Control system design for an electronic gas pressure regulator for space application

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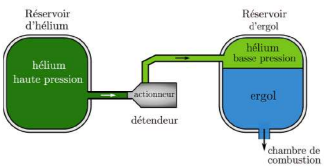
Topic

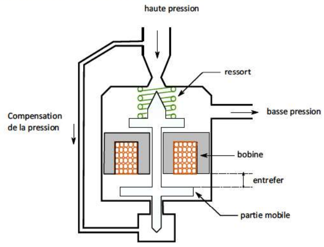
Abstract:

CNES and CSTM, have been working for several years on the development of an electronically controlled pressure regulator. Pressure regulators are used in launchers to expand helium from tanks at 400bar to a few bars. The objective of this PhD thesis is to develop a control law, on one hand to control the position of the actuator valve, and on the other hand, to regulate the output pressure

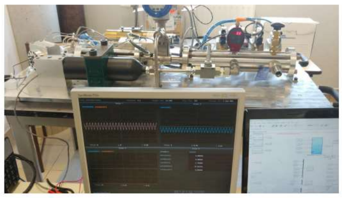
Application:



System schematic:



Testbench:

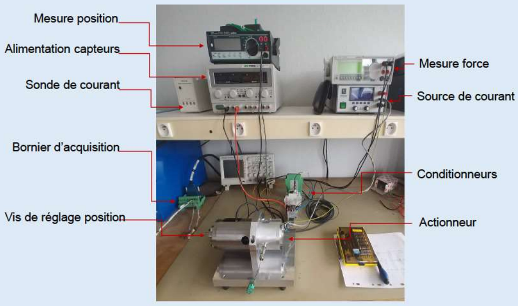


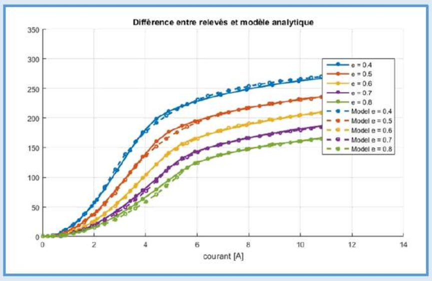
System modeling

Mechanical modeling → Measurements → Model fitting

$$\begin{cases} \frac{dx}{dt} = v \\ \frac{dv}{dt} = \frac{1}{m}\left[-F_{mag}(x,i) - \lambda v - K(x-x_0)\right] \\ \frac{di}{dt} = -\frac{1}{L(x,i)}\left(Ri + i\frac{\partial L(x,i)}{\partial x}\frac{dx}{dt} - u\right) \end{cases}$$

- *State space*: position, speed, current
- *Measured outputs*: position,current
- *Input*: u



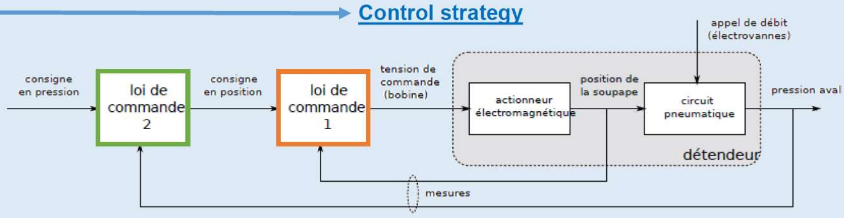


Pressure modeling → Control strategy

State space:

$$\dot{P}_2 = r\frac{T_2}{V_2}\left[\underbrace{\rho_1\left(\frac{2}{\gamma+1}\right)^{\frac{1}{\gamma-1}}\sqrt{\frac{\gamma r 2\,T_1}{\gamma+1}}\,S_{col}(x)}_{D_{in}} - D_{out}\right]$$

- *State space*: pressure
- *Measured outputs*: pressure
- *Input*: D_{in}

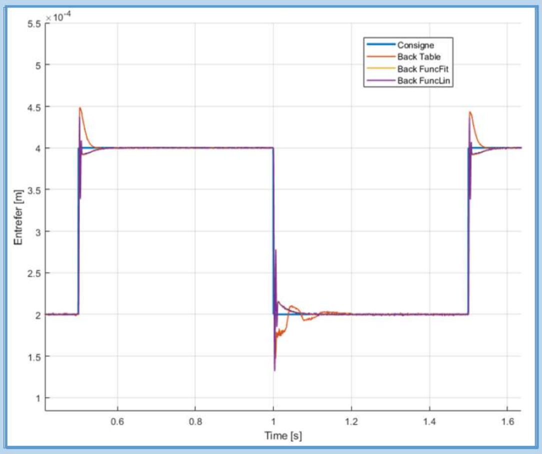


Control design & Expérimental results

Positioning control

A **Backstepping control** has been designed in two steps:

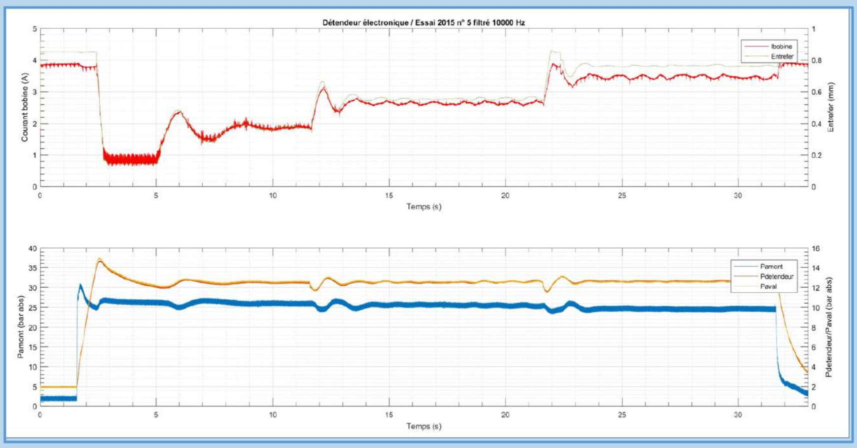
- First, stabilize the mechanical subsystem by calculating the appropriate magnetic force
- Then, **drive the coil current** with the voltage control input in order **to maintain the actual** magnetic force to the desired one



Pressure control

A **Proportional-Integral (PI) control** has been designed in order to regulate the output pressure by compensating the unknown output flow.

It computes the reference the **Backstepping controller** has to track.



Conclusion

- ✓ Theorical to experimental work
- ✓ Control effective with good performances
- ☐ A few improvements left to improve the closed-loop properties

Outlook

- ➢ Use of FPGA or µC to control the system
- ➢ Improve the system power amplifier
- ➢ Use optimization process to find the best control parameters