Research project meeting summary: Trajectory Module for Launcher MDAO

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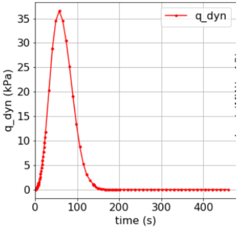
Plan:

1. Review of previous work
   - Difficulties with the original plan
   - Another approach - Complex step
   - Performance comparison
   - Another idea for the original plan
   - On the structural module
2. Key points discussed
   - Report Outline - As suggested by ISAE-SUPAERO
3. Future actions

We wanted to know the maximum dynamic pressure ,q_{max}, to feed it into the structural sizing module. We proposed to:

- Split the gravity turn phase in to two.
- The end of the first phase would correspond to q_{max}.
- Achieved by defining a boundary condition: $\frac{\partial q}{\partial t} = 0$.
- But, I don't have easy access to $\frac{\partial q}{\partial t}$ analytically as $q = \frac{1}{2}\rho v^2$.



- We keep the same phases as before. No splitting of gravity turn phase.
- Constraints approach based on two variables.
- The value used by the structural sizing module is q_{max_s}.
- The vector of values extracted from the trajectory is $\vec{q_t}$.
- A coupling component calculates the residual

$$r = q_{max_s} - max(\vec{q_t}) \tag{1}$$

- With derivatives

$$\frac{\partial r}{q_{max_s}} = 1 \quad , \quad \frac{\partial r}{\vec{q_t}} = \text{complex step} \tag{2}$$

Optimized trajectory for 20 tons payload to 400 km height orbit. Initial guess corresponds to 9 tons.

- Converges successfully. Satisfies $r = 0$.
- Optimization time $4'8''$.
- 196 iterations and 704 function evaluations.

1. **Finite difference based:** 9 loop constraints
2. **Full analytic :** Instead of using q_{max} it reads q at the 6th node of the gravity turn phase.
3. **Constant q :** It eliminates the constraint loop for dynamic pressure and uses a constant value of 36541.9 Pa to size the structures.

	Complex step	**Full analytic**	**Constant q**
Opt time (s)	248.4	171.34	163.1
Function evaluations	704	278	267
Gradient evaluations	196	148	147
Initial mass (kg)	611.6	611.0	611.4

$$q = \frac{1}{2}\rho v^2 = \frac{1}{2}\rho(h(r(t)))v(t)^2$$

$$\frac{\partial q}{\partial t} = \frac{1}{2}\frac{\partial \rho}{\partial h}\frac{\partial h}{\partial r}\frac{\partial r}{\partial t}v^2 + \rho v\frac{\partial v}{\partial t}$$

All of the partials are already calculated in different modules. I would need to figure out how to access to them from one component.

Defining $\dot{q}$ in the EOM component I should be able to access most of the partials required. if $\frac{\partial q}{\partial h}$ is not available, we could try an exponential atmospheric model wit simpler analytic derivatives.

- As in FELIN, there's a parameter with a value of zero making the mass of the inter-stage equal to zero.

  The parameter is the surface area of the interstage. I could define a constant length of 2.5m and use the stage diameter to calculate it.
- The diameters of the the stages are constant. The nozzles exit area are functions of these.
- Is there a skin mass for the stages?

  This is considered in other variables

Key points discussed I

Report Outline - As suggested by ISAE-SUPAERO

1. Short abstract:
   (100-200 words) and Keywords (5 or 6)
2. Introduction
3. Semester section - Distinction between S2 and S3:
   - Context and key issues
   - State of Art
   - Justification of the potential degree of novelty
   - Aims and objectives
   - Work done - Distinction between S2 and S3:
4. Investigation methods
5. Results and analysis
6. Conclusion and perspectives
7. References
8. Appendices: ... Legacy ...

- The report should be 20 - 35 pages long
- ”You can discuss further details about the content with your advisor as she/he will be the main reader of your report at the end.” - ISAE
- I also have to do a 2 page summary and a 20 min presentation

- I will continue with the original plan of splitting the gravity turn phase into two. For this i will need the analytic value of $\dot{q}$ but it seems that is going to be possible to calculate it from the EOM module (state variables) as only $\frac{\partial q}{\partial h}$ is calculated outside it.
- This is worth trying to keep the low computation times
- I will do a more detailed outline of the report