AE3212-II Simulation, Verification and Validation (Structures)

Verification and validation of the internal load distribution and stress analysis of a wing box

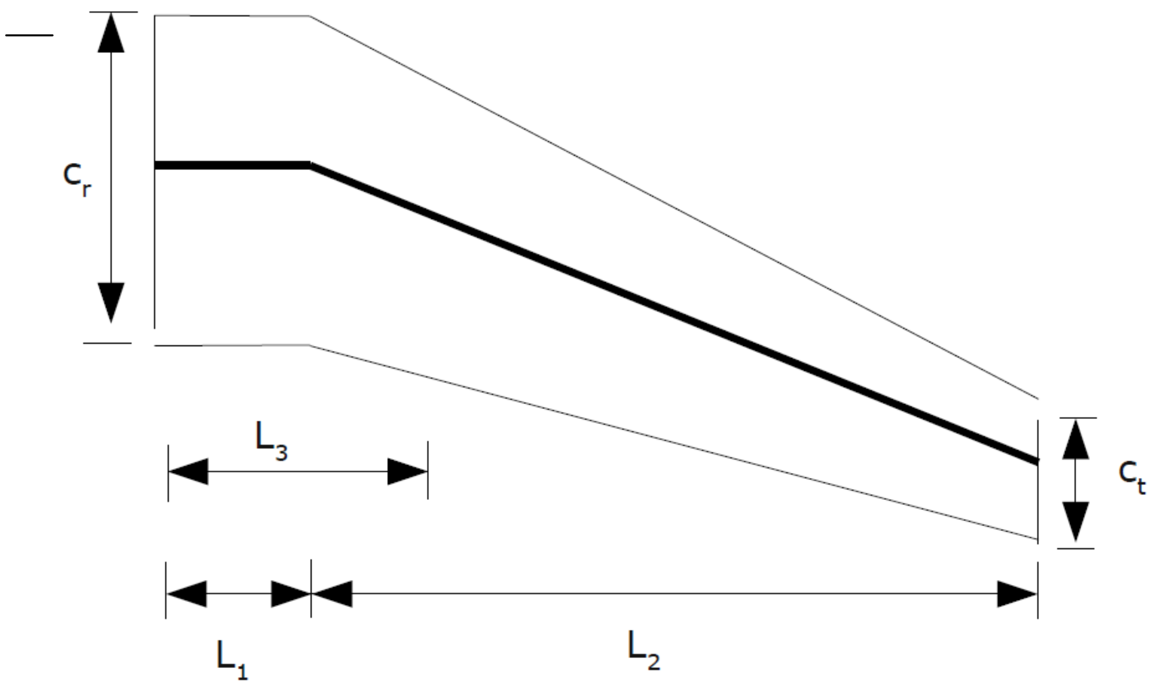
Introduction

Recently Boeing has introduced the 787 Dreamliner while its competitor Airbus, is flight testing the competing A350XWB. Both aircraft have state-of-the-art high-performance wings with an advanced composite structure. The tools used for analysis and design of such composite structures needs to accommodate the proposed aerodynamic shape and loading of the wing and take into account the wing strength and stiffness requirements.

Therefore Boeing and Airbus are interested in developing a structural analysis tool which allows the designers to determine the sizing of the structural components of a wing of such an airliner. Your group is to create such a structural analysis tool which needs to be verified and validated against existing experimental stress results which are obtained from certification tests on prototype wings.

The sought-after tool is intended for preliminary sizing of the wing box, so therefore a low-fidelity analysis tool would be sufficient in this case. To be more specific, the three-dimensional wing box can be modelled as an equivalent closed-section beam which can be discretised in a coupled set of *n* elements, which each have constant geometric properties and stresses.

Aircraft wing properties and loading



Depending on the specific aircraft type the wing will have different dimensions. The wing variations are described by the following seven parameters

1. Root chord c_r,
2. Tip chord c_t,
3. Sweep angle Λ
4. Inner wing box length L_1,
5. Outer wing box length L_2,
6. Span wise engine location L_3
7. Below wing engine location h_3,
8. Engine mass m_e,
9. Engine thrust T_e

Additional data for the wing is

a. The wing box thickness (in lift direction) is 10% of the local chord c(i),
b. The wing box width (in flight direction) is half of the local chord,
c. The local lift $\ell(i)$ is assumed to vary proportionally to the wing chord along the wing span as $\ell(i) = \lambda(t)*c(i)$,
d. The (resulting) lift is acting at the quarter chord line of the wing,
e. The engine is located at the quarter chord line of the wing,
f. The thickness of skins and webs of the wing box is

- Front spar web: $t_{front}*c(i)$,
- Rear spar web: $t_{rear}*c(i)$,
- Top panel skin: $t_{top}*c(i)$,
- Bottom panel skin: $t_{bottom}*c(i)$.

To transform the actual wing dimensions to an equivalent beam model it is assumed the equivalent beam is located at the middle of the wing i.e. at half chord. The equivalent beam is discretised in *n* elements, which each have a normal force, shear force, bending moment, and torsion moment.

The wing is loaded with two types of simultaneously acting loads

1. Distributed lift loading,
2. Discrete engine loading.

Tool capabilities needed:

The tool should be able to calculate the normal and shear stress distribution in the wing box which corresponds to the beam based on the resulting internal forces and moments for the real wing and applied loading conditions.

Numerical parameter values for c_r, c_t, Λ, L_1, L_2, L_3, h_3, m_e, T_e, $\lambda(t)$ and t_i plus the validation data will be released via Bb.

Notes

a. The sweep angle defines the sweep of the beam located in the middle of the wing (*not* the sweep of the leading edge),
b. The lift acts only over the swept part of the wing (from L_1 to $L_1 + L_2$),
c. The lift distribution is $\ell(i) = \lambda(t)*c(i)$ where (for this assignment) the load parameter $\lambda(t)$ is a singular value and not time dependent.
d. The wing-box structure is mass-less. However the validation data consists of the structural engineering parameters resulting from a lift load factor $\lambda(t)$ which may be combined with a fuel load distribution (added mass).
e. The mass of the engine is added as weight (weight = mass * gravity acceleration).