Introduction to Aerospace Engineering

Exams

Materials & Structures

Answers to the exam January 2011

Question 1

An Airbus A320 with a weight of 62000 kg lands on its main landing gear with a deceleration of 1.5g. The acceleration of gravity is 9.81 m/s^2.

a) F_{tot} = M*a = 62000*1.5*9.81 = 912330 N
   For each landing gear this is F_{LG} = 912330/2 = 456 kN.
b) M = F*L = 456000*(7.59/2-1.8) = 9.1*10^5 Nm.
c) The upper wing skin is loaded in compression
   The lower wing skin is loaded in tension.
   (depending on assumed load case and wing bending, reversed answer was accepted)
d) Only statement d. is correct
e) Three of the four aspects may be selected
   - Completely free load bearing structure, no support or strut necessary
   - Thinner wings (at given span) or longer wings (at given thickness)
   - Torsion stiffness and bending stiffness can be engineered separately
   - Lower weight of wing.
   - Natural high stiffness
   - Applicable as fuel tank
f) The specific stiffness E/ρ relates to a load case in tension, whereas the ratio $\sqrt[3]{E}/\rho$ relates to sheet stability (compression). The upper wing skin in c) is loaded in compression and therefore ratio $\sqrt[3]{E}/\rho$ is most appropriate, while the lower wing skin is loaded in tension making the specific stiffness most applicable.
g) Forged and/or machined from bulk material. The wing ribs at these locations are highly loaded by engines or landing gears. Formed ribs are not suitable to transfer high loads.
h) The design philosophy, available equipment and experience, costs

Question 2

a) Mechanically fastening, welding, adhesive bonding.
b) Mechanically fastening: shear and tension
   Welding: shear and tension
   Adhesive bonding: shear.
c) Bearing load, frictional load, by-pass load
d) Secondary bending, interference (i.e. compression due to radial expansion).
e) Shear-out. The fibres between the fastener and edge are not loaded, while the shear strength at the interface between the fibres is related to the matrix material only and thus very low.
f) $$K_t = \frac{\sigma_{peak}}{\sigma_{nom}} = 1 + 2\frac{a}{b} = 1 + 2\sqrt{\frac{a}{r}}$$
   For a circular hole (a=b) the K_t becomes 3.
g) The fact that the hole is filled instead of open, and the compressive stresses due to radial expansion relieve the bearing pressure.

Answers question 3:

a) V_c = sqrt(μ/r), r = R_e+350 → V_c = 7.697 km/s
b) Torbit = 2π sqrt(a^3/μ) = 5492 sec = 91.5 min = 1.53 hrs
c) Tvis = (2 x gamma / 2π) x Torbit (gamma = angle from earth center between zenith direction and satellite at horizon) = 566 sec = 9.4 min
d) a = (rp + ra)/2 = (Re + Re + 350)/2 = 6553 km
e) from rp = a (1 – e) or ra = a (1 + e) → e = 0.0267
f) Using "vis viva" (V^2 = μ(2/ra – 1/a) → ΔV = Va – Vc = -0.10347 km/s (if minus sign is missing also OK)
g) V_{esc} = sqrt(2μ/r) = 10.885 km/s → Vincr = Vesc – Vc = 3.19 km/s

Answers question 4:

a) Start from burnout velocity: $V_{burnout} = I_{sp}\, g_0 \ln(M_{beg}/M_{dry}) - g_0 t_{burn}$ → rewrite equation to express M_{beg} in the other (known) parameters (→ exponential function). Then $M_{prop} = M_{beg} – M_{dry}$ = 2193 kg.
b) Mass flow mdot = M_{prop}/t_b; T = mdot w = (M_{prop} / t_b) I_{sp} g_0 = 71.7 kN;
c) Lift-off: acc = $T/M_{beg} – g_0 = T/(M_{dry}+M_{prop}) – g_0$ = 14.15 m/s^2.
burnout: acc = $T/M_{end} – g_0 = T/M_{dry} – g_0$ = 79.82 m/s^2.
d) $t_{culm} = V_{burnout}/ g_0$ = 305.8 s
e) Hgain = $V_{burnout}$ * t_{culm} - 1/2 g_0 t_{culm}^2 = 458.7 km