Design Studio Week 5 – Technical Analysis 1

Following the review of your solution comparison analysis, your boss has chosen to move forward with the lidar-based self-driving automobile solution.

Option 1: Your boss has informed you that the lidar sensor mounting system will be responsible for securing the sensor in place on the vehicle frame. The mounting system must be designed to meet the following requirements:

1. Secure the sensor at 1.2 m height, withstand impacts, road vibrations, and wind resistance at speeds of up to 80 km/h.
2. Ensure durability and reliability in a variety of environmental conditions (e.g., temperature changes, rain, corrosion).
3. Be lightweight for vehicle efficiency while ensuring sufficient strength and safety.

You must perform a static load analysis for the lidar sensor mounting system, evaluating three potential material solutions:

Table 1: Mechanical Properties and Allowable Design Stresses
Source: Adapted from [4].

Metal and Alloy	Allowable Stress (MPa)	Minimum Yield (MPa)	Elastic Modulus (E) (GPa)	Poisson's Ratio (ν)	Density (ρ) ($\mathrm{kg/m^3}$)
Carbon Steel					
Types E and S, Grade A	149	207	200	0.29	7850
Aluminum					
6063 T5, T52	79*	110	69	0.33	2710
Stainless Steel					
Unannealed Types 302, 304, and 316	207	345	193	0.25	7500

*Reduce allowable stress to 55 MPa within 25 mm of any weld.

→ slightly susceptible to corrosion

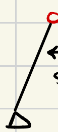
→ lightweight, environmentally friendly & corrosion resistant

→ corrosion resistant

Your boss also provides you with the following set of instructions:

1. The lidar sensor has a mass of 1 kg.
2. The configuration and load analysis can be configured in any orientation.

1. Set up mounting configuration:

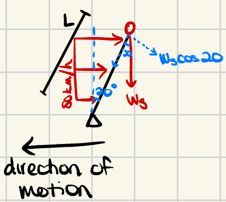


← sensor

← Cylindrical cantilever beam to hold sensor angled 20° for aerodynamics

↑ pin to mount on top of car with a circular base - can be bolted to frame

2. Static load analysis using formulas from CIVENG 2C04:



$$W_s = mg(\cos 20)$$
$$= 1\,\mathrm{kg}(9.81\,\mathrm{m/s^2})(\cos 20)$$
$$= 9.21\ \mathrm{N}$$

drag coeff. for a short cylinder i.e. shape of mount + sensor

(wind)

80 km/h = 22.22 m/s

approximate CSA for sensor

$$F_d = \frac{1}{2} C_d\, \rho_{air} V^2 A$$

↳ CSA of sensor + mount = $(d \times L) + 0.05\,\mathrm{m^2}$

$$= \frac{1}{2}(1.15)(1.293)(22.22)(d \times L + 0.05)$$

3. Sample calculation for $L = 0.15m$, $d = 0.03m$

$W_s = 9.21\ N$

$$F_d = \frac{1}{2}(1.15)(1.293)(22.22)^2\overbrace{((0.1 \times 0.03) + 0.05)}^{\text{CSA of mount + sensor}}$$
$$= 19.45\,N$$

$$\circlearrowright^{+} M_{pin} = (9.21 \times 0.15) + (19.45 \times 0.15)$$
$$= 4.38\ N/m^2$$

$$I_{\text{solid circular beam}} = \frac{\pi d^4}{64}$$
$$= \frac{\pi (0.03)^4}{64}$$
$$= 3.97 \times 10^{-8}\ m^4$$

$$\therefore \sigma_{act} = \frac{M\bar{y}}{I}$$
$$= \frac{4.38\left(\frac{L}{2}\right)}{(3.97 \times 10^{-8})}$$
$$= 8270508.80$$
$$= 8.27\ MPa$$

use this to compare materials

4. Check FDS:

$\rightarrow$ Carbon steel $= \frac{149}{8.27} = 18.015$

$\rightarrow$ Aluminum $- \frac{79}{8.27} = 9.55$

$\rightarrow$ Stai less teel $= \frac{207}{8.27} = 25.03$

5. Check mass:

weight of sensor

$\rightarrow$ Carbon steel $= 7850 \times \left(\frac{1}{4}\pi(0.03)^2 \times 0.15\right) + 1 = 1.83\ kg$

$\rightarrow$ Aluminum $= 2710 \times \left(\frac{1}{4}\pi(0.03)^2 \times 0.15\right) + 1 = 1.29\ kg$

$\rightarrow$ Stainless steel $= 7500 \times \left(\frac{1}{4}\pi(0.03)^2 \times 0.15\right) + 1 = 1.79\ kg$

$\therefore$ go with stainless steel, has highest FDS and lighter than carbon steel + better in environmental conditions.