Organisation for Economic Co-operation and Development

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Sixth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark Workshop (MPCMIV-6)

WPRS Benchmarks Workshops 2025

Department of Engineering of the University of Cambridge, Trumpington Street, CB2 1PZ, Cambridge, United Kingdom

The workshop will be held in Cambridge, UK, as part of the Benchmarks Workshops of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). The WPRS Benchmarks Workshops event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis.

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Sixth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-6)

Sponsorship

The sixth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-6) workshop will be held on 4 July 4 2025 in Cambridge, UK, as part of the Benchmarks Workshops Event of the Working Party on Scientific Issues and Uncertainty of Reactor Systems (WPRS). This event with three parallel tracks combines benchmarking efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis. The full schedule for the incoming WPRS Workshops, SINUS-3 school and CTF-11 Meeting and Training is given on the public meeting web page: https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Executive Summary

Evaluation of transient multi-physics experimental data for Light Water Reactor (LWR) systems is a growing area of interest. Analyses of reactivity-initiated accidents (RIAs) such as design basis accidents (DBAs) as well as the slower and less severe anticipated operating occurrences (AOOs) are important in determining the overall safety of the current fleet and future nuclear power plants. Industry challenge problems, such as the pellet cladding interaction (PCI) and the pellet cladding mechanical interaction (PCMI), are associated with those events. PCI and PCMI are based on multi-physics and multi-scale phenomena requiring accurate and realistic modelling and simulation (M&S). Possible PCI/PCMI fuel failures reduce reactor performance related to power uprates, higher burnup and fuel rod manufacturing quality. PCI and PCMI are possible in many fuel rods in each reactor core and are controlled by local effects but have a system-wide influence. Three-dimensional (3D) fuel performance models coupled with reactor physics and thermal-hydraulics models are needed to assess the complex coupled physics and the irregular geometries responsible for PCI/PCMI fuel failures. The Multi-physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) benchmark addresses the need for adequate high-quality experimental data for PCI/PCMI industry challenge problem to properly validate both the existing (traditional) multi-physics tools and as well as the next generation (novel) high-fidelity multi-physics code systems being developed. The MPCMIV benchmark is based on experiments conducted at the Studsvik R2 research and test reactor that require coupling between reactor physics, thermal-hydraulics, and fuel performance tools to achieve a multi-physics M&S and utilizes test reactor data from controlled experimentation to validate this M&S. The objectives of this benchmark activities, which are supported by US Department of Energy (DOE) Nuclear Energy University Program (NEUP), also include the development of integral evaluation to be submitted to the NEA International Reactor Physics Benchmark Experiments (IRPhE) Project Handbook and multi-physics handbooks. The evaluation process includes an internal review, an independent peer review, and an OECD/NEA review.

A four-tiered structure of fidelity has been proposed to accommodate as many participants and computational tools as possible:

- Tier 1 (for novel tools): A 3D heterogeneous model of the R2 reactor and fuel rodlet (3D deterministic core physics simulator of both R2 core domain and fuel rodlet domain).
- Tier 2 (for novel tools – simplified): The benchmark team will generate a cross-section data set for the R2 reactor and then perform a core physics calculation (e.g., with a nodal diffusion code) to obtain the boundary conditions (i.e., neutron and gamma fluxes) for the fuel rodlet domain. These boundary conditions will then be used by the participants to develop a high-fidelity model of the fuel rodlet domain.
- Tier 3 (for traditional tools): The procedure is like tier 2, but the modelling is conducted with traditional tools. In this case, the cross-section generation step is needed.
- Tier 4 (only Fuel Performance tools): The benchmark team will provide appropriate boundary conditions to allow the use of only fuel performance tools in the benchmark.

For each tier, the MPCMIV benchmark is structured into four main phases:

- the development phase;
- the pre-qualification phase (data based on calibration ramp - empty rodlet, and initial ramp with the Boiling Water Reactor (BWR) rodlet);
- the blind simulation phase (data based on a repeated ramp with the BWR rodlet), including uncertainty analysis (the results will not be attributed to any particular organization in NEA reports – individual participants are free to publish their results openly);
- the open or post-test phase, including sensitivity analysis.

Validation requirements will be set for all the steps.

The last version of the Specification will be discussed along with the available support data developed by the benchmark team. The benchmark team (consisting of NCSU, NINE, INL, University of Illinois, and McMaster University) has performed benchmark support studies, which will be presented and discussed at the workshop. The central topic of discussion will be the development of transient multi-physics validation protocols and guidelines. Current challenges and proposed approaches will be presented and analyzed.

The information about the MPCMIV benchmark is provided at:

https://www.oecd-nea.org/jcms/pl_32203/multi-physics-pellet-cladding-mechanical-interaction-validation-mpcmiv-benchmark

Scope and Technical Content of the Meeting

The topics to be addressed at the workshop include:

- Review and discussion of the latest revision of the Benchmark Specifications and updated support data;
- Discussion of templates for submitting participants' results for different exercises from different tiers;
- Presentations on benchmark team support studies and results for different physics domains and calculation tiers;
- Discussions of the development of multi-physics validation guidelines and protocol for transient applications;
- Benchmark participants' presentation on their models and results;

- Presentations on multi-physics modeling and simulation and analysis of PCI/PCMI phenomena and events;
- Defining a work plan and schedule for the MPCMIV benchmark activities.

The proposed meeting program is attached as Annex 1.

Organization of the Meeting

The meeting is organized around the discussion in depth of the development of appropriate validation guidelines and protocols for multi-physics transient applications. Additional discussions will cover the current benchmark specifications and support data, templates for submission of participants' results, reference solutions, and proposed work plan and time schedule for the OECD/NEA MPCMIV validation benchmark activities. The participants are requested to present their modelling and results as well as their experience and expertise in PCMI multi-physics analysis.

Participation in the Meeting

Participation is restricted to individuals from OECD/NEA member country institutions who agree to the benchmark non-disclosure agreement (NDA). Participants are asked to sign and send the corresponding NDA form to wprs@oecd-nea.org.

The benchmark NDA form can be found at:

https://www.oecd-nea.org/upload/docs/application/pdf/2022-03/nda-mpcmiv-benchmark-23_04_2018.pdf

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the MPCMIV-6 benchmark workshop and to draw up the final program, etc.

The members of the Program Committee are:

Gregory Delipei - *Co-Chair*
North Carolina State University, USA

Domenico De Luca – *Co-Chair*
NINE S.r.l., Italy

Maria Avramova - *Coordinator*
North Carolina State University, USA

NEA Secretariat: **Oliver Buss**
OECD/Nuclear Energy Agency, France

Proposed Program of the Meeting

The proposed program was drawn up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the MPCMIV-6 Benchmark workshop is English.

Proceedings of the Meeting

The program committee and the session Chairs will prepare a summary report on the main results of the meeting for presentation to the EGMUP, WPRS, and NSC. Presentations will be available free of charge to the benchmark participants to download from participants' restricted area of the benchmark website after the workshop.

Contacts and Registrations

Link to the registration page for the WPRS-related workshops and meetings (including CTF-11 registration) and the overall program.
https://www.oecd-nea.org/jcms/pl_98752/wprs-benchmarks-workshops-2025

Workshop Location

The meeting place/venue for the meetings/workshops during the week of 30 June to 4 July 2025 is the Department of Engineering of the University of Cambridge:

Trumpington Street, CB2 1PZ, Cambridge, United Kingdom.

Annex 1:

OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) - Sixth Workshop (MPCMIV-6)

Host Organization

Hosted by Cambridge Nuclear Energy Centre, University of Cambridge,

Cambridge, United Kingdom

July 4, 2025

PROPOSED PROGRAM

M1-11: Session code

M1. Introduction and opening remarks

M2. Overview of benchmark activities since the last MPCMIV workshop.

M3. Presentations on related activities and PCMI multi-physics analysis

M4. Discussion about the current Specifications

M5. Presentation of updated support data

M6. Presentation and discussion of benchmark team's support studies and results

M7. Participants' presentations on their modelling and results of the MPCMIV benchmark.

M8. Presentation and discussion on the development of appropriate validation protocols and guidelines for multi-physics transient applications.

M10. Action items and schedule of benchmark activities

M11. Conclusions and closing remarks.