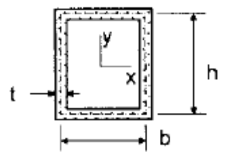
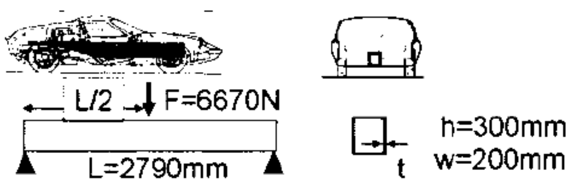
1. Body structure typically consists of beams with thin walled sections in which the width to thickness ratio, b/t is large (b/t > 60).



(1) Write an expression for the exact area moment of inertia about the x axis, I_{xx}. (10 pts)

(2) When t is very small compared to the other section dimensions, we can approximate the exact I_{xx} with an expression linear in t. Using either a Talyor expansion of (1) or by elimination of terms of t of second and higher order write the linear approximation for I_{xx}. [Ans. $I_{xx} = h^2t(3b+h)/6$] (5 pts)

2. One topology for resisting bending load is a back bone beam down the center of the vehicle. The back-bone can be idealized as a uniform beam supported at the axle position. The test load condition is shown. The basic equation for maximum stress is $\sigma = Mc/I$ and for maximum deflection of a center loaded span is $\delta = FL^3/(48EI)$. Assume the material is steel with E = 207,000 N/mm^2, $\sigma_{allowable}$ = 175 N/mm^2. [Use I obtained in Problem 1 (2)]

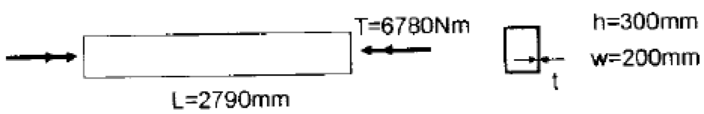


(1) Compute the minimum thickness to meet the strength requirement of supporting a 6670 N load. (5 pts)

(2) Compute the minimum thickness if the deflection at center span is to be at most 1 mm. (5 pts)

(3) How short does the wheel base L need to be before strength and stiffness criteria require the same thickness? (10 pts)

The twisted ditch torque is 6780 Nm with an allowable shear stress $\tau_{allowable}$ = 86 N/mm^2. Also, the stiffness requirement for torsion is 12,000 Nm/degree measured between the axles (L = 2790 mm). Assume the material is steel with G = 83,000 N/mm^2.



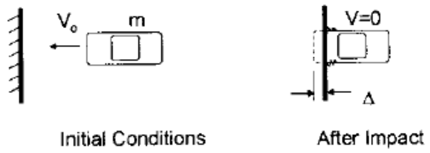
[for closed section: $J_{eff} = \dfrac{4A^2}{\oint \frac{dS}{t}}$, $\theta = \dfrac{Tl}{GJ_{eff}}$, $\tau = \dfrac{T}{2At}$]

(4) Compute the required thickness to meet the twisted ditch strength requirement. (5 pts)

(5) Compute the required thickness to meet the torsional stiffness requirement. (5 pts)

(6) Which is the dominant requirement? (5 pts)

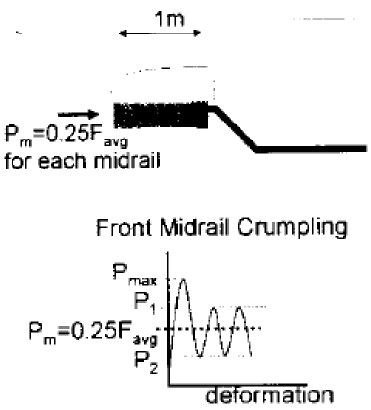
3. A 1000kg car impacts a rigid barrier at V_0 = 48 km/h. It is desired that the maximum deceleration level be a_{max} = 20g. The anticipated crush efficiency is η = 0.8. Assume fully plastic behavior.



(1) What is the required crushable space Δ? (5 pts)

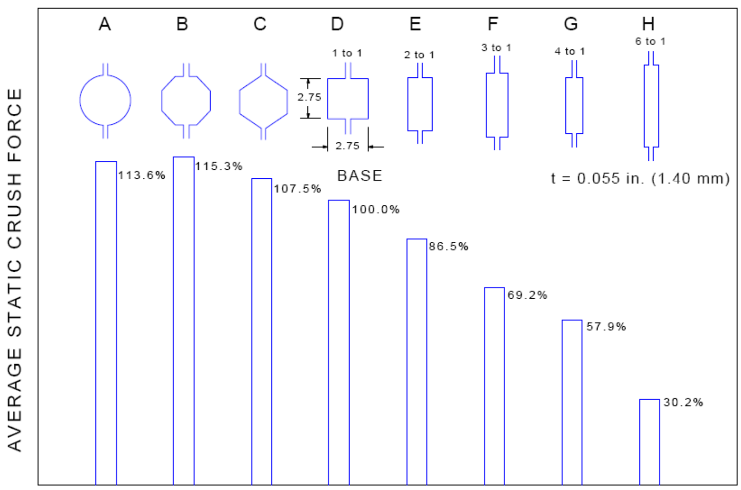
(2) What is the mean crush force which must be generated by the vehicle F_{avg}? (5 pts)

Assume that the two midrails will provide 25% of the average crumpling force F_{avg} required. The body will be tested statically for this force level. Material yield is σ_y = 207 N/mm^2.



$$P_m = 386 t^{1.86} b^{0.14} \sigma_Y^{0.57}$$

For same perimeter and thickness



(3) Determine the size (b, t) of the square section required to generate 0.25 F_{avg} if the width to thickness ratio b/t = 60. What is the mass of the two rails(density $= 7.83 \times 10^{-6}\ kg/mm^3$)? (10 pts)

(4) A hexagonal section is being considered with the same b/t ratio. What is the resulting mass? (5 pts)

(5) Compare the two sections. What is preferred? (5 pts)

4. Consider the impact of the vehicle(M_2) by a moving barrier(M_1). We can model each as a point mass with the impact being perfectly plastic. In this linear model, we are looking at motions lateral to the vehicle and will consider the lateral component of the barrier velocity as the initial impact velocity.

(1) Sketch the velocity-time histories for the barrier, the vehicle and the occupant based on the following figures. Indicate t_a, t_{final} and t_f in the time axis and corresponding V_a, V_{final} and V_f in the velocity axis. (10 pts)

(2) Specify Δ_0, Δ and a_{occ} (acceleration of occupant) in the histories. (10 pts)