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Inter-Code Calibration exercise series#2, Amaryllis results

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Leading Partner in
Test & Mechatronic Simulation

LMS
ENGINEERING INNOVATION

SAMCEF Amaryllis

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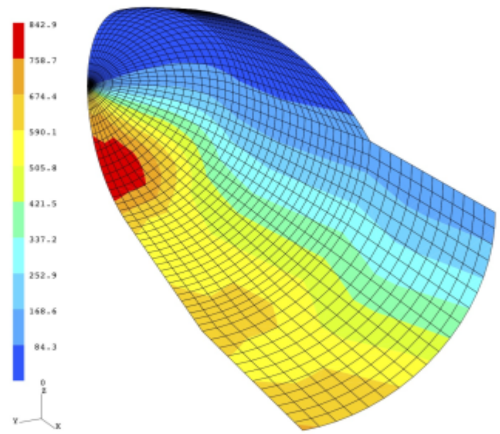
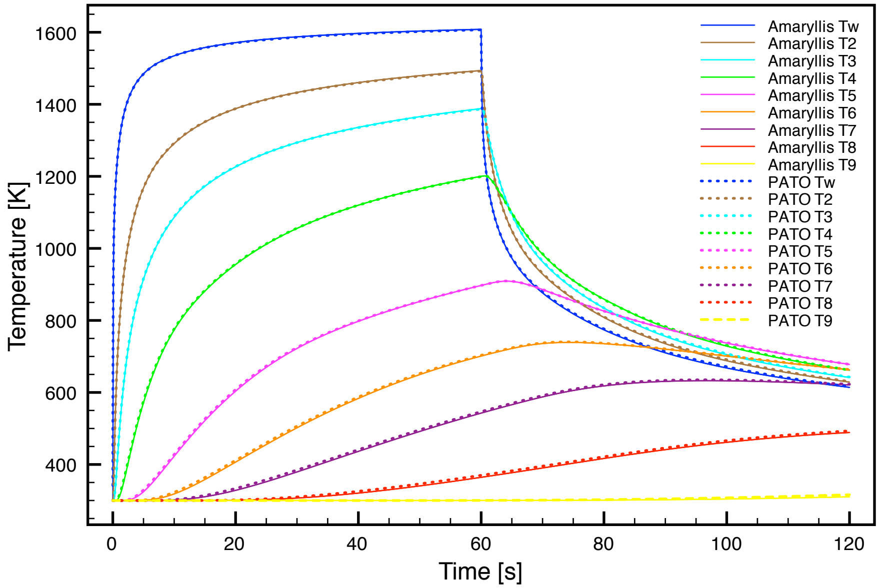
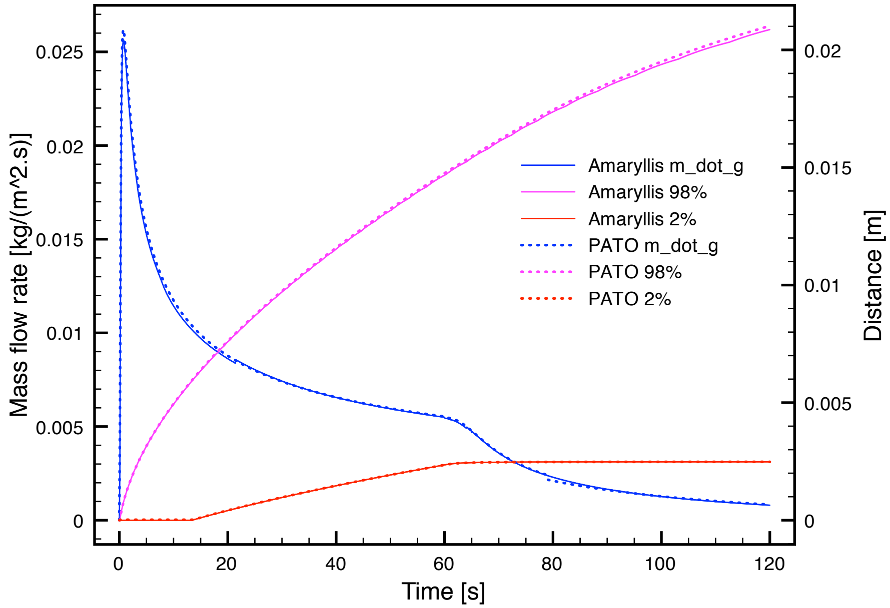
- 1D/Axis-symmetric/3D finite element code:
  - Non-linear structural analysis + thermal + charring-ablation code
  - Temperature (T), Pressure (P), density (ρ) and species density (α_i)
  - Mesh deformation due to ablation (multiple ablation zones)
  - Thermal contact algorithms for contact between:
    - Different ablation zones
    - Support structure and ablation zone
  - Multiple boundary condition types:
    - Convection (classical, enthalpy form)
    - flux
    - radiation
  - Ablation (imposed boundary condition):
    - Phase change
    - Chemical (explicit ablation speed or Bc' table; Bc'=Bc'(T,P,Bg'))
    - Mechanical (erosion; temperature and/or density dependent)
  - Fully coupled thermo-mechanical solution (char swell)

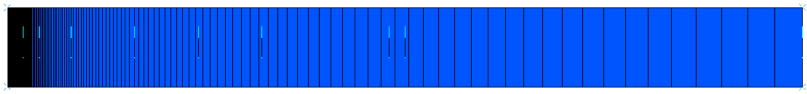


Amaryllis Test 2.1

- Comparison Amaryllis:
  - PATO-PAM2 results are “identical”
  - No CMA/FIAT baseline available
- Fine mesh distribution is needed for the gas mass flow, not for temperatures

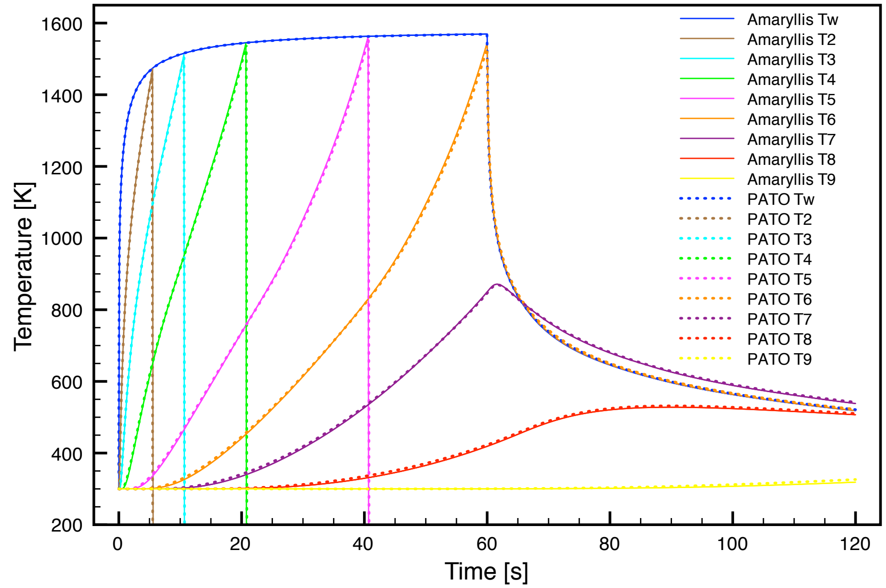


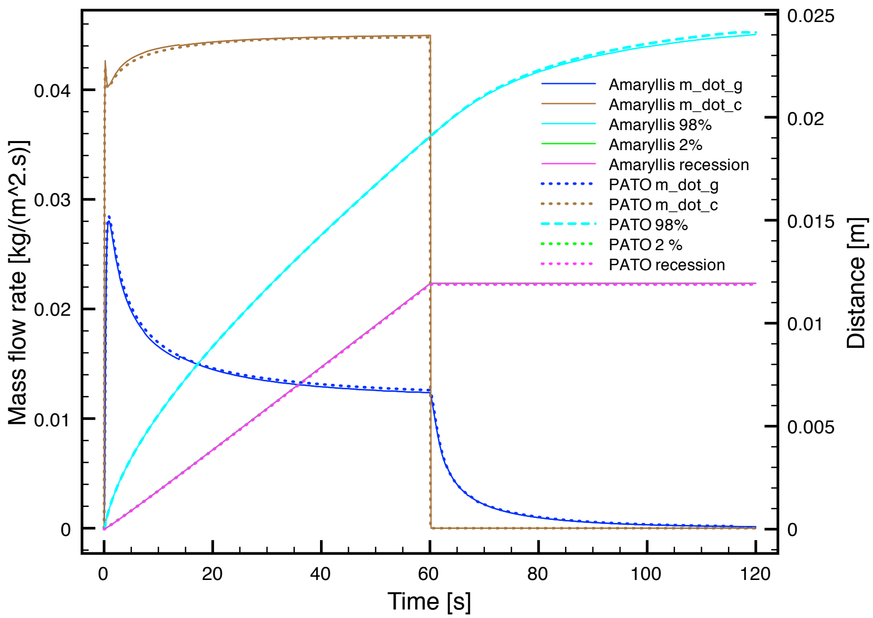




Amaryllis Test 2.2

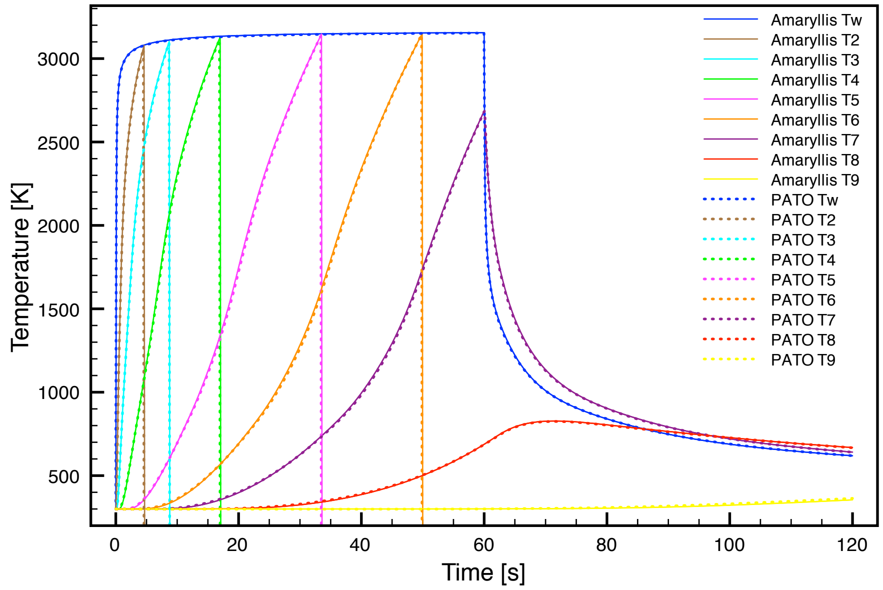
- Comparison Amaryllis:
  - PATO-PAM2 results are “identical”
  - No CMA/FIAT baseline available

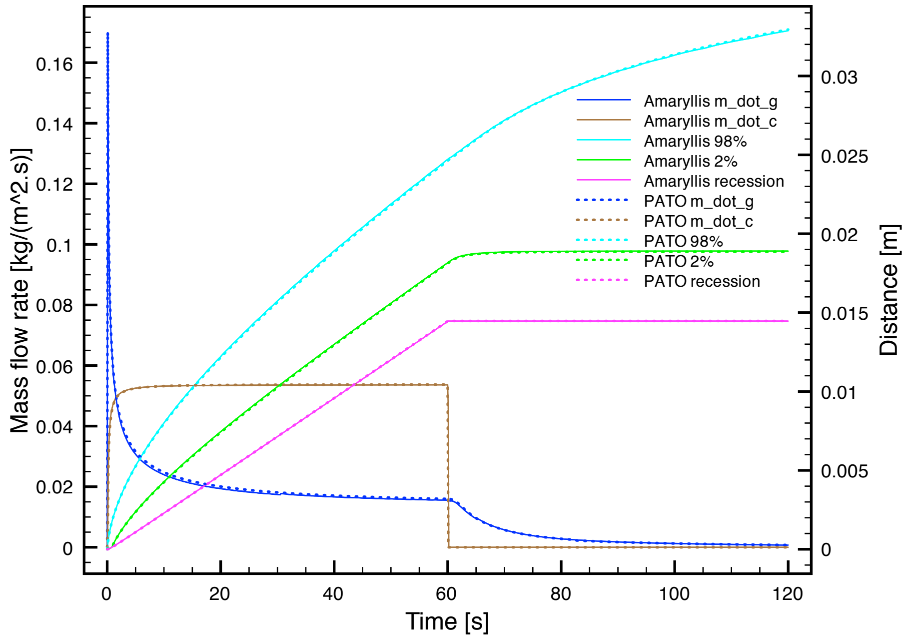




Amaryllis Test 2.3

- Comparison Amaryllis:
  - PATO-PAM2 results are “identical”
  - No CMA/FIAT baseline available





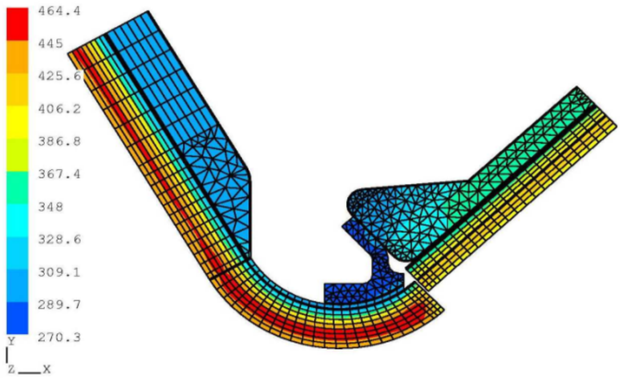
SAMCEF Amaryllis

- Arrhenius type charring equations

$$\dot{\rho} = -\sum \Delta\rho^i A_i \rho_v^{1-N_i} \left(\rho_v - \rho_c\right)^{N_i - 1} \left(1 - \alpha_i\right)^{N_i} e^{-E_i/RT}$$

  - Generalized densities $0 \le \alpha_i \le 1$

$$\rho = \rho_v - \sum \Delta\rho^i \alpha_i$$



- Mass balance equations

$$\nabla.\left(K_p \nabla P\right) = \dot{\rho}$$

$$\dot{\overline{m}}^g = -K_P \nabla P$$

- Heat balance equation

$$-\frac{\partial\rho}{\partial t} H_p + \rho c \frac{\partial T}{\partial t} = \nabla.\left(\lambda \nabla T\right) - \dot{\overline{m}}^g . \nabla h^g$$

$$\overline{q} = -\lambda . \nabla T$$

SAMCEF Amaryllis

- Equivalence with the FIAT formulation.
  - Interpolation $$\alpha = \frac{\rho_v - \rho}{\rho_v - \rho_c}$$
    - Capacity $$\rho c = \rho c_v(T) - \alpha\left(\rho c_v(T) - \rho c_c(T)\right)$$
  - Pyrolysis heat $$H_p = h^g - \frac{\rho_v h_v - \rho_c h_c}{\rho_v - \rho_c}$$
  - Charring $$\Delta\rho^i = \frac{\rho_{0_i} - \rho_{r_i}}{\sum\left(\rho_{0_i} - \rho_{r_i}\right)}\left(\rho_v - \rho_c\right) \qquad A_i = \frac{\Gamma_i(1-\varphi)B_i\rho_{0_i}^{1-N_i}\left(\rho_{0_i} - \rho_{r_i}\right)^{N_i}}{\Delta\rho^i\rho_v^{1-N_i}\left(\rho_v - \rho_c\right)^{N_i - 1}}$$
- Difference with the FIAT formulation
  - Interpolation
    - conductivity $$\lambda(T,\rho) = \lambda_v(T) - \alpha\left(\lambda_v(T) - \lambda_c(T)\right)$$
  - Mass balance
    - Perfect gas: $$K_P = \frac{M^g \beta P}{\mu R T} \qquad \beta = \beta_v \frac{\Omega}{\Omega_v} \qquad \Omega = \Omega_v + (1 - \Omega_v)\frac{\rho_v - \rho}{\rho_v}$$
    - K_p interpolation: $$K_p(T,\rho) = K_{p_v}(T) - \alpha\left(K_{p_v}(T) - K_{p_c}(T)\right)$$