

**N.I.N.E.** NUCLEAR AND INDUSTRIAL
ENGINEERING**NC STATE UNIVERSITY**

Department of Nuclear Engineering

Fifth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-5) Workshop

Lucca, Italy
Tuesday, May 21, 2024 (track 2 afternoon)
In conjunction with the BEPU 2024 Conference

Hosted by N.I.N.E. (Nuclear and Industrial Engineering), Italy

Announcement and Proposed Program

Sponsorship

The fifth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-5) workshop will be held on May 21, 2024 (track 2 afternoon), in Lucca, Italy in conjunction with the 2024 Best-Estimate Plus Uncertainty (BEPU-2024) international conference as well as with other OECD/ Nuclear Energy Agency (NEA), Nuclear Science Committee (NSC) Working Party on scientific issues and uncertainty of Reactor Systems (WPRS) meetings/workshops to facilitate co-ordination and sharing of work. The other meetings are being held in three parallel tracks at Lucca, Italy during the same week to combine efforts in common areas such as neutronics, thermal-hydraulics, and multi-physics modelling and uncertainty analysis and to make the participation more efficient. The meetings/workshops concerned are:

- *May 19, 2024 (morning)* – COBRA-TF (CTF)-10 a Hands-on Training Session
- *May 19, 2024 (afternoon)* – CTF-10 User Group (UG) Meeting
- *May 20, 2024 (track 1 morning)* – Third OECD/NEA Lead Fast Reactor (LFR) benchmark - Thermal-Hydraulic (T/H) Stage (LFR-3 T/H) workshop
- *May 20, 2024 (track 2 morning)* - Third OECD/NEA Fluoride High Temperature (FHR) Reactor Benchmark (FHR-3) workshop
- *May 20, 2024 (track 1 afternoon)* – Third OECD/NEA Lead Fast Reactor (LFR) benchmark– LFR Neutronics (N) Stage - (LFR-3 N) workshop
- *May 20, 2024 (track 2 afternoon)* – Sixth OECD/NEA Rostov-2 VVER-1000 Multi-Physics Transient Benchmark (Rostov2-6) workshop
- *May 21, 2024 (track 1)* - Ninth OECD/NEA Sodium Fast Reactor (SFR) UAM Benchmark (SFR-UAM-9) workshop
- *May 21, 2024 (track 2 morning)* - Ninth OECD/NEA Time-Dependent Neutron Transport (C5G7-TD) Benchmark (C5G7-TD-9) workshop
- *May 20-21 (track 3), 2024* – 2nd OECD/NEA International School on Simulation of Nuclear Reactor Systems (SINUS-2)
- *May 22, 2024 (track 1)* – Seventeen OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM-17) workshop
- *May 22, 2024 (track 2 morning)* - Fourth Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulic (T/H) Benchmark (LMFR T/H-4) workshop
- *May 22, 2024 (track 2 afternoon)* – First OECD/NEA HTGR-TH Benchmark (Based on HTTF Data) workshop (HTGR-TH-1)
- *May 23, 2024 (track 1)* – Fourth OECD/NEA TVA Watts Bar 1 (WB1) Multi-Physics Multi-Cycle Depletion Benchmark (TVA-WB1-4) workshop
- *May 23, 2024 (track 2 morning)* - Summary session with presentations of recently concluded benchmarks: OECD/NEA First Burst-Fission-Gas Release Benchmark (BFGR) and OECD/NEA McMaster Core Thermal-Hydraulics (CTH) Benchmark
- *May 23, 2024 (track 2 afternoon)* – OECD/NEA Task Force Artificial Intelligence & Machine Learning (TF AI&ML) meeting

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, 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 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.

Background and Purpose of the Benchmark Workshop

A four-tiered structure of fidelity has been pro-posed 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 organisation 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.

An updated version of the Specification along with updated support data has been developed by the benchmark team and distributed to the participants and will be discussed at the incoming benchmark workshop. 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 information about the MPCMIV benchmark is provided at:

[Nuclear Energy Agency \(NEA\) - Multi-physics Pellet Cladding Mechanical Interaction Validation \(MPCMIV\) Benchmark \(oecd-nea.org\)](http://www.oecd-nea.org/mciv/)

Scope and Technical Content of the Benchmark Workshop

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;
- Presentations on development and validation of simulation models against the provided Pre-Qualification data;
- Presentations on multi-fidelity single- and multi-physics calculations;
- Discussions of development of multi-physics validation guidelines and protocol for transient applications;
- Benchmark participants’ presentation on their models and results;
- Presentations on multi-physics modelling 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 Benchmark Workshop

The meeting is organized around the discussion in depth of updated 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.

Benchmark NDA form:

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-5 benchmark workshop and to draw up the final program, etc. The members of the Program Committee are:

Alessandro Petruzzi – *Co-Chair, and Local Host*
NINE S.r.l., Italy

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

Domenico De Luca
NINE S.r.l., Italy

Maria Avramova
North Carolina State University, USA

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

Proposed Program of the Meeting

The proposed program for the fifth OECD/NEA MPCMIV Benchmark Workshop (MPCMIV-5) was drawn-up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the MPCMIV-5 Benchmark workshop is English.

Proceedings of the Meeting

A summary of the workshop will be published by the OECD/NEA after the meeting. The summary will be distributed free of charge to the benchmark participants and to Delegates of the EGMUP, WPRS, and NSC. The program committee and the session Chairmen 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

The annual benchmark workshops/meetings of the [Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems](#) (WPRS) and CTF UG Meeting and Training will be hosted by NINE S.r.l. in Lucca (Italy). The meetings will take place in three tracks in parallel during the week of May 19 to May 23, 2024, to exchange our results and lessons-learned for the different WPRS benchmark activities and to discuss future activities.

Link to registration page for the WPRS-related workshops/meetings including CTF-10 registration, and overall program:

https://www.oecd-nea.org/jcms/pl_89133/wprs-benchmarks-workshops-2024

In addition, there is a link to registration form for the CTF-10 UG Meeting and Training is at NCSU/RDFMG website:

<https://www.ne.ncsu.edu/rdfmg/cobra-tf/tenth-ctf-user-group-ug-meeting-and-training/>

Workshops' Location

The meeting place/venue for the BEPU-2024 conference and the eleven meetings/workshops during the week of May 19 to May 23, 2024, is the Real Collegio, which is located inside the city walls of Lucca. The local information for transportation and hotels is given at:

<https://www.nineeng.com/bepu2024/index.php/conference-info/about-the-conference>

The schedule for the incoming WPRS Workshops, SINUS-2 school and CTF-10 Meeting and Training is given in the table below (all times in CEST):

The program and schedule of the meetings is shown below:

Sunday, 19 May 2024	<u>9:00-13:00</u>	CTF UG Training		
	<u>14:00-18:00</u>	CTF UG Meeting		
	<u>Starting at 18:00</u>	Registration & informal networking		
		Track 1	Track 2	Track 3 (SINUS)
Monday, 20 May 2024	<u>Starting at 8:00</u>	Registration		
	<u>9:00-13:00</u>	Lead-cooled Fast Reactor Benchmark (LFR) - T/H Stage	FHR - Fluoride High Temperature Reactor Benchmark	OECD NEA International School on Simulation of Nuclear Reactor Systems (SINUS)
	<u>14:00-18:00</u>	Lead-cooled Fast Reactor Benchmark (LFR) - Neutronics Stage	Rostov-2 VVER-1000 Benchmark	SINUS
Tuesday, 21 May 2024	<u>9:00-13:00</u>	Uncertainty Analysis in Modelling (UAM) for Design, Operation and Safety Analysis of Sodium-cooled Fast Reactors (SFR-UAM)	C5G7-TD: The Deterministic Time-Dependent Neutron Transport Benchmark C5G7-TD without Spatial Homogenization	SINUS
	<u>14:00-18:00</u>	SFR UAM	Multi-physics Pellet Cladding	SINUS

		Mechanical Interaction Validation (MPCMIV) Benchmark	
		Track 1	Track 2
Wednesday, 22 May 2024	<u>9:00-13:00</u>	Benchmark for Uncertainty Analysis in Best-Estimate Modelling for Design, Operation and Safety Analysis of Light Water Reactors (LWR-UAM)	Liquid Metal Fast Reactor Core Thermal-Hydraulics Benchmark (LMFR T/H)
	<u>14:00-18:00</u>	LWR UAM including session on EGMUP Task Force on Doppler effective fuel temperature	HTGR T/H Benchmark based on HTTF Data
Thursday, 23 May 2023	<u>9:00-13:00</u>	TVA Watts Bar Unit 1 Multi-Physics Benchmark	9:00-11:00 Summary presentations of recently concluded benchmarks: - Burst Fission Gas Release (1h) - McMaster CTH (1h)
			11:00-13:00 EGMUP Task Force Artificial Intelligence & Machine Learning
	<u>14:00-18:00</u>	TVA Watts Bar Unit 1 Multi-Physics Benchmark	EGMUP Task Force Artificial Intelligence & Machine Learning

ANNEX 1

OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation (MPCMIV) - Fifth Workshop (MPCMIV-5)

Host Organization

Hosted by N.IN.E. (Nuclear and Industrial Engineering)

Lucca, Italy

May 21, 2024 (track 2 afternoon)

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 of the updated Specifications
- M5. Presentation of updated support data
- M6. Presentation and discussion of benchmark team's support studies and results
- M7. Presentations on development and validation of simulation models against the provided Pre-Qualification data.
- M8. Participants' presentations on their modelling and results of the MPCMIV benchmark.
- M9. Integral benchmark evaluation and development of validation protocol and guidelines for multi-physics transient applications.
- M10. Action items and schedule of benchmark activities
- M11. Conclusions and closing remarks.