modelling high-level-waste vitrification in cold crucibles

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DE LA RECHERCHE À L'INDUSTRIE

MODELLING HIGH-LEVEL-WASTE VITRIFICATION IN COLD CRUCIBLES

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www.cea.fr

Short overview of the HLW confinement process

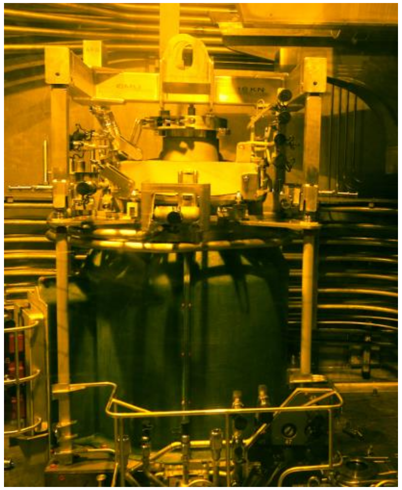
- Ensure long-time confinement of High-Level-Waste (HLW) of spent nuclear fuel reprocessing

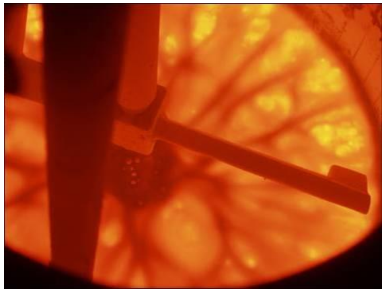
- Steps
  - **Vitrification**: atomic-scale incorporation of HLW in a glass melt
  - Nuclear glass poured in metallic canisters
  - Underground disposal in a deep geological repository

- Technology used for vitrification
  - **Induction-heated cold crucible**

Melting with cold crucibles

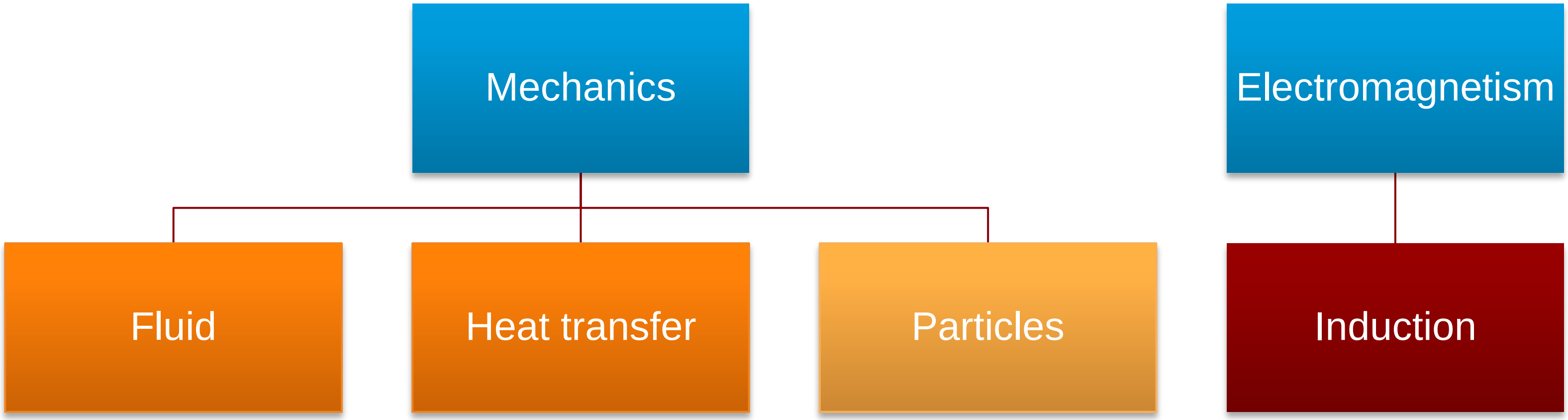
- Main principles
  - Calcined HLW and glass frit are heated by direct electromagnetic induction
  - The crucible is cooled by an internal water-cooling system
  - The glass melt is mechanically stirred with a rotating agitator
  - Further homogenization is achieved with air bubbling in the glass
- A cold crucible is already working at the La Hague reprocessing plant (France) since 2010
- Mission of CEA
  - Back industrial support
  - R&D and design of more efficient crucibles for future nuclear waste
  - **Modelling and simulating the full vitrification process (hence diminishing new development costs)**





Glass surface in the crucible

Electro-thermo-hydraulic modelling of the cold crucible



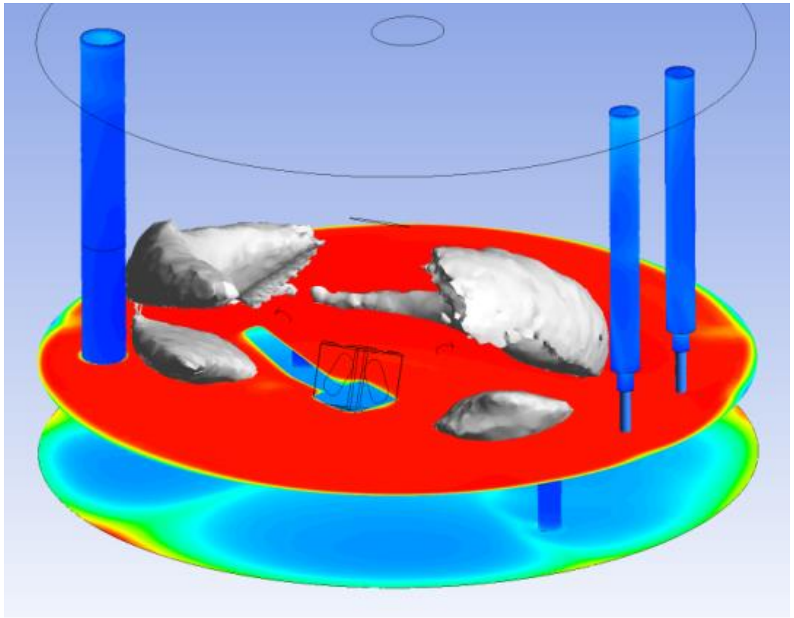
- The all thing is coupled
  - Induction of heat power
  - Time and space-varying physical properties (conductivity, density, …)

Solving Navier-Stokes equations and energy transport

- Modelling forced heat convection taking into account
  - Radiative heat exchange
  - Temperature-dependent density and viscosity
  - Temperature-dependent Heat Transfer Coefficient at walls
  - …

Fluid

Heat transfer

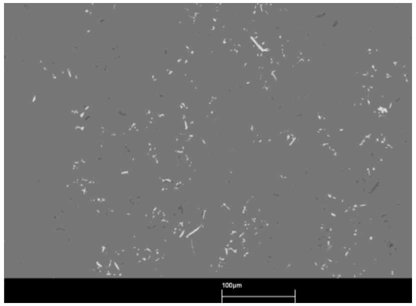


Full thermo-hydraulic numerical simulation of the cold crucible

Solving particles transport

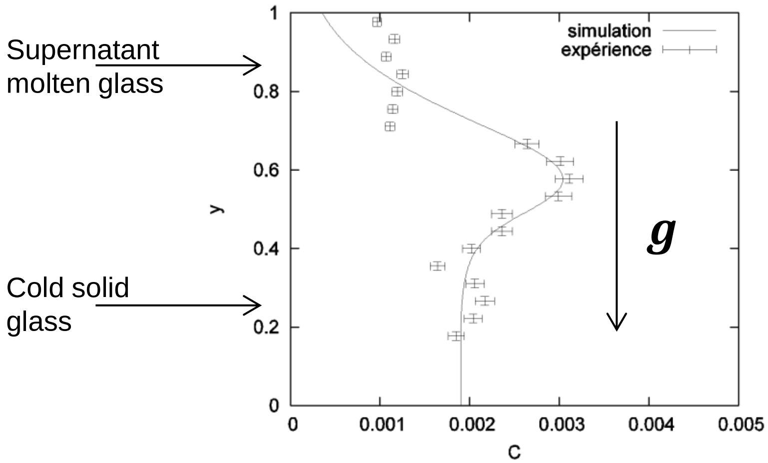
Particles

- Strong technological issue
  - Platinum-Group-Metals (PGM) are fission products with low solubility in glass
  - The glass melt is a dilute suspension of **PGM particles**
  - **Particles tend to settle and may impact the distribution of currents and local viscosity**

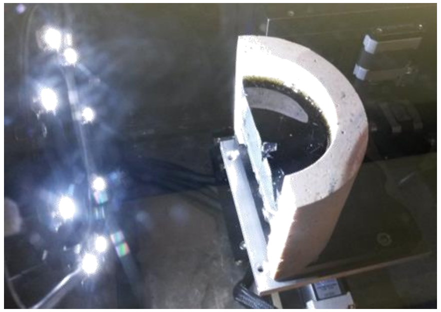


SEM view of RuO_2 particles in glass

- Designing a “one-fluid” transport model to account for particles settling



PGM volume fraction



LIBS measurements

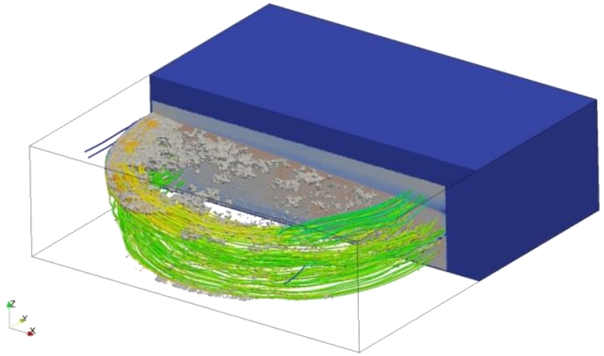
Solving Maxwell equations

Induction

- Induction of heat power in the melt (Joule effect) taking into account
  - Temperature-dependent electrical conductivity
  - PGM-concentration-dependent electrical conductivity

- Multi-scale approach to compute electrical conductivity

- Simulations performed on large HPC clusters



Eddy currents in a PGM-loaded-glass

HPC clusters of CEA

THANK YOU FOR YOUR ATTENTION