LMAPR2020: Second homework on multiple constraints and conflicting objectives

Practical details for report :

Questions are to be answered per team.

Report should be no longer than 5 pages.

Accepted formats : PDF or clean and readable scan of handwritten report compiled in a single PDF.

Upload the file to the corresponding homework on Gradescope by 31/03 (before 11.59 am)

Elon Musk is tired of electrical cars and now wants to build a steel satellite launcher. Is it a good idea and can we help him make the right choice?

Start by watching the first minutes of the youtube video:
`https://www.youtube.com/watch?v=6AcE7hBhpYU&feature=youtu.be`

Let's first simplify the problem:
The hollow cylindrical launcher should not buckle under the weight of the payload. We will assume that the cryogenic fuel that fills the launcher and the weight of the launcher itself do not contribute to this, one way or another. So, we forget about the issue described in the video of unstable structure in the absence of pressurization of the fuel tank. Let's assume a payload of 5000 kg, a height of 50 m and an internal diameter of 5 m (roughly inspired by Ariane 5 characteristics). This is just to fix ideas, but keep at the back of your mind that the aspect ratio of the rocket pictured in the video is not really that of a classical one...

The launcher must be as light as possible. Cost, in first approximation, is not relevant up to at least 1000€/kg.

The launcher must also prevent the cryogenic fuel from evaporating too fast from thermal conduction. We can treat this part of the problem as a second objective that conflicts the first one: the better the insulation, the heavier the launcher. The classical way to solve this is conflict is by designing a two-layer structure: a shell of high rigidity material covered by insulating material. We can further assume that the insulating layer thickness is free within minimum and maximum bounds. Details are not essential for the exercise.

Start resolving this problem by selecting 2 materials. The first one should avoid buckling with the smallest mass, the second should maximise isolation. Discuss this solution.

By the way, a more sophisticated approach would treat the structure as a hybrid as in the next chapter (including reinforcing ribs or grids, even sandwich panels) but this is beyond the exercise and we will simply decouple the stiffness constraint, which is solely controlled by the structural material, from the thermal insulation which does only depend on the insulating material. On the other hand, we cannot neglect the added

weight coming from the insulation.

Elon Musk's idea is apparently to dispense of the insulating layer by using a structural material with a low thermal conductivity (a tricky combination). Stainless steel is mentioned in the video, perhaps other ones should be considered as well.

> The question is obvious: find the best material based on the single constraint and two objectives. Is steel the best structural material? Can a single stainless steel structure compete with the traditional design? If it is not, do you think Mr Musk should attend the course, or did we miss something when considering constraints and objectives, and he did not?

Part 2 - exchange constants

A classical trade-off we all make in life is the alternative between buying a good that is expensive but durable (and perhaps eco-friendly as well as ethically produced) vs. a cheap but quickly out of order one.

1. Choose 2 everyday examples, in as distinct as possible categories, with clear links to materials selection (e.g. tools, communication devices, transportation devices, etc.). Write down a reasonable value function, i.e. identify the major categories of performance
2. Consider now the insulation of a fridge. The total cost of such device depends on the initial cost, and the electrical consumption (and thus its thermal insulation). Write the penalty function and identify the values of the exchange constant in 2 different cases.