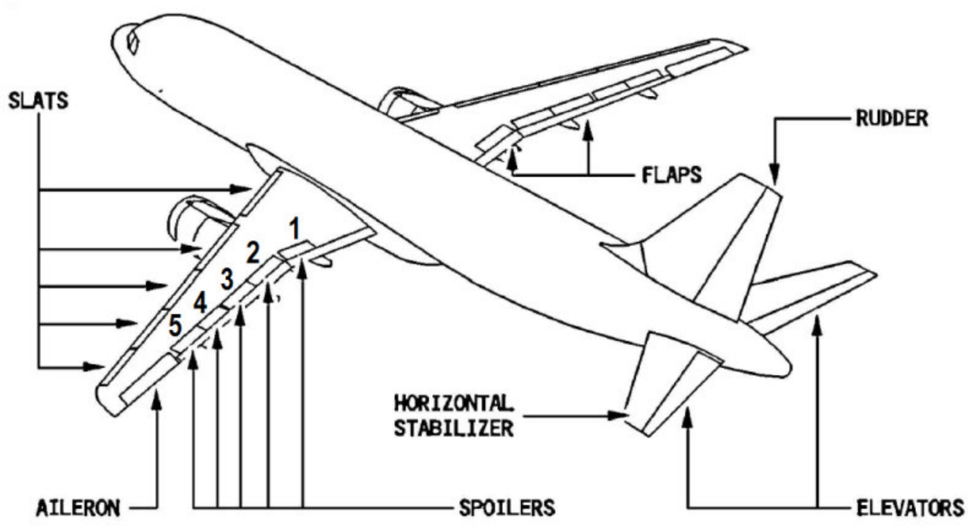

Figure 1: Aileron [http://theflyingengineer.com/tag/alleviation/].

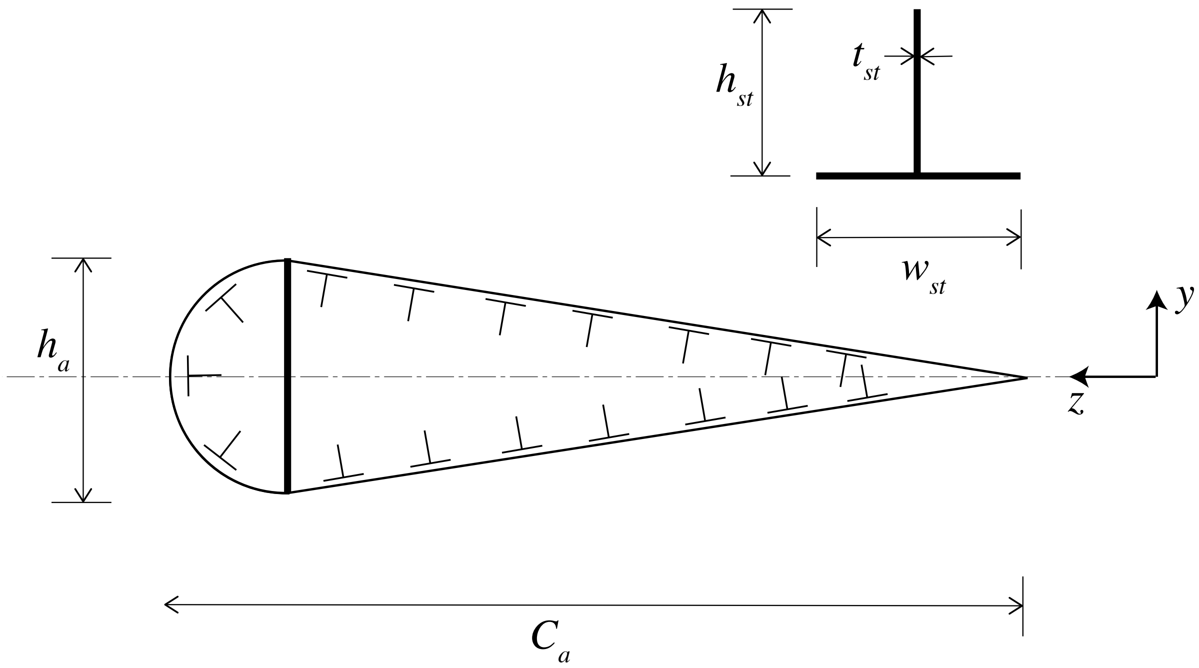

Figure 2: Cross-section of aileron.

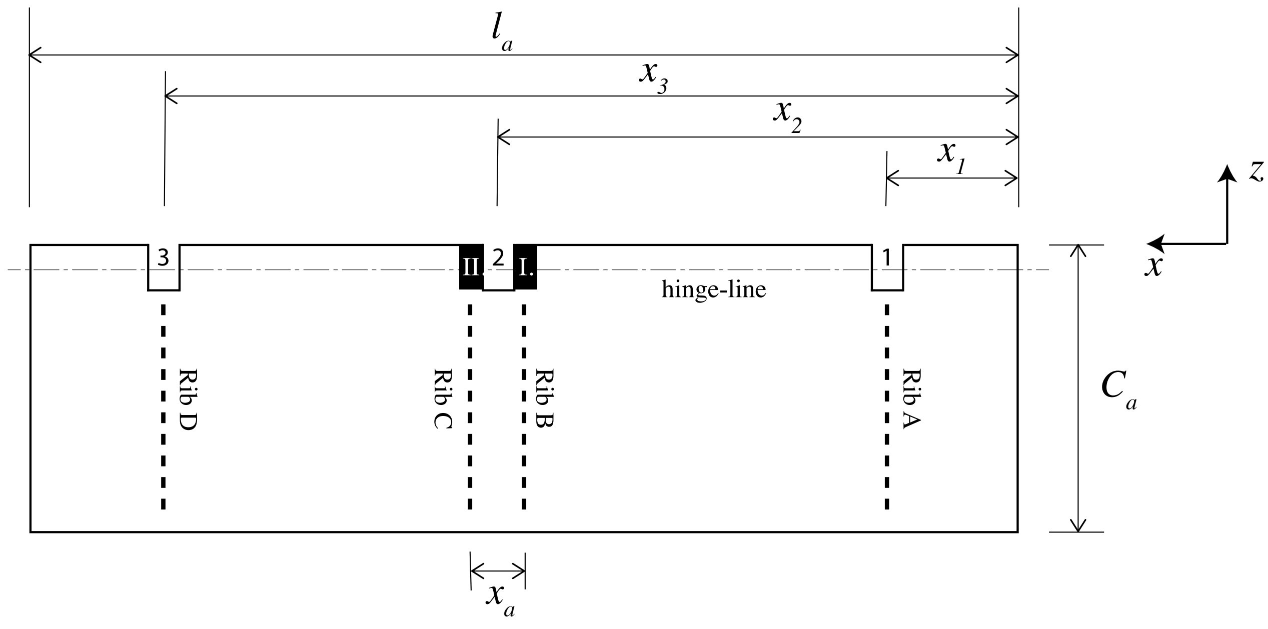

Figure 3: Hinge points and actuator attachment of aileron.

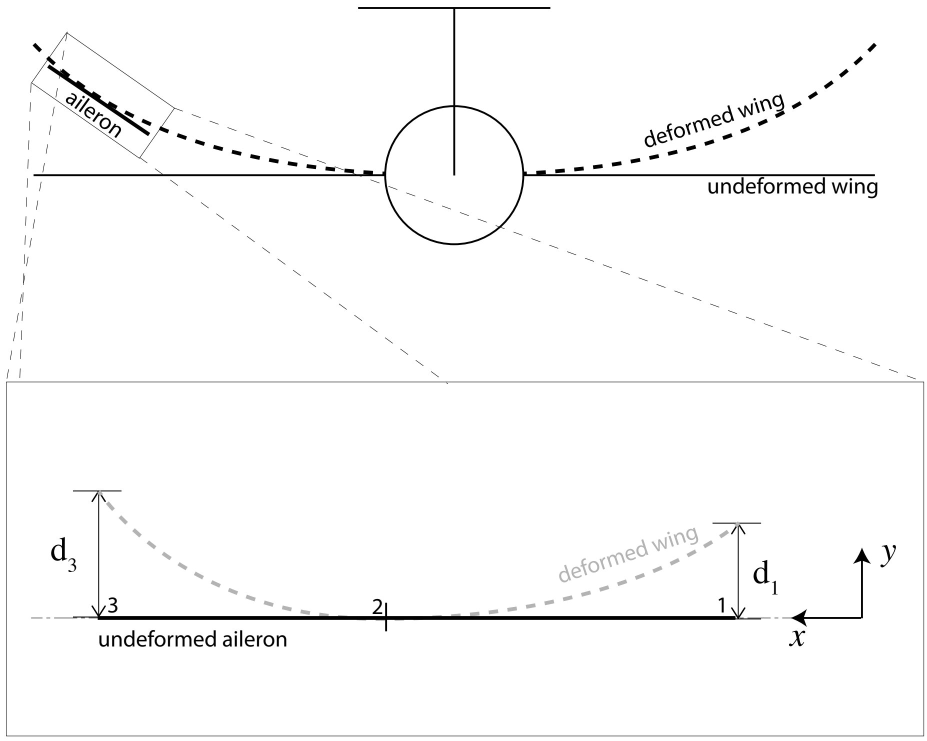

Figure 4: Wing deformation under limit load and required aileron deformation to match wing deformation. The test fixture mimics this deformation state by fixing hinge 2 and by moving hinges 1 and 3 in the positive y-direction.

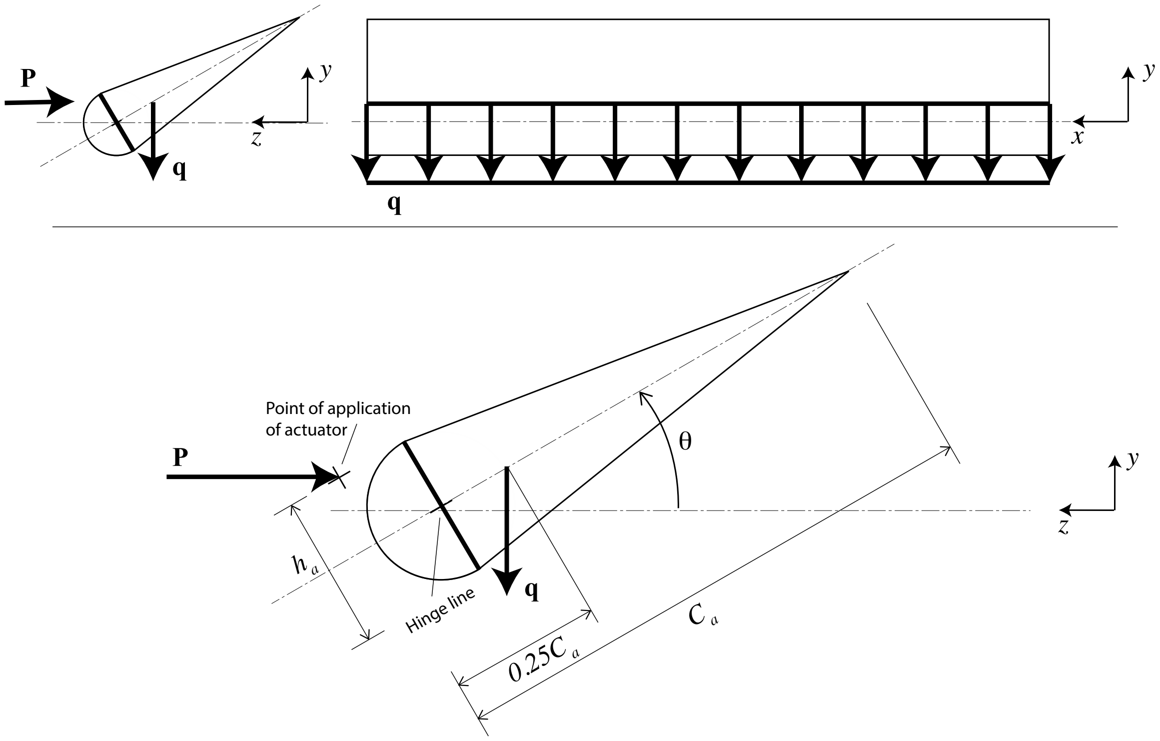

Figure 5: Deflected aileron, rear and side view with loading.