New experimental programmes in the CROCUS reactor

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  • VOID
  • PETALE

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The CROCUS teaching and research reactor

- Reactor type
  LWR with partially submerged core
  Atmospheric P and room T
  Forced convection (160 l.min$^{-1}$)
The CROCUS teaching and research reactor

- Reactor type
  - LWR with partially submerged core
  - Atmospheric P and room T
  - Forced convection (160 l.min\(^{-1}\))

- Power
  - 100 W (zero-power reactor)
  - i.e. maximum \(2.5 \times 10^9\) cm\(^{-2}\).s\(^{-1}\)
  - Controlled by water level or B\(_4\)C rods

1 rod S-curve

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<th>Position Barre [mm]</th>
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réactivité
Polynomial
Réactivité [pcm]
Position Barre [mm]
The CROCUS teaching and research reactor

• Reactor type
  LWR with partially submerged core
  Atmospheric P and room T
  Forced convection (160 l.min⁻¹)

• Power
  100 W (zero-power reactor)
  i.e. maximum 2.5×10⁹ cm⁻².s⁻¹
  Controlled by water level or B₄C rods

• Core dimensions
  ∅60 cm/100 cm

• Fuel lattices
  2-zone: 336/176 rods actually
  Inner: UO₂  1.806 wt%  1.837 cm
  Outer: Uₘₑᵗ  0.947 wt%  2.917 cm
The CROCUS teaching and research reactor

- 1.5 m-thick concrete shielding cavity
- Safety systems
  - 4 valves & expansion tanks (water dumping)
  - 2 cruciform Cd blades (inner zone)
Investigation of power fluctuations induced by fuel oscillations

- Motivation
  - Parallel code development and experimental prospects of coupling between mechanical noise and neutronics effect

- New experimental program in CROCUS for measuring noise induced by fuel vibration
  - Design of a device for oscillating fuel rods group at various representative amplitudes and frequencies
  - Measurement of the induced perturbation using neutron noise techniques
  - Experiments will serve to validate the simulation tool developed in parallel
Setup and status

- Specifications of COLIBRI
  - Number of rods selected: up to 18
  - Frequency: from 0.1 to 5 Hz
  - Amplitude: up to ±3 mm radial

- Measurements
  - Induced perturbation (MCNP) for 18 $U_{\text{met}}$ rods ±3 mm radial: ±8 pcm
  - Neutron noise measurement station in pulse mode already developed

- Schedule
  - Device tested out of core on reactor interfaces and with dummy fuel rods in January 2016
  - Licensing in progress
  - Start of the experiments in 2016
Development of an experimental setup to reconstruct axial void profile in BWR through neutron noise measurements of in-core detectors

- A theoretical method\(^1\) to reconstruct the void profile within a BWR channel using in-core neutron noise has been developed at Chalmers University
  - Transit time of the bubbles is measured by correlations in detector signals at discrete locations
  - Relationship between void and transit time is known
  - Third order polynomial fit of void profile

- The method will be tested in clean conditions in CROCUS with a channel containing a two-phase flow with known void distribution

- Separate characterisation of the bubble distribution using existing visualization techniques.

Flow characterisation setup
- Out of pile
- Based on standard techniques for 2-phase flow visualization: attenuation measurements
- \(\gamma\)-ray source + NaI detector

Neutron noise analysis setup
- In-core bubble channel: square Plexiglas tube (5 cm)
- 5 neutron detectors axially spaced
- To be set in the reflector
- Target void: 80% at top to be representative of BWR profile

Safety assessment
- Positive reactivity insertion \(\sim 20\) pcm (MCNP) in case of leakage
Goals

Contribute to the validation effort on the cross sections for materials of heavy steel reflector in GEN-III PWR

- **PERLE programme** in the French EOLE reactor for nuclear data validation
  - Reactivity effects
  - Reaction rates in pins at interface
  - Attenuation in the reflector: foils, FC

Cross section of the EOLE core for PERLE

$^{56}$Fe inelastic scattering cross section
Goals

Contribute to the validation effort on the cross sections for materials of heavy steel reflector in GEN-III PWR

- **PERLE programme** in the French EOLE reactor for nuclear data validation
  - Reactivity effects
  - Reaction rates in pins at interface
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- **Proposal for new experiments in CROCUS** for separated elements
  - s.s., Fe, Cr and Ni separately
  - In-core experiment for extracting nuclear data in the MeV range from criticality effects and attenuation measurements
  - Analysis using data assimilation
Setup and status

Instrumented reflector of material of interest set close to the reactor core

• Instrumented reflector
  • Sheets of s.s., pure Fe, Ni and Cr
  • 30 x 30 cm² for reducing impact of scattered thermal neutrons
  • 8 sheets 2 cm-thick (20 cm in NPPs)
  • Instrumentation within the sheets: dosimetry (foils, TLDs), FCs
  • Box-like & in-air positioning device

• Status
  • New Project within SCK-CEA-PSI VEP collaboration
  • Metal sheets purchased in 2015
  • Manufacture of the device and experiments starting in 2017
Co-development and testing of sCVD\textsuperscript{1} diamond detectors for gammas and thermal/fast neutrons with CIVIDEC: from accelerator toward reactor physics

- Installation and testing campaign in CROCUS in November 2015
  - sCVD\textsuperscript{1} detector was installed in the SW guide tube of the CROCUS control rod
  - E. Griesmayer (CIVIDEC) and C. Weiss (CERN) came to install/test the detector in CROCUS and teach how to use it

- Journal paper in preparation
  - Summarizing the installation and testing in CROCUS
  - To be submitted early 2016
  - In collaboration with CIVIDEC/CERN

\textsuperscript{1} single crystal Chemical Vapor Deposition
Neutron noise experimental systems were recently developed in CROCUS to measure the reactor’s delayed neutron fraction ($\beta$) and generation time ($\Lambda$).

Initially based on pulse mode acquisition (individual events), development of a similar measurement station in current mode to discard detector dead-time and gain speed/accuracy.

**Status**
- Current selection of hardware and assembling of the measurement station
- Adaptation of acquisition & processing algorithms
- Measurements in 2016 in CROCUS and comparison with calculations

Considered detectors location:
- Ionisation chambers
- Fission chambers
- Periphery positions
- Control rods positions

PSD data from previous measurements in CROCUS
Conclusion and prospects

Research in several directions of nuclear field
- 3 new reactor physics experimental programmes related to:
  - Coupling of thermo-hydraulic and neutronics physics
  - Development of nuclear measurement method
  - Validation of nuclear data
- Development of cutting-edge instrumentation

The CROCUS reactor: a safe multipurpose reactor
- Teaching
- Research

Thanks for your attention