AE4509 Advanced design and optimization of composites

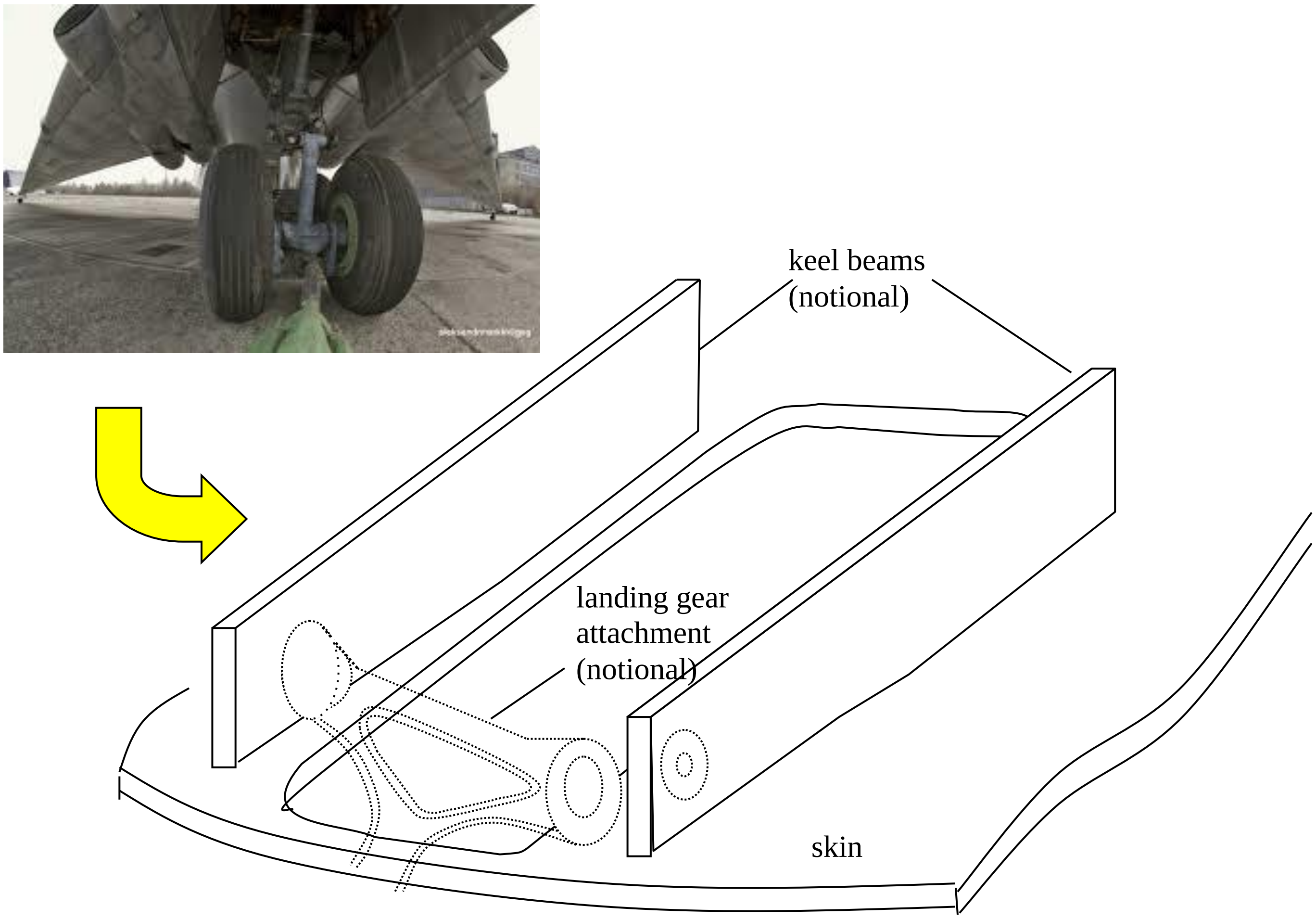
Assignments

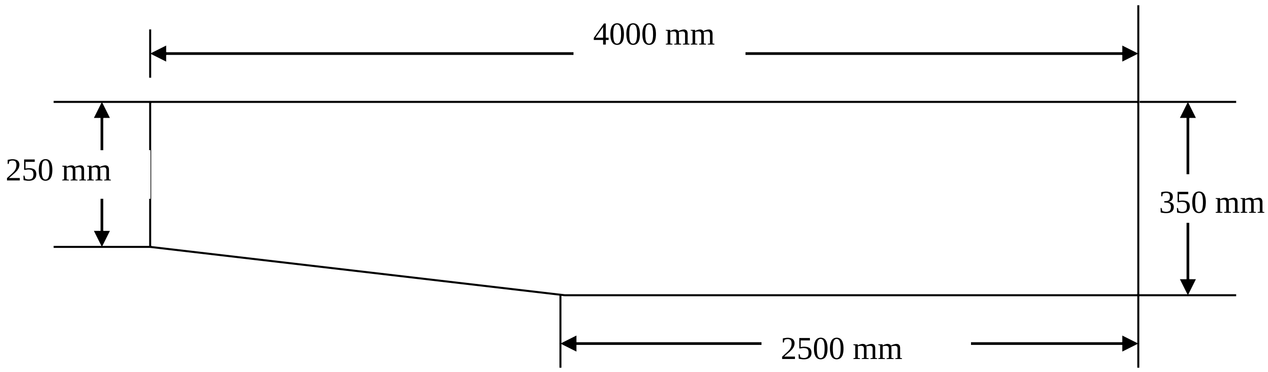
Delft
University of
Technology

Challenge the future

AE4-509 Final Project

Two massive keel beams are used on either side of the cutout for the forward landing gear of an aircraft as shown in the Figure below:



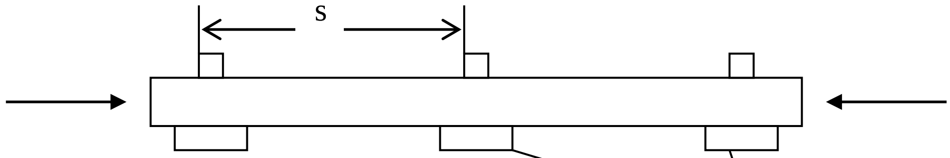


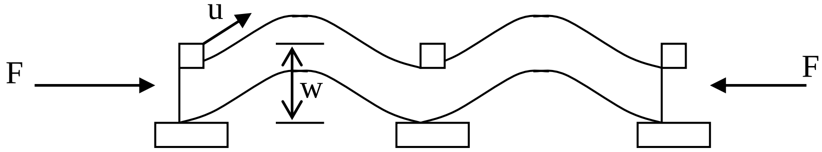
side view of each keel beam

1. Given a composite material, design each keel beam under an applied vertical shear load (coming from the landing gear) of 0.9MN (on each keel beam) and uniform compressive load of 200 kN (coming from inertia loads) on each keel beam acting on the left end. You can assume the right end of each keel beam is clamped. All around the edges of the beam you are supposed to have enough material to accommodate one row of fasteners each with diameter 8 mm and taking 28kN of load parallel to the nearest edge. This is a monolithic/skin/stiffened design. Select geometry and layup so there is no failure and the design is lightest. Calculate the final weight/keel beam of your design.

2. Repeat 1 with sandwich. Compare the weights. For the sandwich weight, increase your final value by 30% to account for auxiliary material (extra adhesive, splices, etc) .

3. After you have completed the monolithic design, you are required to check its ability to absorb energy during a forward crash of the aircraft. Find the most highly loaded flange in compression in your design. Keep the width of the flange constant and use inter-rivet buckling as the crash absorption mechanism. Even if originally this flange was co-cured or bonded on the rest of the structure, you are now to attach it using fasteners and check for post-buckling after inter-rivet buckling. This is done as follows: You select a fastener spacing s and apply a compressive load on the flange. You allow it to post-buckle treating it as a beam (see below). Calculate by how much each portion between two successive fasteners shortens at the time the flange fails in the post-buckling regime. Multiply the corresponding force by the shortening and by the number of segments into which the fasteners divide the flange along its length. This gives an estimate of the energy absorbed for this flange. What is the maximum energy you can absorb with this flange? Note that you are allowed to change the flange layup if you want as long as it does not fail in any other failure mode. Do not update your previous design in part 1 if you change the flange (i.e. do not do any load redistribution etc.)





The equation for a beam in bending with moderate deflections is given by:

$$\left[1+\frac{1}{2}\left(\frac{dw}{du}\right)^2\right]\frac{d^2w}{du^2}+\frac{P}{EI}w=0$$

This is for a simply supported beam but, for this problem, you are allowed to use it for any type of fastener you may select.

Assume a solution in the form

$$w=q_1\sin\frac{\pi u}{s}$$

Determine q_1 by solving approximately the governing differential equation using a Galerkin approach with characteristic function $\sin\pi u/s$.

You can now determine the amount of shortening δ. For this (and only for this part) you will need to make an approximation of a certain square root involving w.

You can now determine the maximum moment and force on the post-buckled flange which you will need to check for failure. Procedure:

(1) Determine inter-rivet buckling load
(2) For loads greater than inter-rivet buckling load obtain q_1
(3) Check if there is failure. If not, increase load. If yes, reduce load
(4) Find the failure load. For this failure load determine shortening and calculate energy absorbed.

Material properties:

	UD tape		PW Fabric
Ex	1.23E+11	Pa	55.152E9 Pa
Ey	8.48E+09	Pa	55.152E9 Pa
nuxy	0.29		0.05
Gxy	5.24E+09	Pa	4.826E9 Pa
tply	0.13970	mm	0.4191 mm
Xt	1693855800	Pa	534.3 MPa
Xc	1276079400	Pa	577.7 MPa
Yt	25507800	Pa	534.3 MPa
Yc	115819200	Pa	577.7 MPa
S	100652400	Pa	70.3 MPa
Density	1650 kg/m^3		1650 kg/m^3

Core (x is ribbon direction)
Ec=186 MPa
Gxz = 117.2 MPa
Gyz = 48.2 MPa
Z_c = 1.86 MPa (out-of-plane compression strength)
Zxz = 1.03 MPa (shear strength in ribbon direction)
Zyz=0.52 MPa (shear strength perp ribbon direction)
Cell size = 3/16 inches
density = 48 kg/m^3
Adhesive density= 0.293 kg/m^2

Notes:
(1) Use knockdowns wherever appropriate.
(2) Indicate clearly which design rules you used and justify why you did not use any you chose not to use.
(3) For any buckling calculations, for non-rectangular shapes, you can pick a conservative rectangular shape to do your analysis. For plate buckling, even though the right end is assumed clamped, you can, conservatively, assume that it is simply supported. Similarly, all edges of anything that may be buckling sensitive will be assumed simply supported (except inter-rivet buckling calculations which have their own boundary conditions).
(4) Discuss fabrication issues briefly from the perspective of which design might be more expensive to manufacture.
(5) Create plot of cross-section of the keel beam showing flanges, webs, terminated plies, etc. at various locations along the length of the keel beam if necessary. Clearly show which plies are continuous and which are not. Show the same type of plot for any other auxiliary structure (e.g. stiffeners) you may choose to use.
(6) For fasteners, the bearing stress is P/(Dt) where D is the diameter and t is the thickness. This stress should not exceed the bearing strength of the materials which, for both UD and fabric materials is 760 MPa (RTA, mean value). This value is valid as long as your laminate locally has stiffness in the direction of the load which is within 30% of the corresponding quasi-isotropic stiffness.
(7) Do not include fastener weight in your weight calculations.