

# MOPAR: Results for the Inter-code Calibration

Jonathan E. Wiebenga and Iain D. Boyd  
University of Michigan

Alexandre Martin  
University of Kentucky

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- Modeling of Pyrolysis and Ablation Response
- Uses the same formulation as a code developed at Sandia National Laboratory and North Carolina State University (Amar, Blackwell, and Edwards)
- Includes pyrolysis gas phase equation
- Includes moving boundaries using Landau coordinates
- Includes spherical and cylindrical coordinates
- Allows ablation of both sides of the domain
- Takes into account the kinetic energy of the pyrolysis gas
- Models the flow through porous media using Forchheimer's Law

## Mixture Energy Equation

$$\underbrace{\int_{cs} \dot{\mathbf{q}}'' \cdot d\mathbf{S}}_{\text{conduction}} + \underbrace{\int_{cs} \phi \rho_g h_g \mathbf{v}_g \cdot d\mathbf{S}}_{\text{gas flux}} - \underbrace{\int_{cs} \rho h \mathbf{v}_{cs} \cdot d\mathbf{S}}_{\text{grid convection}} + \underbrace{\frac{d}{dt} \int_{cv} \rho e dV}_{\text{energy content}} = 0$$

## Solid Phase Continuity Equation

$$\underbrace{\frac{d}{dt} \int_{cv} \rho_s dV}_{\text{solid mass content}} - \underbrace{\int_{cs} \rho_s \mathbf{v}_{cs} \cdot d\mathbf{S}}_{\text{grid convection}} = \underbrace{\int_{cv} \dot{m}_s''' dV}_{\text{solid mass source}}$$

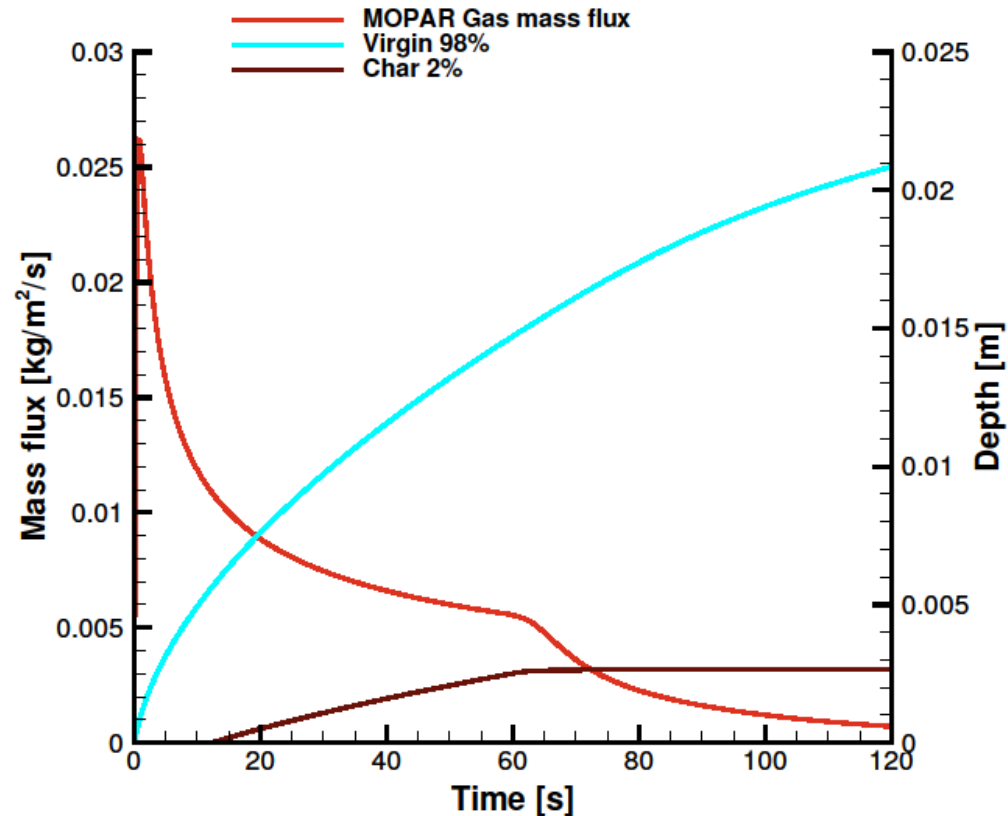
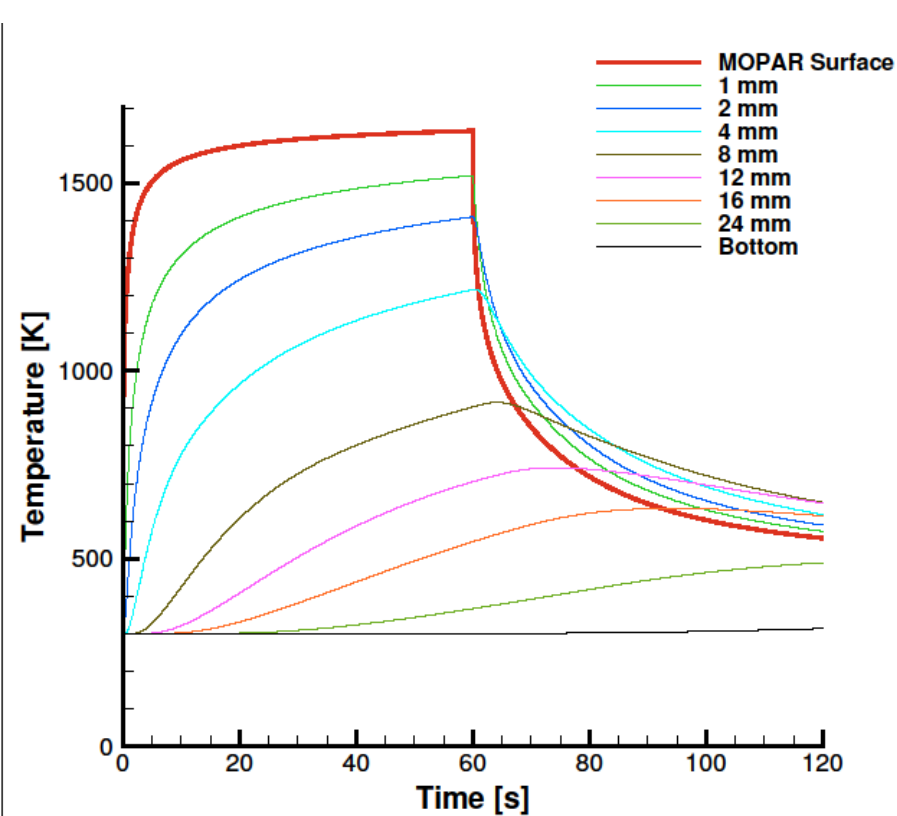
## Gas Phase Continuity Equation

$$\underbrace{\frac{d}{dt} \int_{cv} \phi \rho_g dV}_{\text{gas mass content}} + \underbrace{\int_{cs} \phi \rho_g \mathbf{v}_g \cdot d\mathbf{S}}_{\text{gas flux}} - \underbrace{\int_{cs} \phi \rho_g \mathbf{v}_{cs} \cdot d\mathbf{S}}_{\text{grid convection}} = \underbrace{\int_{cv} \dot{m}_g''' dV}_{\text{gas mass source}}$$

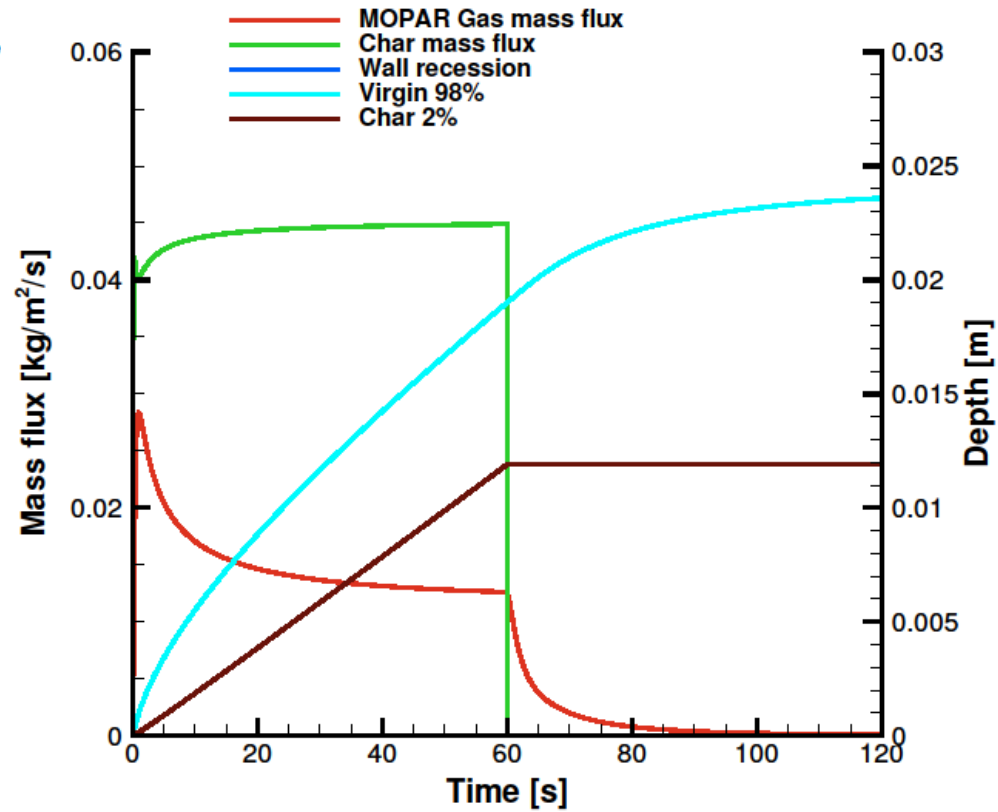
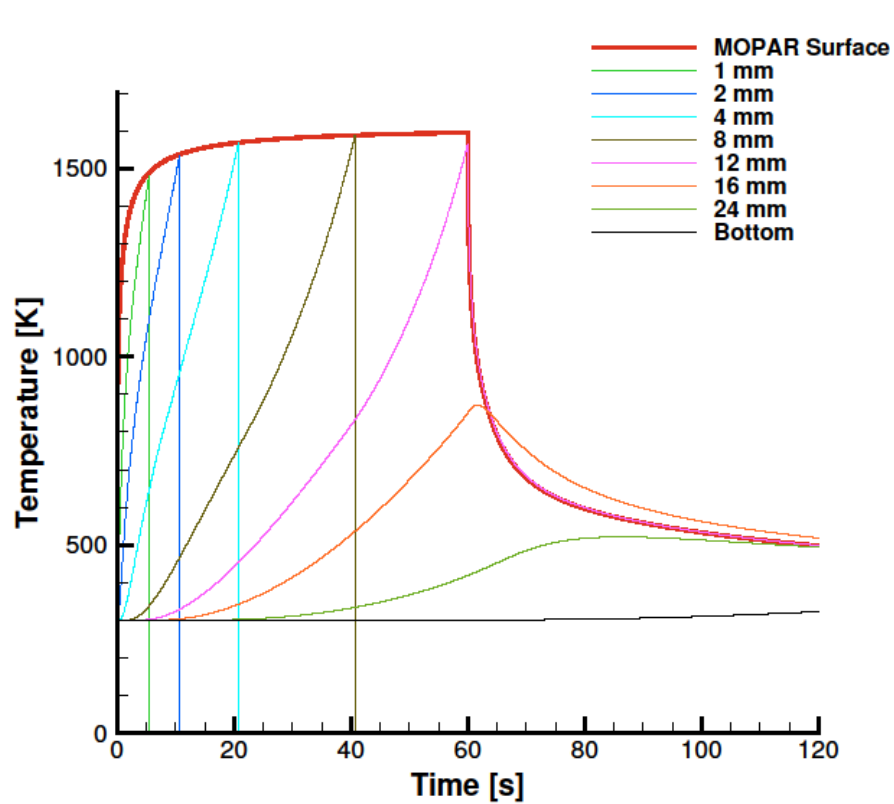
## Forchheimer's law

$$\frac{\partial p}{\partial x} = -\frac{\mu}{K} v_g' - \beta \rho v_g'^2$$

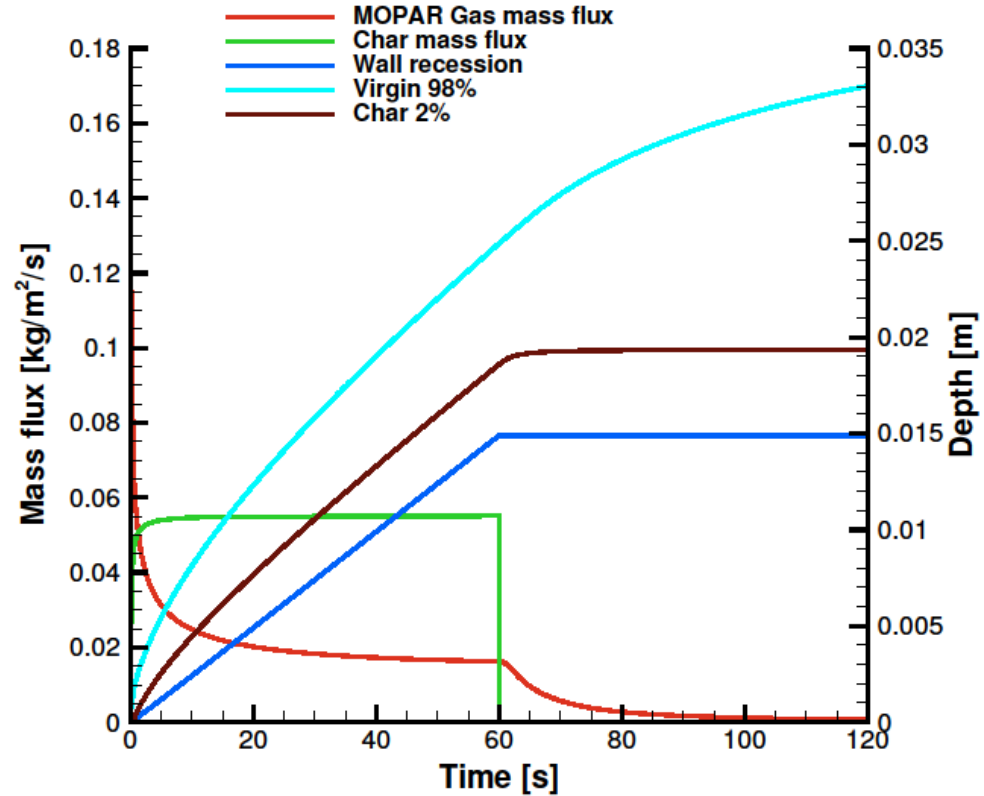
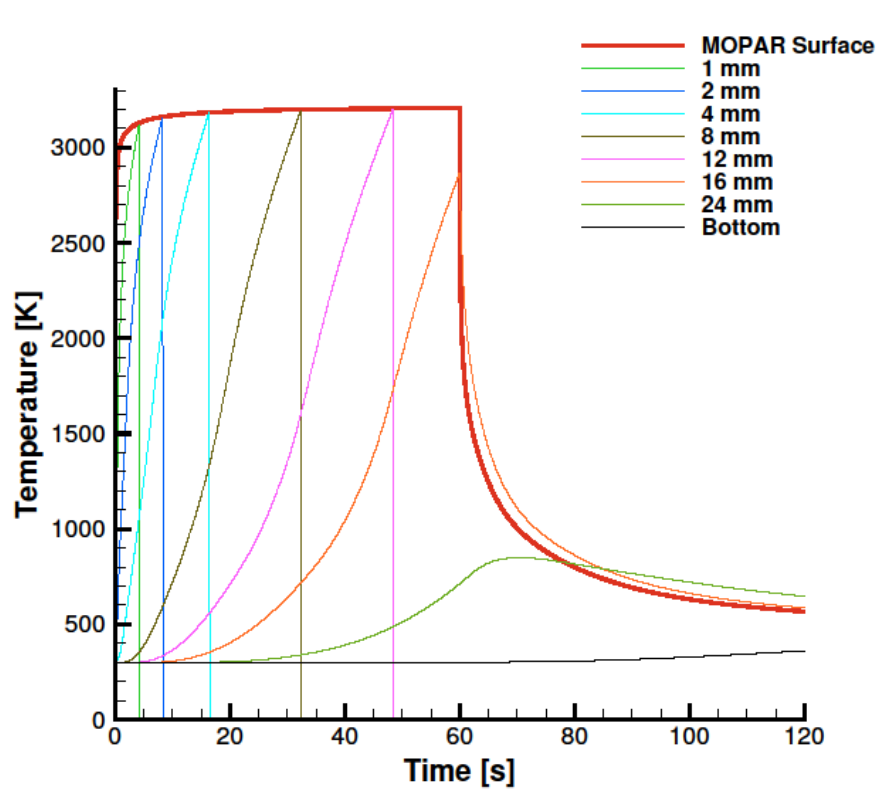
# Test Case 2.1



# Test Case 2.2



# Test Case 2.3



# Comments

- Needed to set recession rate to 0.0 after 60s for case 2.3 to prevent negative recession during cool down
- Other cases ran robustly without specifying recession rate