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YRA poster session - July 25 2019

July 2019

Changing the World's Energy Future

Paolo Balestra, Sebastian Schunert, Gerhard Strydom, R. Carlsen, S. R. Sen, R. C. Martineau

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Pronghorn: A MOOSE Based TH Tool for Advanced Reactor Concepts

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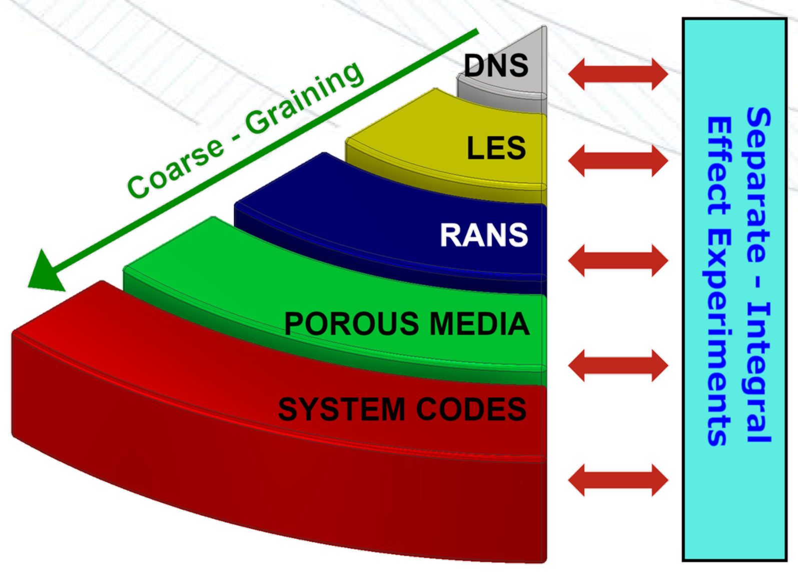
Reactor Systems Design and Analysis, Nuclear Engineering Methods Development

Pronghorn history & activities

- NEK5000
- STARCCM+
- Pronghorn
- RELAP5-3D
- RELAP-7



Pronghorn under the hood

Governing Equations, Approach #1: Two-Phases with Compressible Flow Phase and a Stationary Solid Phase

Conservation of Mass

$$\frac{\partial \alpha\rho}{\partial t} + \nabla\cdot(\alpha\rho\vec{u}) = 0$$

Balance of Momentum

$$\frac{\partial \alpha\rho\vec{u}}{\partial t} + \nabla\cdot\left[\alpha(\rho\vec{u}\otimes\vec{u} + p\mathbf{I})\right] = p_i\nabla\alpha + \nabla\cdot(\alpha\mu_{eff}\nabla\vec{u}) + \alpha(1-\alpha)K_m(\vec{u}_s - \vec{u})$$

Conservation of Total Energ

$$\frac{\partial \alpha\rho E}{\partial t} + \nabla\cdot(\alpha\rho\vec{u}H) = p_i\vec{u}_i\cdot\nabla\alpha - \nabla\cdot(\alpha\vec{q}) + \alpha\rho Q + \alpha(1-\alpha)K_e(T_s - T) + \vec{u}\cdot(\alpha\rho\vec{g})$$

Solid Phase Energy Balance

$$(1-\alpha)\rho_s c_{v,s}\frac{\partial T_s}{\partial t} = \nabla\cdot\left[(1-\alpha)\vec{q}_s\right] + (1-\alpha)\rho_s Q_s - \alpha(1-\alpha)K_e(T_s - T)$$

Governing Equations, Approach #2: Thermally Expansive, Nearly Incompressible (liquid) Flow Phase and a Stationary Solid Phase

Conservation of Mass

$$\frac{\partial \alpha\rho}{\partial t} + \nabla\cdot(\alpha\rho\vec{u}) = 0$$

Balance of Momentum

$$\alpha\rho\frac{D\vec{u}}{Dt} = -\alpha\nabla p + \nabla\cdot(\mu_{eff}\alpha\nabla\vec{u}) - \alpha(1-\alpha)K_m\vec{u} + \alpha\rho\vec{g}$$

Liquid Phase Energy Balance

$$\alpha\rho c_p\left(\frac{\partial T}{\partial t} + \nabla T\cdot\vec{u}\right) = (p - p_i)\vec{u}\cdot\nabla\alpha + \nabla\cdot(\alpha k_{eff}\nabla T) + \alpha\rho Q + \alpha(1-\alpha)K_e(T_s - T)$$

Solid Phase Energy Balance

$$(1-\alpha)\rho_s c_{v,s}\frac{\partial T_s}{\partial t} = \nabla\cdot\left[(1-\alpha)\vec{q}_s\right] + (1-\alpha)\rho_s Q_s - \alpha(1-\alpha)K_e(T_s - T)$$

Legacy Governing Equations, Approach #3: Porous flow approximation. Reproduces legacy THERMIX approach.

Conservation of Mass

$$\epsilon\frac{\partial \rho}{\partial t} + \nabla\cdot\left[\frac{\epsilon^2}{W}(-\nabla P + \rho_f\vec{g})\right] = 0$$

Balance Momentum

$$\epsilon\nabla P - \epsilon\rho_f\vec{g} + W\rho_f\vec{V} = 0$$

Liquid Phase Energy Balance

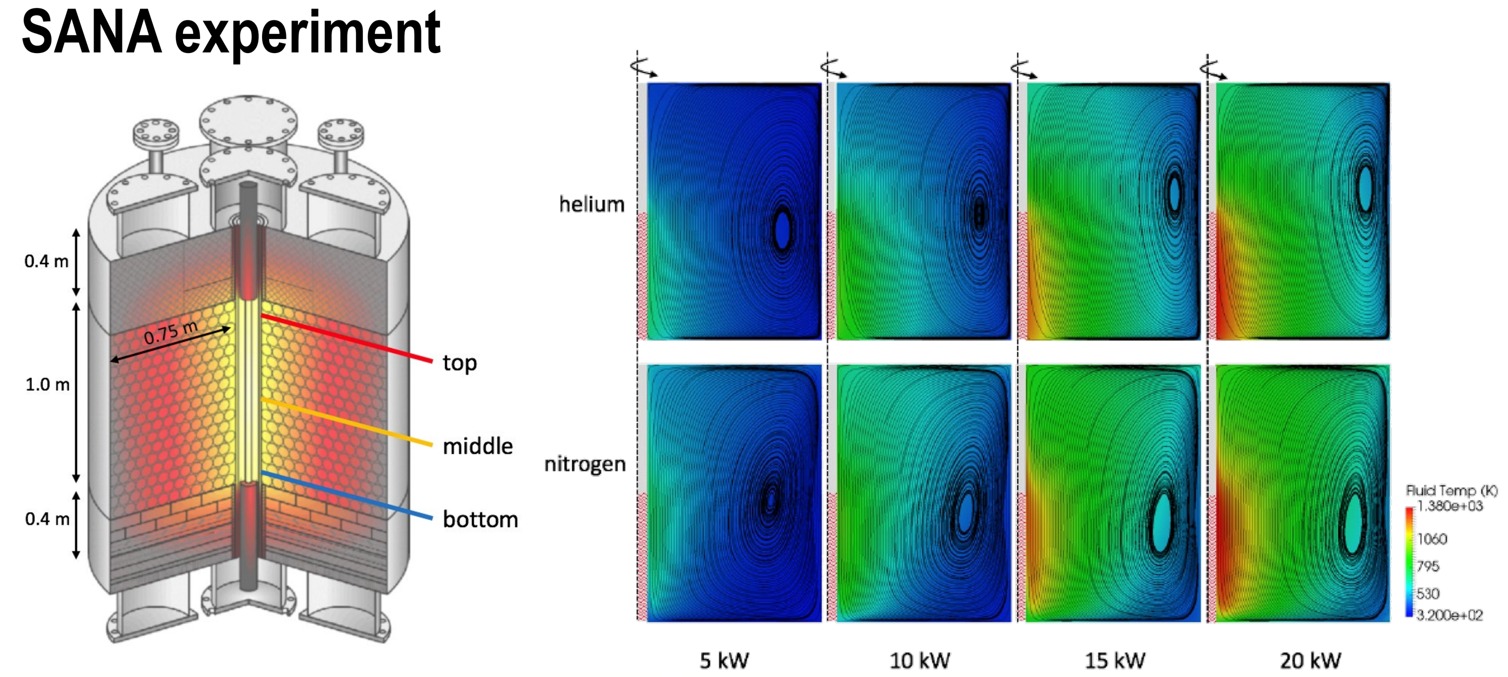
$$\epsilon\rho_f C_{p,f}\frac{\partial T_f}{\partial t} + \epsilon\rho_f C_{p,f}\vec{V}\cdot\nabla T_f - \nabla\cdot(\kappa_f\nabla T_f) + \alpha(T_f - T_s) + \dot{q}_f = 0$$

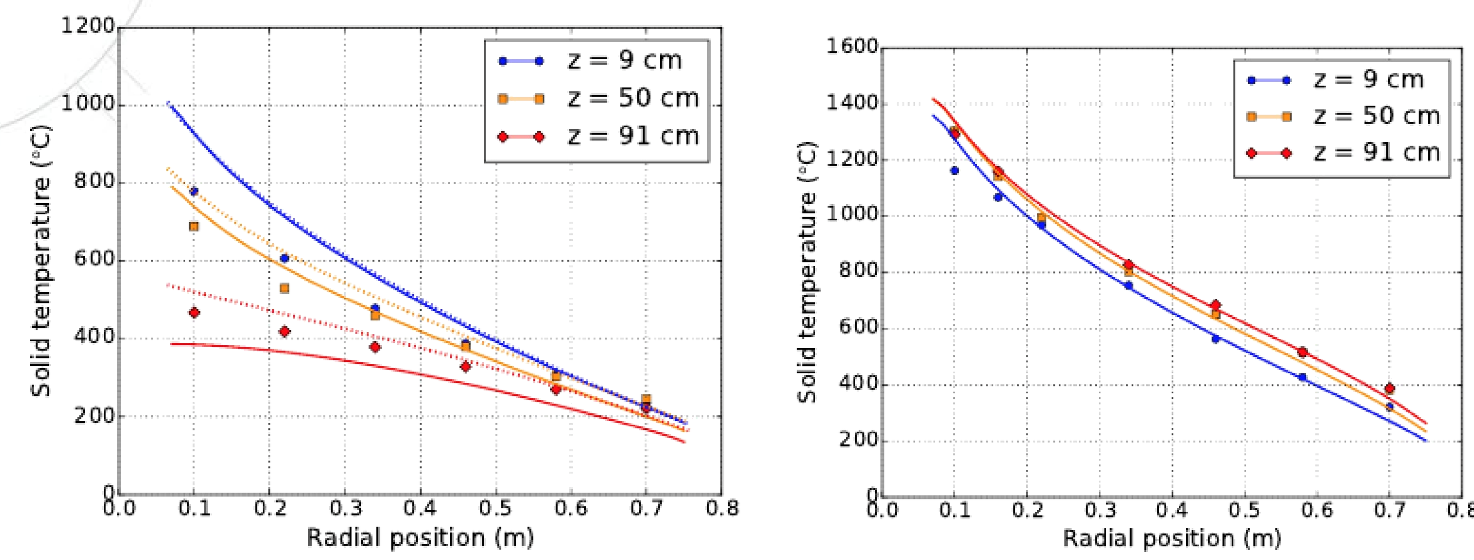
Solid Phase Energy Balance

$$(1-\epsilon)\rho_s C_{p,s}\frac{\partial T_s}{\partial t} - \nabla\cdot(\kappa_s\nabla T_s) + \alpha(T_s - T_f) + \dot{q}_s = 0$$

Code Validation & Verification

- **SANA experiment**





- **PBMR-400 benchmark**