Computational Analysis of Metal Hydride Reactor for Thermal Energy Storage

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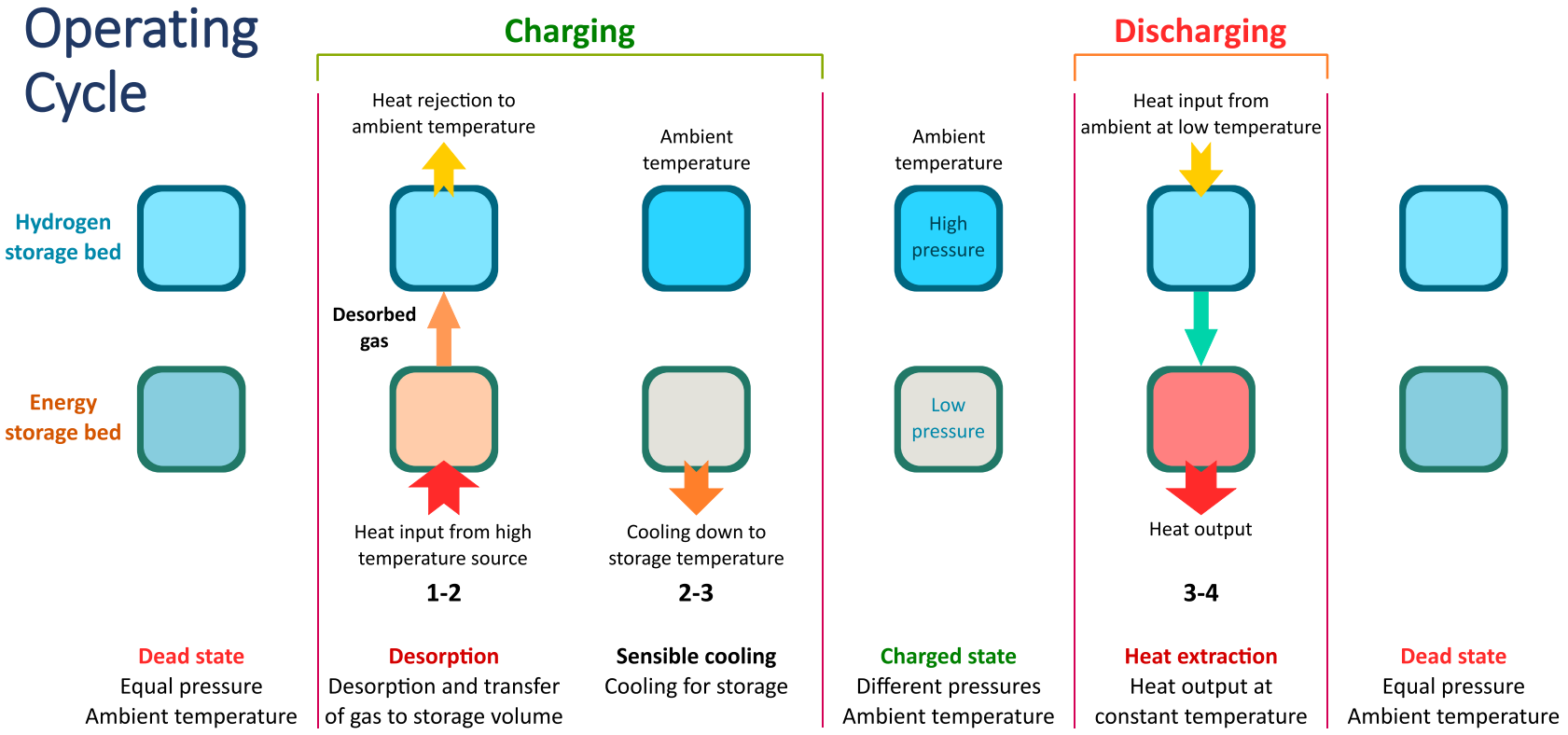
Thermal Energy Storage

- Heat storage systems – stores available heat for later use
- Thermochemical heat storage
  - Reversible chemical reaction with considerable amount of heat of reaction
  - High values for preliminary performance estimates
  - Possibility of storage at atmospheric temperature
- Metal hydrides
  - Already have undergone a lot of research for hydrogen storage

Metal hydrides: Thermal Energy Storage

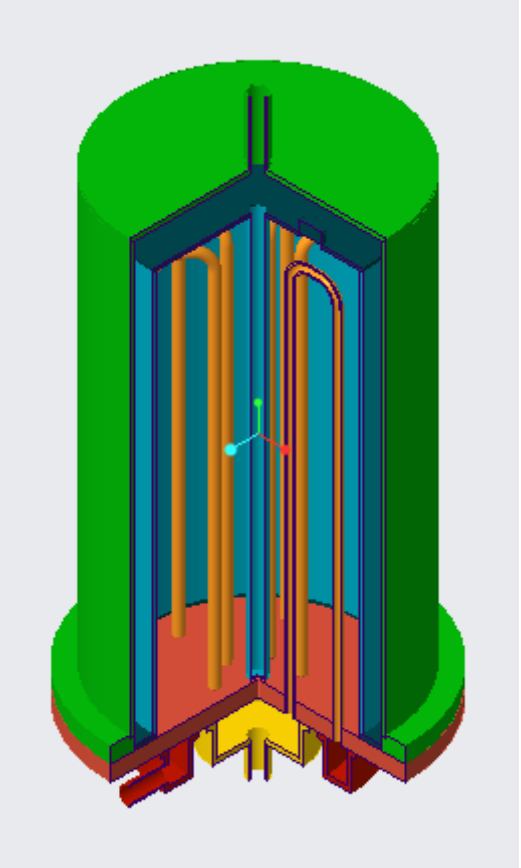


Reactors

- Enclose porous bed of powdered metal with pressurized gas and heat transfer equipment
- Reactor for heat absorption and release
  - Minimum heat loss to surroundings
  - Easy transport of heat from/to heat transfer fluid to/from porous metal hydride bed
  - Minimum heat capacities for passive materials
    - Higher discharge temperature
- Reactor for hydrogen storage
  - Easy removal/addition of heat to facilitate hydrogen absorption/release

Reactor : Initial configuration

- Radial layout of U-tubes
  - Hotter legs in the core
- Filter enclosing metal around the tube bundle
- Outer shell enclosing hydrogen supply
- With/without fins

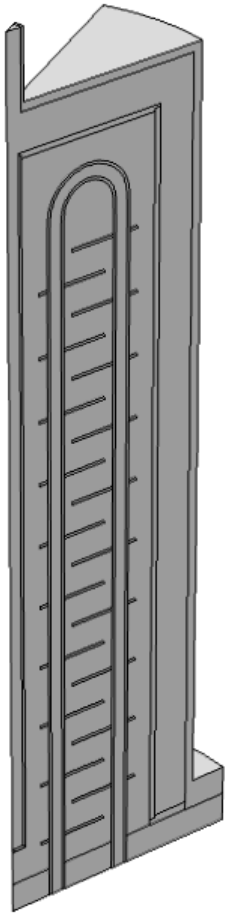


Reactors : Simulation

- Chemical reaction
  - Metal hydride formation/decomposition
- Gaseous hydrogen transport through solid porous metal bed
  - Absorption/liberation of hydrogen by/from metal
- Heat transfer from/to the heat transfer fluid
  - Heat generation/consumption in the bed due to hydride formation/decomposition reaction

Reactors : Simulation – COMSOL Multiphysics®

- Geometry – single slice – asymmetry removed
- Chemical Reaction Engineering
  - (Initially by Coefficient Form PDE from mathematics)
  - Chemistry
  - Transport of Diluted Species
- CFD
  - Laminar/Turbulent Flow
  - Darcy's law/Free and Porous media Flow
- Heat Transfer
  - Heat Transfer in Porous Media



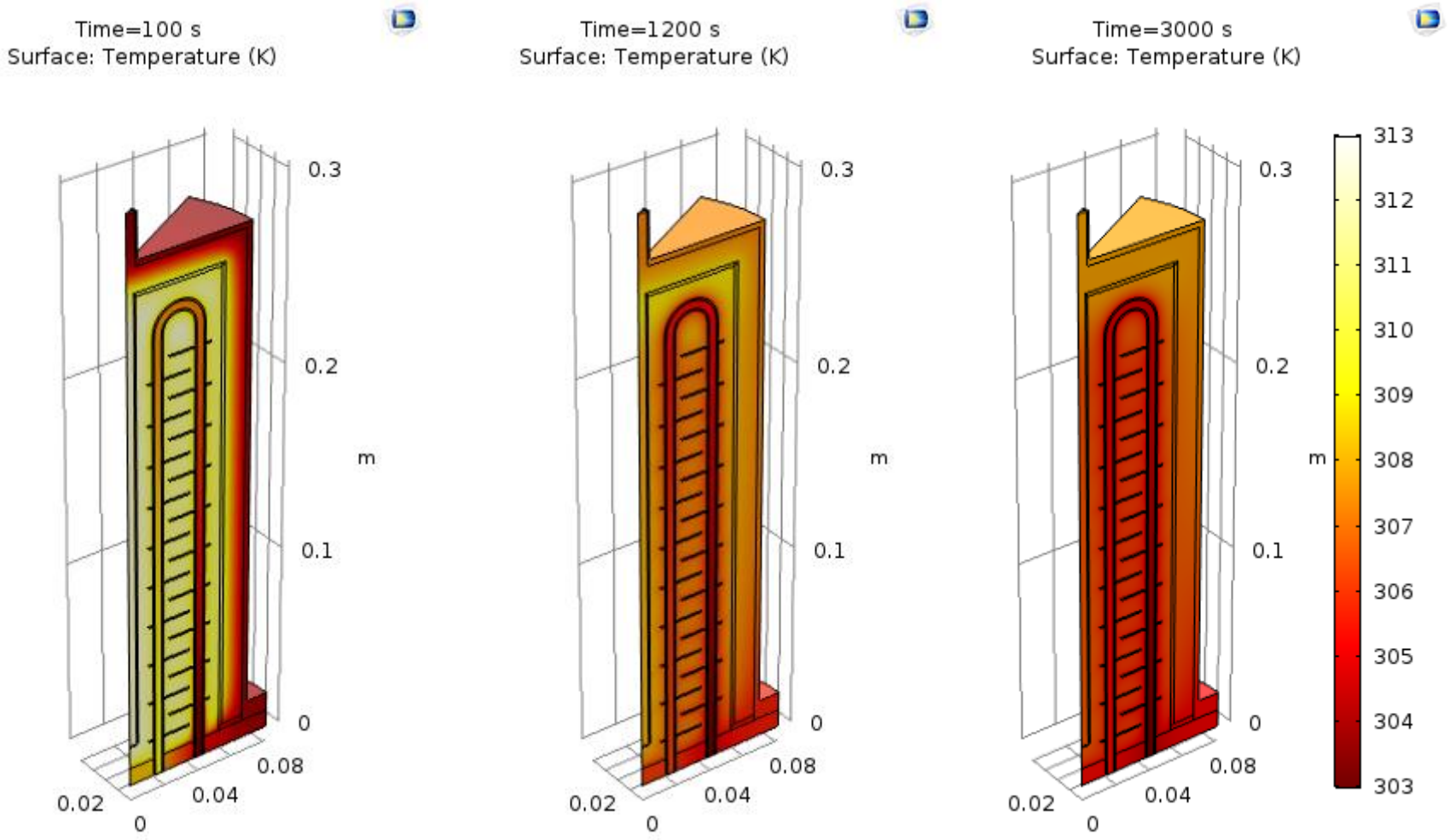
Couplings

- Laminar flow + Heat Transfer in Porous Media
- Darcy's Law + Heat Transfer in Porous Media
- Chemistry
  - Mass source – Darcy's law
  - Heat Source – Heat Transfer in Porous Media
  - Reaction – Transport of Dilute Species

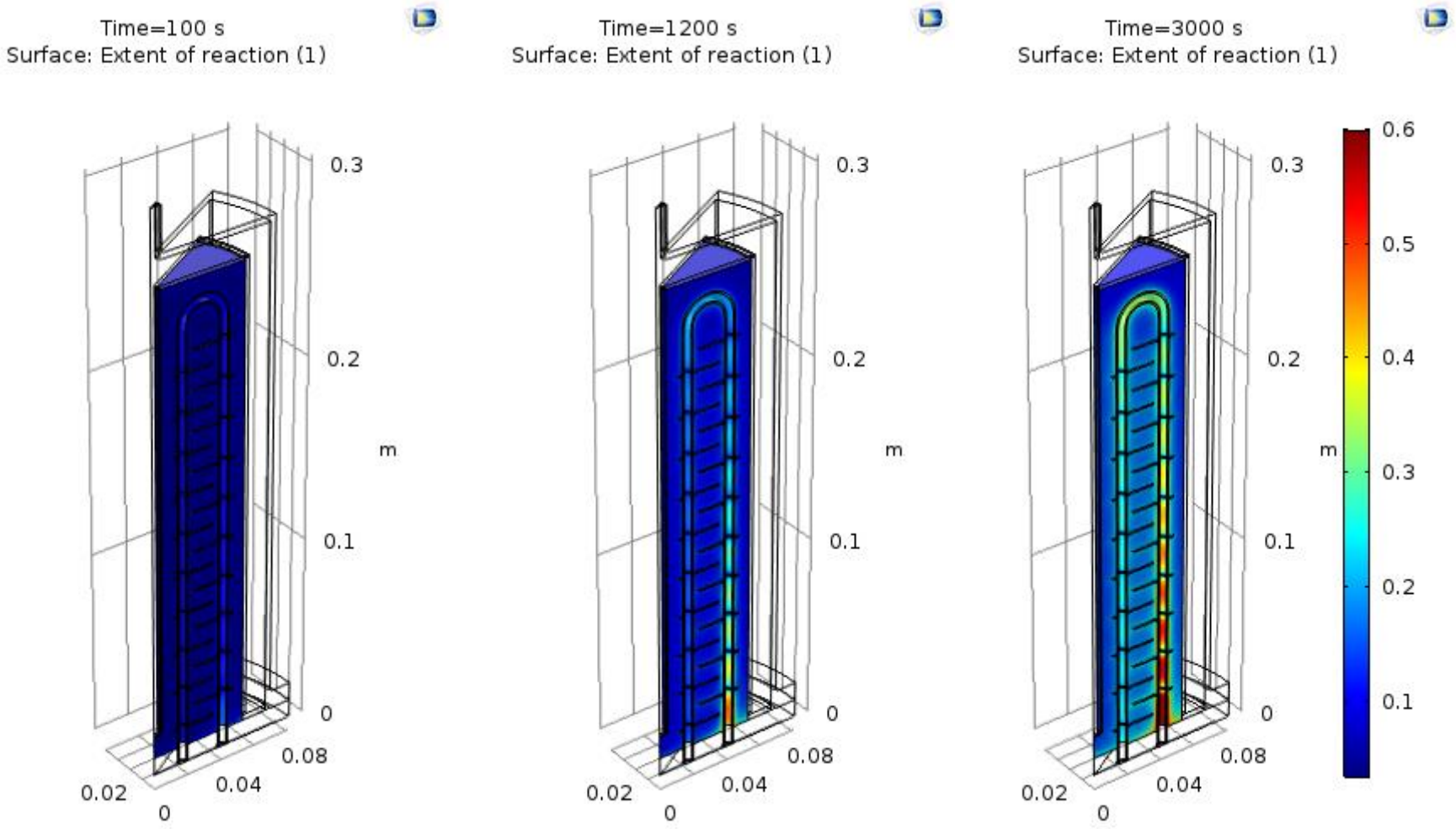
Operating conditions

- Material - $LaNi_5$
- Hydrogen pressure - $3\ \text{bar}$
- Heat Transfer fluid inlet - $303\ \text{K}$ at $0.5\ \text{ms}^{-1}$
- Initial state of reaction – equilibrium corresponding to $1\ \text{bar}, 303\ \text{K}$
- Slice corresponding to 6 tube arrangement
- Annular fins – on inner and outer arms

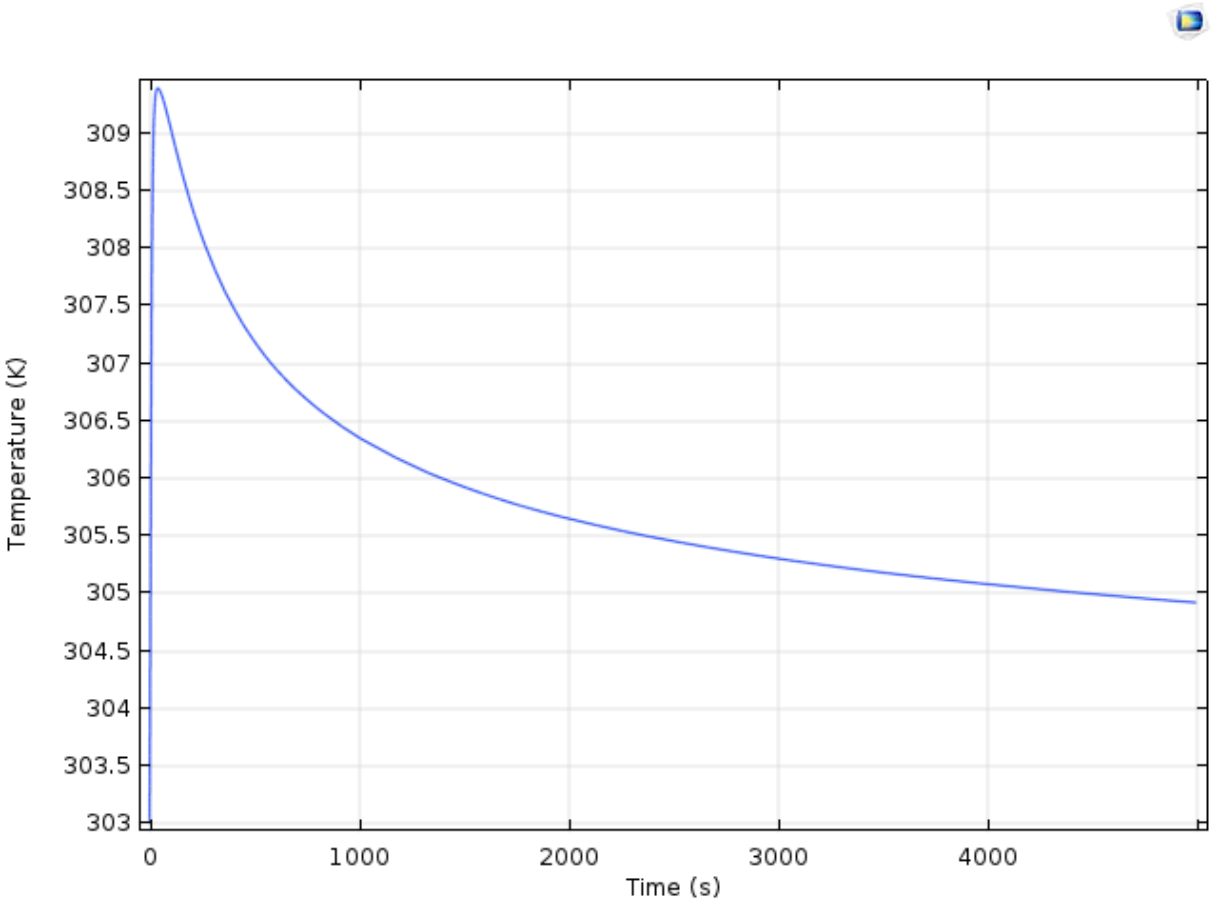
Core temperature



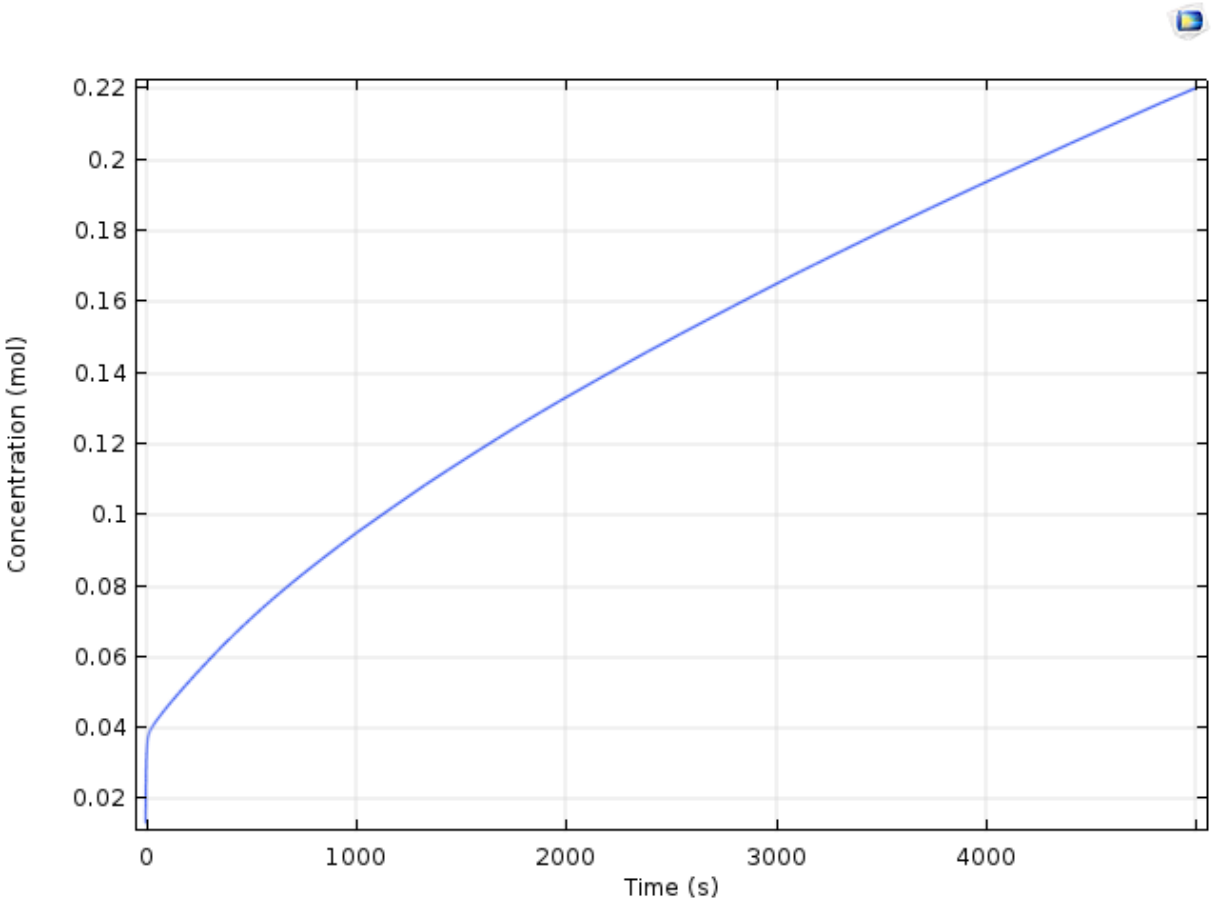
Extent of reaction



Heat Transfer Fluid :
Outlet temperature



Amount of hydride



Thank You.

Q & A