

OECD Nuclear Energy Agency workshop: nuclear fuel modelling in support of safety and performance enhancement for water-cooled reactors

OECD Conference Centre, 2 rue André Pascal, Paris

7-9 March 2017

Background

Advanced techniques for fuel modelling have progressed considerably in the last decade in part aided due to progress in high-performance computational capability. At the engineering scale, this has resulted in improved mechanistic description within fuel-performance codes with a trend to progressively replace empirical models and correlations with physical models that allow, in principle, extension of the predictive capability of the codes beyond the domain for which experimental results are available. As an example, mesoscale codes (at the fuel-grain scale, typically microns) provide predictions of microstructure evolution and determine their impact on fuel properties, describing phenomena such as grain-boundary sweeping, grain growth, bubble nucleation, growth and coalescence, precipitation of solid fission products, their speciation and phase separation. Inclusion of these models within engineering-oriented fuel-performance codes offers improved predictions of thermal conductivity, elastic constants, swelling, and fission-gas release under conditions beyond their usual range of validity and creates an exploratory capability.

At the OECD Nuclear Energy Agency (NEA), the importance of fuel modelling and its improvement through development of phenomenological representations has been recognized and multiple technical groups related to materials modelling and the support of advanced fuels and safety codes are considering these issues. A prime example is the Working Party on Multiscale Modelling of Fuels and Structural Materials for Nuclear Energy Systems, and in particular the Expert Group on Multiscale Modelling of Fuels, which published in October 2015 a [State-of-the-Art Report of Multiscale Modelling of Nuclear Fuels](#). To improve further the coordination of these activities, both within the NEA and in the broader technical world, and to identify future needs, this workshop on *nuclear fuel modelling in support of safety and performance enhancement for water-cooled reactors* is proposed.

Objectives and Scope

The main objectives of the workshop are to:

- identify areas where **advanced rod-scale, mesoscale or microscale plus multiscale integration modelling of nuclear fuels is contributing or may contribute to significant progress on or insights into fuel safety and/or fuel performance** for water-cooled reactors; the focus will be on the design and operation of nuclear fuel, with consideration of nominal and off-nominal operating conditions including design-basis accidents;
- identify impacts these advanced modelling approaches might have on the current nuclear fuel design safety limits (evolution or new types of safety limits);
- identify gaps and possible experimental needs;
- identify areas for enhanced international collaboration and the NEA contribution.

The workshop will include keynote speakers, technical talks and panel discussions involving experts from a broad spectrum of stakeholders from NEA member countries including R&D organisations, academia, industry and regulatory bodies along with representatives of other international bodies. The workshop topics cover major insights related to *performance and safety improvements during normal operation and under off-normal conditions* for nuclear fuel of water-cooled reactors including:

- release of fission gases;
- formation of high burn-up structures (rim and MOX clusters);
- fuel swelling (diametral and axial) and pellet-clad interaction;
- the impact of dopants such as gadolinia;
- analytical investigation of margins associated with fuel-safety criteria including uncertainties;
- other issues such as clad oxidation, crud deposition, fretting, fuel assembly bowing;
- factors affecting burn-up and cycle length, power uprates and more flexible operating modes;
- reduction of uncertainties in the fuel design process and consequences for licensing margins;
- fuel fragmentation under LOCA conditions.

Technical discussions will also cover – but will not be limited to – the development of accident-tolerant fuels including: improved uranium oxide fuels; various types of high-density fuels and ceramic microencapsulated fuels; advanced cladding materials including coated/improved zirconium-based alloys, ceramic composites, advanced steels and refractory metals.

For each of the areas the workshop will promote discussion among the different communities of fuel experts, i.e., advanced modelling, safety and fuel performance. The key aim is to identify fuel issues in nominal and off-normal/design-basis accident conditions that would strongly benefit from the application of advanced-modelling techniques available within a reasonable timeframe (5-10 years). It is expected that within that period such efforts will provide not only improved insights into fuel behaviour, but that the use of integrated advanced modelling should, for example, lead to progress in fuel efficiency and provide alternative methodologies for assessment of fuel safety.

Workshop Format

The anticipated length of the workshop is 2½ days with sequential sessions in which everyone participates.

Expected Outcomes

- Workshop proceedings will be drafted by workshop chairs and will contain the main achievements of the workshop.
- The summary proceedings of the workshop will be presented to the [Committee on the Safety of Nuclear Installations](#) (CSNI) and the [Nuclear Science Committee](#) (NSC) for final endorsement and for input regarding follow-on activities and then be published by the NEA Secretariat.

Organisation

Relevant bodies from NEA:

- CSNI Working Group on Fuel Safety;
- NSC Working Party on Multiscale Modelling of Fuels and Structural Materials, Expert Group on Multiscale Modelling of Fuels;
- NSC WPRS Expert Group on Reactor Fuel Performance;
- NSC Expert Group on Accident Tolerant Fuels for LWRs;
- NSC Expert Group on Multi-Physics, Experimental data, Benchmark and Validation;
- NSC WPFC Expert Group on Innovative Fuels;

along with inputs from NEA safety-research projects investigating fuel (Halden Reactor Project, Studsvik Cladding Integrity Project and the CABRI International Project) and the IAEA (Technical Working Group on Fuel Performance and Technology)

Scientific Advisory Committee (tentative)

- T. Besmann (USC)
- M. Freyss (CEA)
- V. Garat (AREVA)
- C.B. Lee (KAERI)
- M. Moatti (EDF)
- F. Nagase (JAEA)
- K. Pasamehmetoglu (INL)
- M. Petit (IRSN)
- G. Rossiter (NNL)
- P. van Uffelen (JRC-ITU)
- C. Valot (CEA)
- M. Veshchunov (IAEA)
- N. Waeckel (EDF)
- W. Wiesenack (IFE-HRP)
- B. Wirth (UT-ORNL)
- K. Yueh (EPRI)

Workshop General Co-Chairs

- K. Pasamehmetoglu (INL / Chair of NEA Expert Group on Accident Tolerant Fuels for LWRs)
- M. Petit (IRSN / Chair of NEA Working Group on Fuel Safety)
- T. Besmann (University of South Carolina / Chair of NEA Working Party on Multiscale Modelling of Fuels and Structural Materials)

Technical Secretariat

- NEA Nuclear Science Division (S. Massara)
- NEA Nuclear Safety Technology and Regulation Division (M. Kissane)

Schedule

- October 2016:** registration opens; a second announcement will be circulated providing registration details.
- 30 January 2017:** deadline for registrations (however, please register early to provide NEA with an idea of the number of participants).
- 7 March 2017:** workshop opens at 9am, OECD Conference Centre (Paris).

NB: there is no fee for participation in this workshop.

Provisional programme

7 March 2017 (9.00-17.30)

8.00-9.00	Arrival formalities: security clearance, collection of badges, etc.
9.00-9.15	NEA Welcome
9.15-9.30	Welcome from the Workshop Co-Chairs; review of the programme; objectives. <i>K. Pasamehmetoglu (INL), M. Petit (IRSN), T. Besmann (USC)</i>
9.30-9.45	Introduction of attendees
9.45-12.30	Session 1: recent developments and future challenges for nuclear fuel Workshop Co-Chairs: K. Pasamehmetoglu (INL), M. Petit (IRSN), T. Besmann (USC)
9.45-10.15	Recent developments in multiscale-modelling methods applied to nuclear fuel <i>TBD</i>
10.15-10.45	Utility perspective on needs related to nuclear-fuel operation <i>TBD</i>
10.45 – 11.00	<i>Coffee break</i>
11.00-11.30	Fuel-vendor perspective on trends and future needs for improvements <i>TBD</i>
11.30-12.00	Safety and/or regulatory aspects related to nuclear fuel and activities within NEA CSNI/WGFS <i>TBD</i>
12.00-12.15	Link with <i>NEA Innovation 2050</i> initiative <i>TBD</i>
12.15-12.30	IAEA activities on fuel performance <i>TBD</i>
12.30 – 13.45	<i>Lunch break</i>
13.45-17.30	Session 2: nuclear-fuel modelling in support of operating performance Co-Chairs: people contacted, confirmation in progress
13.45-14.00	Suggested list of items for reflection, pre-distributed 2 weeks ahead of the workshop, in order to start the discussion <i>Session Co-Chairs</i>
14.00-16.30	Technical presentations upon suggestions by attendees (20' each + 10' Q&A)
16.00 – 16.15	<i>Coffee break</i>
16.15-17.30	Panel discussion moderated by the Session Co-Chairs
17.30	Adjourn for the day

8 March 2017 (9.00-17.30)

- 9.00-10.00 Session 2 wrap-up: key items identified
Session Co-Chairs
- 10.00-10.30 Discussion
- 10.30 Closure of session 2**
- 10.30 – 10.45 *Coffee break*
- 10.45-17.15 Session 3: nuclear-fuel modelling in support of performance and safety improvements under off-normal conditions**
Co-Chairs: people contacted, confirmation in progress
- 10.45-11.00 Suggested list of items for reflection, pre-distributed 2 weeks ahead of the workshop, in order to start the discussion
Session Co-Chairs
- 11.00-16.00 Technical presentations upon suggestion by attendees (20' each + 10' Q&A)
- 15.30 – 15.45 *Coffee break*
- 16.15-17.30 Panel discussion moderated by the Session Co-Chairs
- 17.30 ***Adjourn for the day***

9 March 2017 (9.00-12.30)

- 9.00-10.00 Session 3 wrap-up: key items identified
Session Co-Chairs
- 10.00 Closure of session 3**
- 10.00-12.15 Session 4: general wrap-up**
Workshop Co-Chairs: K. Pasamehmetoglu (INL), M. Petit (IRSN), T. Besmann (USC)
- 10.00-11.00 Discussion animated by the workshop Chairs
- Recommendations on key items identified during the workshop
 - Key cross-cutting issues between safety and economic performance
 - New requirements for experimental validation
 - Other issues (regulatory, IP, ...)
- 11.00 – 11.15 *Coffee break*
- 11.15-12.15 Existing frameworks for collaborative activities (NEA, IAEA) and possible new activities or means for cooperation
- 12.15-12.30 Conclusion of the workshop
Workshop Co-Chairs, NEA
- 12.30 Workshop adjournment**