WIEFP 2022

NOVEMBER 22-23 ▪ SÃO PAULO ▪ BRAZIL

THERMOHYDRAULIC MODELING OF AN ELECTRO-HYDRAULIC SERVO ACTUATOR ON DAMPED MODE

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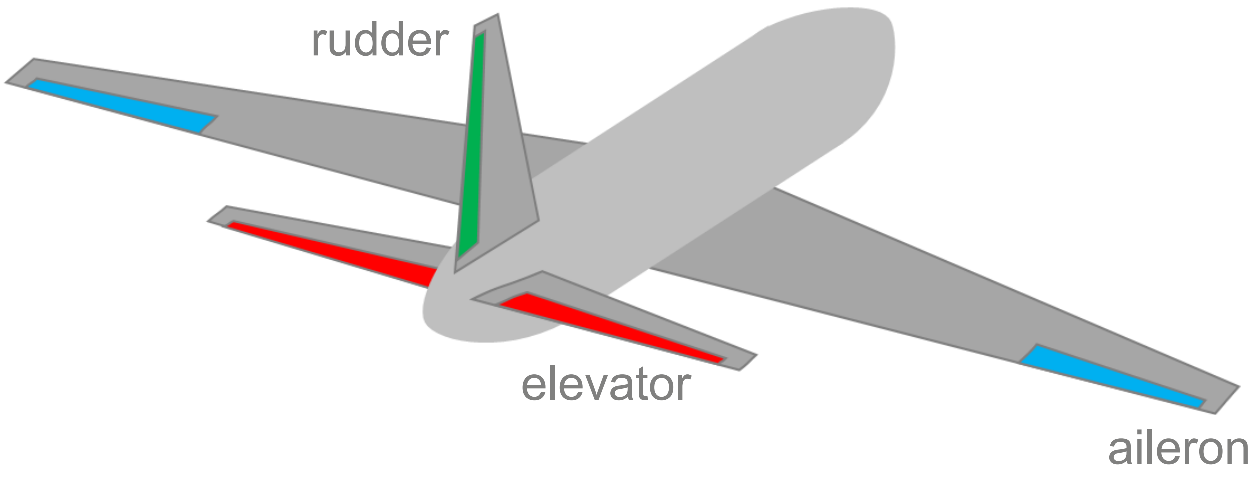
- Hydraulic powered flight control systems are widely used in aviation
- The primary surfaces are essential for aircraft control and must meet safety requirements

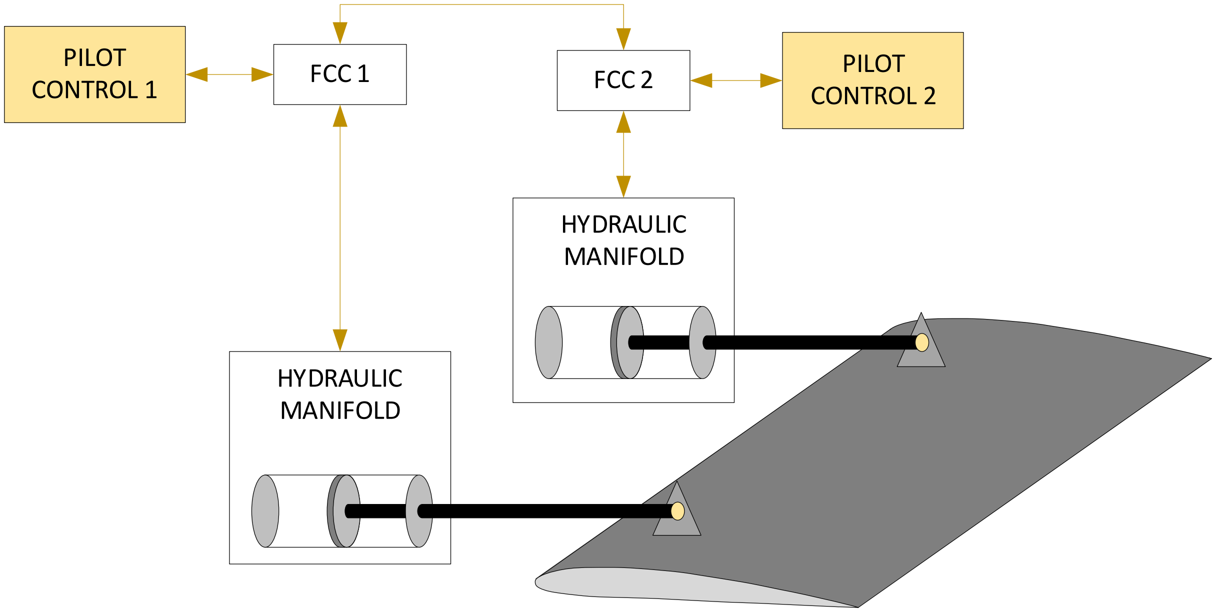


Motivation and Objective

- Smaller, lighter and more efficient
- Flutter criteria and dynamic requirements
- Temperature and thermal effects
- Avoid overheating

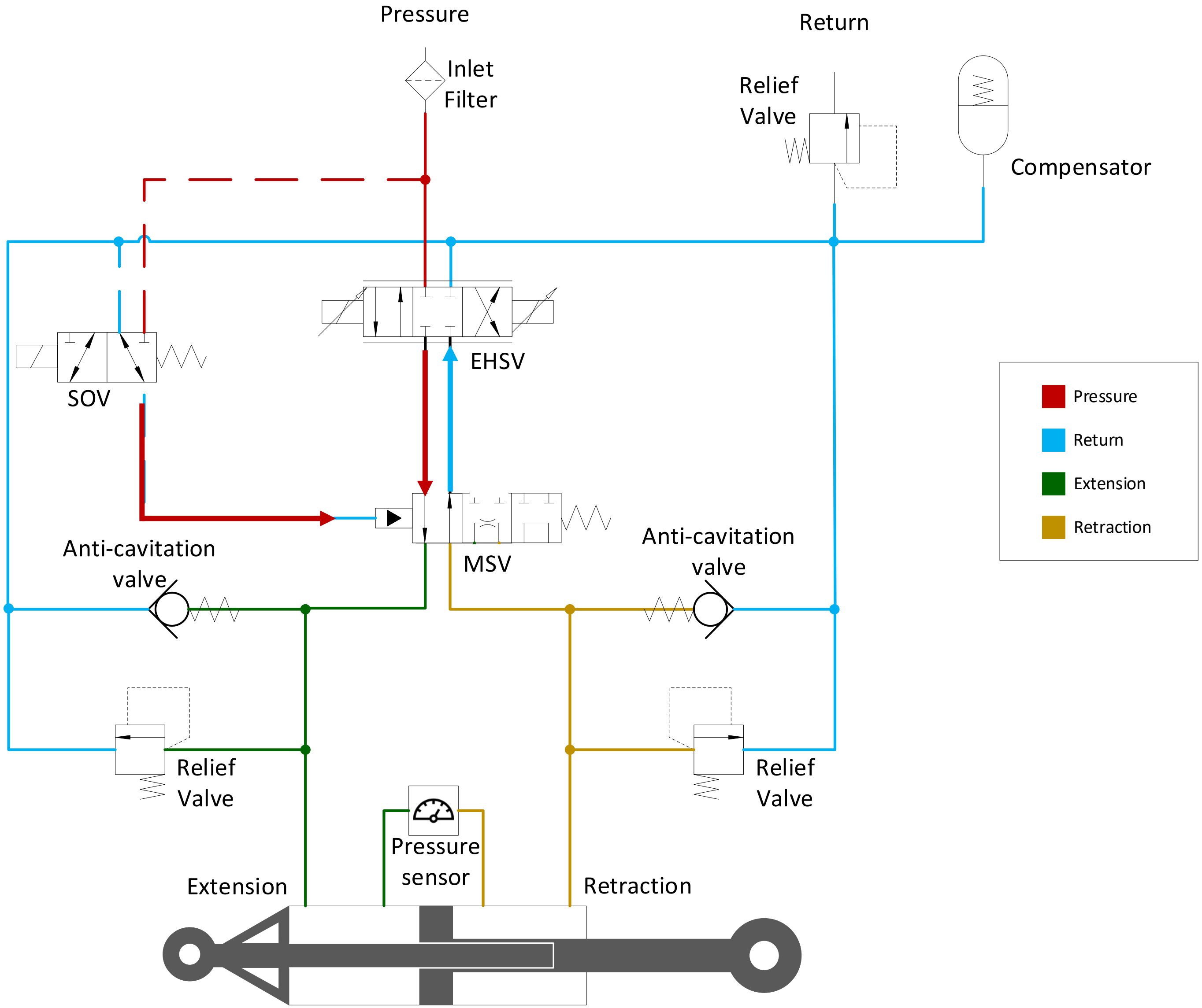
- This study focuses on modeling the thermal behavior of the main components of a flight control system in the damped operation of a civil aircraft

Flight Control System Architecture

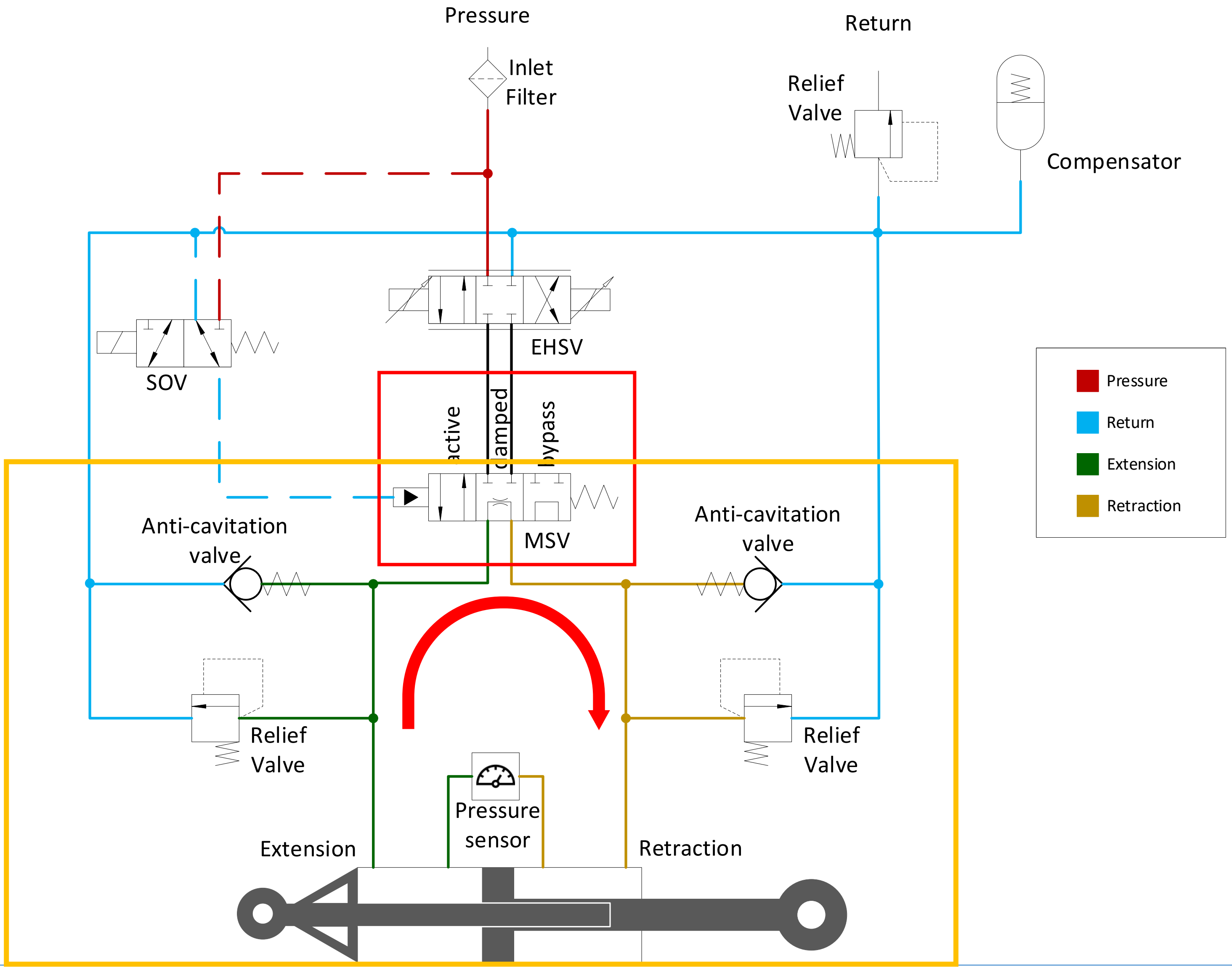


- Two Flight Control Computer (FCC)
- Two Electro-Hydraulic Servo Actuators (EHSA)
- Two operation modes
  - Active-active
  - Active-standby
  - Active-damped

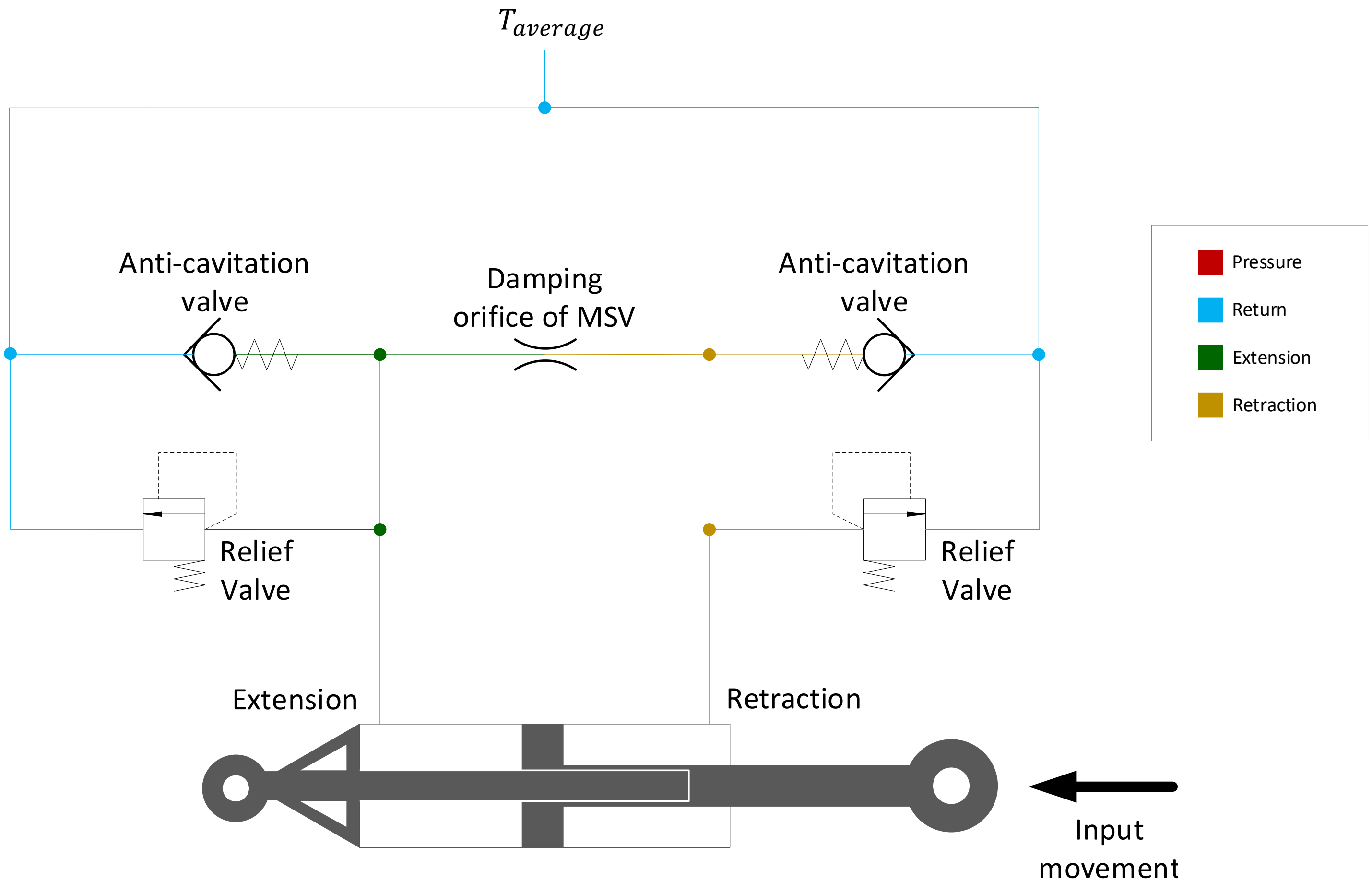
Active Operation



Damped Operation



Actuation Architecture



Resistive Elements

- Mass flow

$$\dot{m} = \rho \cdot c_q \cdot A \cdot \sqrt{\frac{2}{\rho}(p_1 - p_2)}$$

- Temperature increase

$$\frac{dh}{dt} = c_p \frac{dT}{dt} + \frac{(1 - \alpha T)}{\rho} \frac{dp}{dt}$$

$$T_{out} = T_{in} + \frac{(1 - \alpha T_{in}) \cdot |\Delta p|}{\rho \cdot c_p}$$

- Pressure variation

$$d\rho = \left(\frac{\partial \rho}{\partial p}\right)_T dp + \left(\frac{\partial \rho}{\partial T}\right)_p dT$$

$$\alpha(\mathrm{p}, \mathrm{T}) = -\frac{1}{\rho} \cdot \frac{\partial \rho}{\partial \mathrm{T}}$$

$$\beta_t = -\mathrm{V} \cdot \frac{\partial \mathrm{p}}{\partial \mathrm{V}} = \rho \frac{\partial \mathrm{p}}{\partial \rho}$$

$$\frac{dp}{dt} = \beta \left(\frac{\Sigma(\dot{m}) - \rho \frac{dV}{dt}}{\rho V} + \alpha \frac{dT}{dt}\right)$$

- Temperature variation

$$\frac{dE}{dt} = \dot{Q} - p\frac{dV}{dt} + \sum \dot{m}\,h$$

$$\frac{dE}{dt} = \frac{dU}{dt} = \frac{d(mh - pV)}{dt}$$

$$\frac{dh}{dt} = c_p\frac{dT}{dt} + \frac{(1 - \alpha T)}{\rho}\frac{dp}{dt}$$

$$\frac{dT}{dt} = \frac{\dot{Q} + \Sigma(\dot{m}\mathrm{h_i}) - h \cdot \Sigma(\dot{m})}{\rho \cdot c_p \cdot V} + \frac{\alpha \cdot T}{\rho \cdot c_p}\frac{dp}{dt}$$

Thermal Exchanges

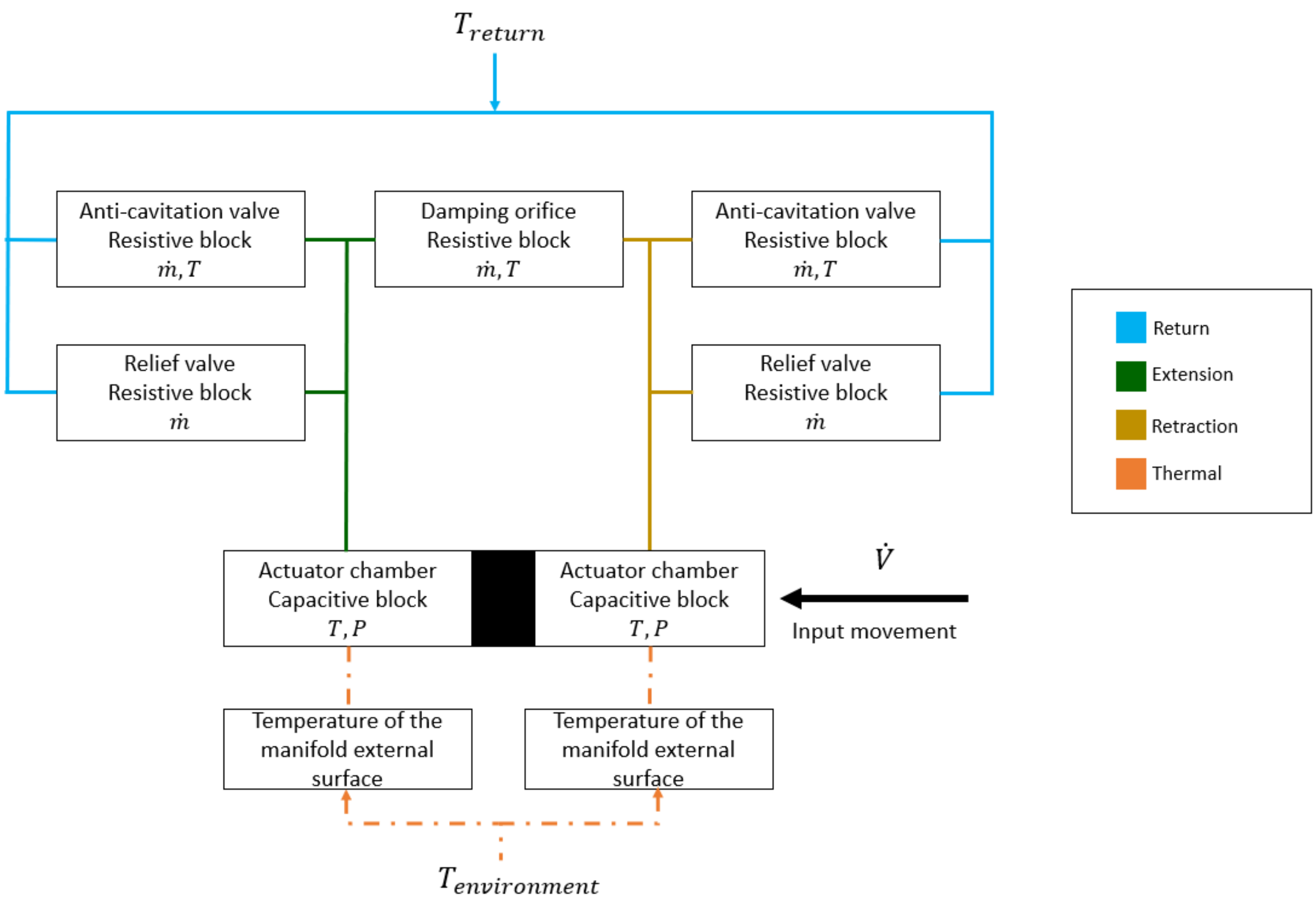
- Total thermal resistance and equivalent capacitance

$$R_{tot} = \sum R = \frac{\Delta T}{\dot{Q}} = \frac{1}{U_t A}$$

$$\frac{dT}{dt} = \frac{\sum \dot{Q}}{m c_p} = \frac{\sum \dot{Q}}{C_t}$$

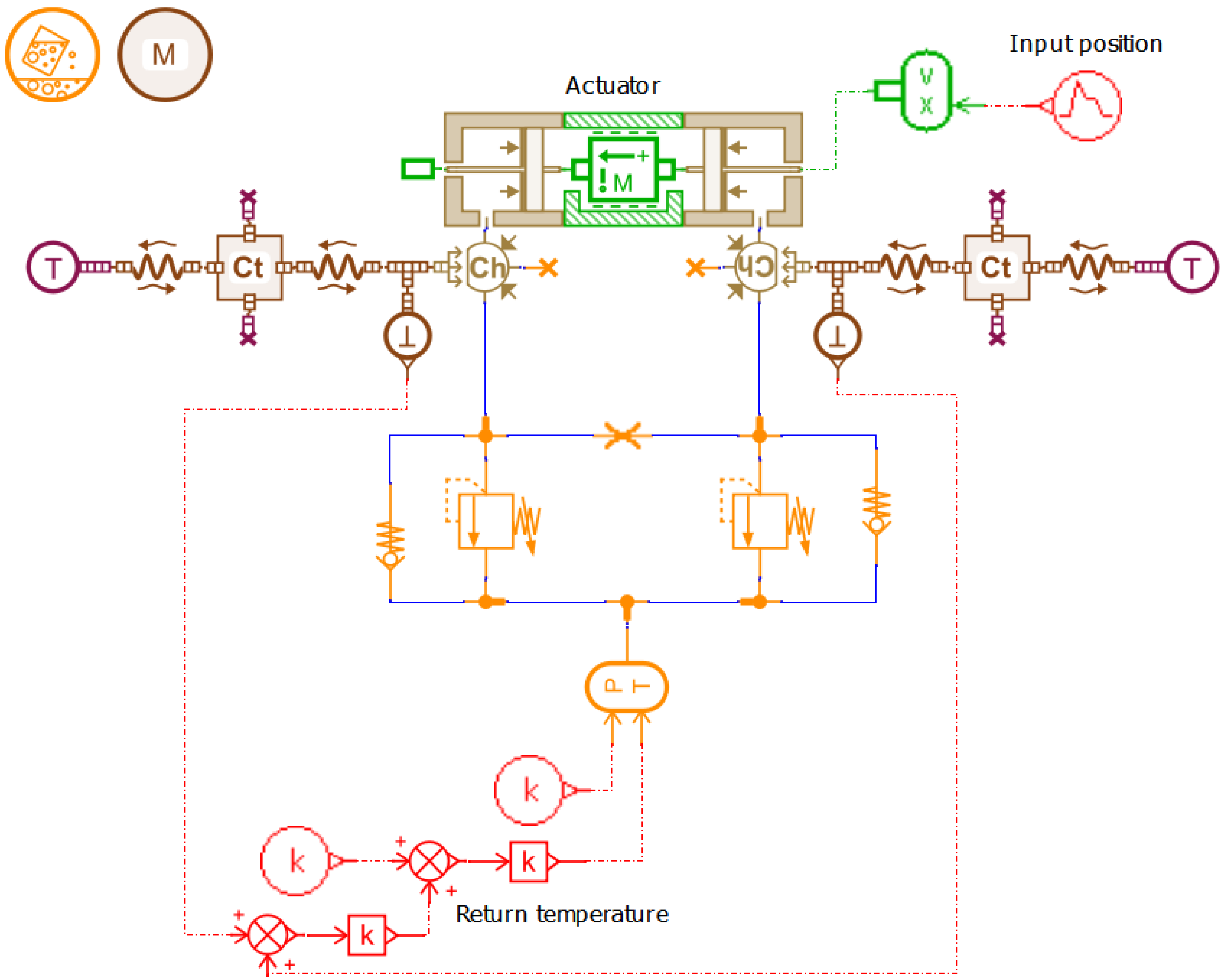
Modeling Platforms

- Building blocks in MATLAB/Simulink



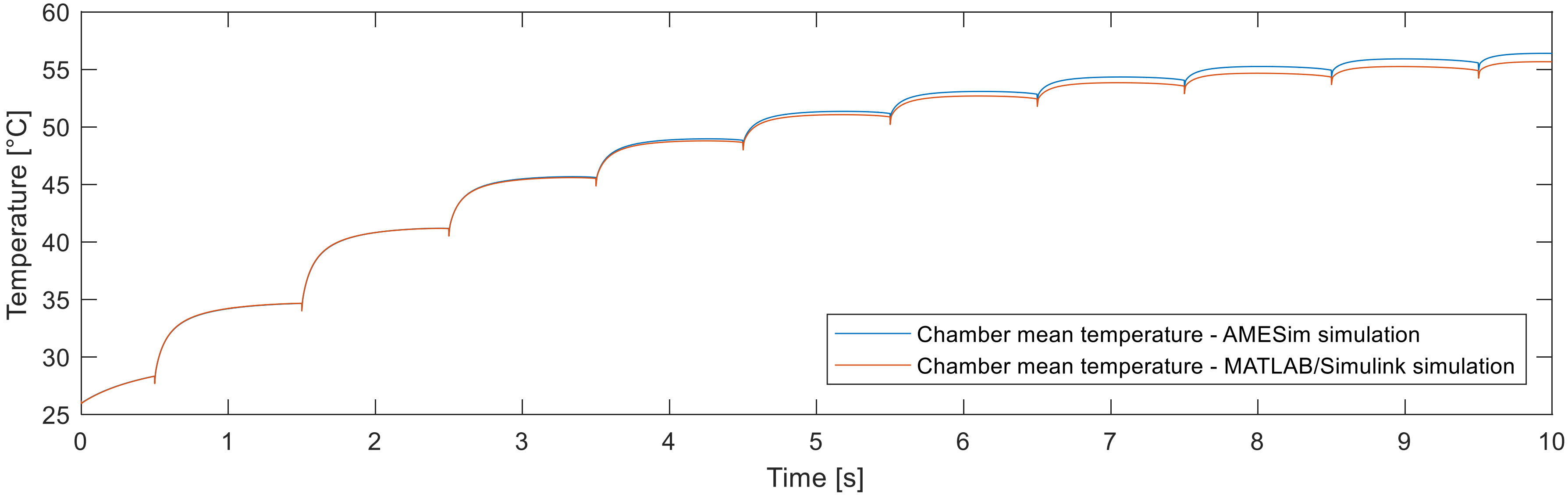
Modeling Platforms

- Building blocks in AMESIM

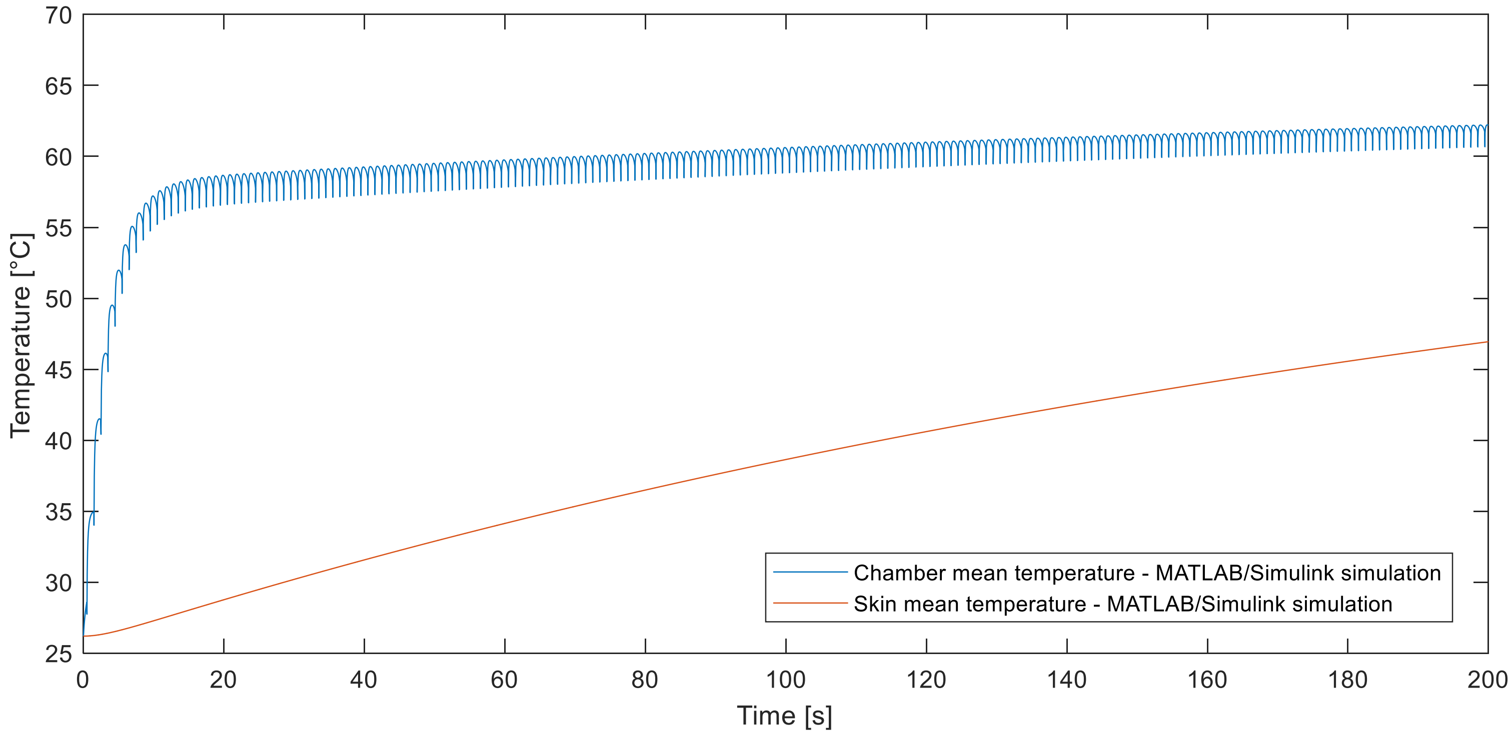


Results

- Both software achieved similar behaviors
- 1.3% of variation after 10s
- Fluid modeling: standard SAE AS1241 and built-in



- Cases evaluated did not induce overheating
- Different test conditions are possible with the model



Conclusion

- Both models achieved satisfactory results
- The models can simulate the temperature of the manifold
- The thermohydraulic blocks can be reused

Future Assessments:

- To evaluate the heat transfer inside the manifold
- To compare the results achieved with data from tests to verify hypothesis and thermal coefficients
- To perform a sensitivity analysis regarding the temperature impacts of each design change
- To perform a parametric identification to fit the models

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