c3Design

APPLICATION PROJECT 2

Contributions (briefly summarize each member's contributions to the project. Each person should initial this):

Pledge: On our honor, we have not received or given assistance on this project to any other team.

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INSTRUCTIONS: Each team will turn in a single report representing the team's effort, including this cover sheet (which has to be printed, signed, and scanned back in). Your report summarizes your approach, reasoning and detailed solutions. Please type this in PowerPoint – handwritten reports won't be accepted, and do graphs in Excel or something better. Save the final version of this document as pdf. Each team must also turn in their completed spreadsheet, **with all columns labeled, including units**. *You will upload two files onto Collab, as, for example, Metglass Report.pdf and Metglass Calculations.xlsx.*

On-Board Hydrogen Storage: The Old-Fashioned Way

Hydrogen fuel cells could be useful as motive power for automobiles, with zero carbon emissions *at the point of use* (making the hydrogen itself would require burning fossil fuels). One major challenge is the storage of hydrogen on board the vehicle. Ideally, the hydrogen "tank" would have small volume, be lightweight, keep enough fuel for a 300 mile journey, and be safe, even in the event of an accident. Also, draining (that is, using) and recharging the "tank" should be straightfoward.

For this problem, let's consider the conventional solution – an actual tank containing pressurized, gaseous H_2. This has the advantage of being immediately implementable, and drain/recharge is easy. Manufacturers have set the following design targets:

Empty tank weight: < 110 kg
Weight of H_2 on board: 6 kg

Volumetric density: 30 kg H_2/m^3 Pressure: 70 MPa ($70x10^6$ Pa) = 10,000 psi

1. (10 pts) Based on these numbers, calculate the volume of the tank.
2. (10 pts) Assuming a spherical tank, calculate the tank inner diameter, D_i.
3. (25 pts) The safe wall thickness of the tank, **t**, relative to the *outer* diameter, D_o, is given by:

$$\frac{t}{D_o} = \frac{2.25P}{4\sigma_T}$$

where P is the gas pressure and σT is the tensile strength of the tank material.

PLOT the ratios t/D_o and t/D_i as a function of σ_T for P = 70 Mpa. Take σ_T to vary from 10-1100 MPa. Also show on your plot (as vertical lines) the 5 materials in the table on the next page.

Note 1: Follow my brief description of what a proper graph should look like on the final page.
Note 2: this equation assumes that the wall thickness is $t < D_o/5$.

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4. (30 pts) Use your graph to determine the wall thickness for the following materials. Then calculate the weight and total cost for spherical hydrogen tanks made of each material. You might get something odd-seeming for high-density polyethylene. Explain what is going on here.

Material	Density (g/cm3)	Tensile Strength (MPa)	Unit Cost ($/kg)
Stainless Steel	7.80	515	7.10
High-strength steel 4340	7.86	745	2.55
Aluminum 2014-–T6	2.80	483	7.50
High-–density Polyethylene	0.96	30	1.65
E-Glass fiber-reinforced epoxy composite	2.1	1020	32.00

5. (15 pts) Which material would you make your tank from, and why?
6. (10 pts) Do you have any suggestions or strategies for how to reduce the cost of the tank?

Just FYI, 6 kg of H_2 has about the same energy content as 10 gal of gasoline. Also, 1 gal of gasoline has more hydrogen than 1 gal of pure liquid hydrogen!

http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/hphsc.html

http://www.edmunds.com/fuel-economy/8-things-you-need-to-know-about-hydrogen-fuel-cell-cars.html

http://www.greencarreports.com/news/1095985_2016-toyota-mirai-first-drive-of-hydrogen-fuel-cell-sedan

http://www.popsci.com/2016-toyota-mirai-test-drive-hydrogen-powered-car-remarkably-unremarkable-and-thats-good-thing

http://www.toyota.com/fuelcell/index.html

http://www.digitaltrends.com/cars/toyota-hydrogen-fuel-cell-vehicle-fuel-tanks-tested-with-bullets/

Good graphs can convey information much more effectively than tables or formulae, and top-notch engineers and scientists should master this art. Here are some characteristics of a good graph:

1. Axes are labelled, including units
2. Sufficient numbers of points are shown and/or calculated to form smooth curves
3. Real data often has "noise", and doing a "connect the dots" graph is often not appropriate (this is not an issue here, since you're plotting results of an equation rather than data).
4. Graphs should be large enough to be readable, and use appropriate fonts.
5. You should pay close attention to what parts of the graph are most important for interpretation of results. You don't necessarily have to plot all the data you calculate -- if most of the "action" is in one region of the graph, you can either focus on that region, or make 2 plots, one showing everything, and one showing the region of interest.