OPERA HPC

NEWSLETTER

Issue 1

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OPERA HPC IN A NUTSHELL

Electrification of the energy sector will be a key step for its transition to climate-neutrality. In order to achieve it by 2050, it will be necessary to maintain and even extend the production capacity of current nuclear reactors, while taking into account the evolving electricity mix and increasing requirements regarding the safety assessment of nuclear reactors.

On these points, the question of nuclear fuel behaviour is essential because it sets the main constraints to be satisfied for safe operation of nuclear reactors and defines the source term for accidental conditions.

Fuel performance codes, which enable the simulation of the behaviour of the fuel elements in reactor, are now an essential component of the design, licensing and safety assessment of nuclear fuels. The licensing of innovative fuel materials and design requires an extension of the modelling capabilities of the current fuel performance codes to meet safety authority's requirements.

OperaHPC will work on the main aspects needed to improve the approach and the computational tools used by the nuclear research community and industry:

- a basic research program on the mechanical behaviour of irradiated fuel and the development of improved mechanical laws for fuels and claddings
- the development and the validation of open source fuel performance codes for simulating fuel rod behaviour in reactor
- the application of these advanced tools for safety studies on enhanced Accident Tolerant Fuel elements (eATF).

Another important aspect is the training of the next generation of engineers and researchers that will work on innovative and advanced fuels.

MESSAGE FROM THE COORDINATOR (1/2)

Along the three OperaHPC strategic objectives, the project will develop a new experimental equipment for measuring the creep behaviour of irradiated fuel, and characterizing the physical-mechanical properties using a multiscale approach combining simulation and experiment.

Then, High Performance Computation tools will be developed and validated to simulate fuel behaviour at rod scale with the OFFBEAT code, and at microstructure scale with the MMM code.

Finally, the tools developed and enhanced will enable us to improve the models used in existing industrial fuel performance codes and to perform safety analysis on eATF for VVER and PWR generation 2&3 reactors in Design Basis Accidents, such as Reactivity Insertion Accident or Loss Of Coolant Accident.

OperaHPC started a bit more than a year ago, and during the first year, the foundations of the work were lawn. Documents describing the project management, the detailed work plan, the organization of the education and training activities, as well as the communication and exploitation of results, were prepared.

Technical activities yielded the first results, with on the experimental side the design of the creep test device and a detailed characterization of irradiated fuel microstructure with a Transmission Electronic Microscope.

These results will provide the input data for the small-scale simulation and the physics-based modelling for which the mobility of dislocations was calculated using atomic scale simulation. State of the art of fuel and cladding mechanical laws was performed to prepare the development of advanced mechanical modelling.

MESSAGE FROM THE COORDINATOR (2/2)

The HPC code development is under progress with the following topics:

- OFFBEAT/SCIANTIX: fission gas behaviour, large strain formulation for cladding ballooning, cladding oxide layer, RIA transients.
- MMM: viscoplasticity in a UO_2 polycrystalline microstructure
- SPH: representative thermo-mechanical study cases

In link with fuel modelling improvement and industrial applications, the exchanges on Machine Learning methods and the computation of input data for fuel safety analysis are under progress. Finally, exchanges with the User Group have started.

This progress was presented during the first year plenary meeting, which was hosted by POLIMI in Milano (Italy) the 21 and 22 of November and gathered 40 participants on site and online. This meeting also enabled fruitful exchanges between the project's participants. I thank all the contributors of the OperaHPC project for their enthusiasm and their involvement in this collaboration.

A FRENCH STUDENT AT CIEMAT: A MOBILITY EXPERIENCE

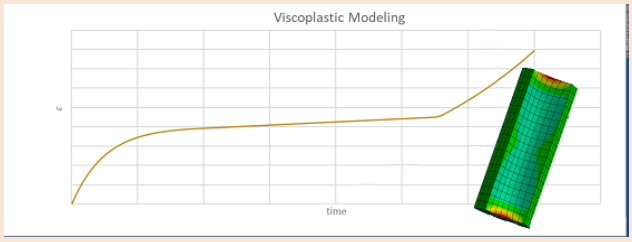
Julien Gros, a French student from Supmicrotech ENSMM in Besançon, has spent a 5 month internship at CIEMAT at the end of 2023 to contribute to the "State-of-the-art and proven methodology selection" for cladding mechanical laws.

His objectives were first to select constitutive equations and material parameters to describe the fuel cladding viscoplastic behaviour, under steady state loading conditions, from the bibliography. Criteria were defined to select the law in best agreement with the fuel safety studies targeted in the project. In this work, irradiation effects and anisotropy of the cladding Zircaloy material were carefully studied. The domain of use was defined as operational nominal conditions.

In a second step, the selected law was implemented in a code generation tool named MFront https://tfel.sourceforge.net in order to be used in a nonlinear mechanical computation at the fuel rod scale. At the end of the analysis, one law has been selected and complementary work is being carried out to compare it with the law used by OFFBEAT.

This work prepares the transfer of new mechanical laws to the OFFBEAT 3D code developed in OperaHPC.

Julien in front of CIEMAT site in Madrid



Cladding creep strain versus time

European School on Nuclear Materials Science

ESNMS 2022

The second edition of the ESNMS took place in Cargèse (France) from November 7 to 11, 2022. It was co-organized by the CEA Energy Division, the CNRS/CEMHTI laboratory and KTH. It was funded by EERA-JPNM, OperaHPC, CEA MINOS platform and KTH Energy platform.

41 participants from all over Europe, mostly doctoral students, but also post-docs and young permanent researchers participated in the event.

17 lectures were held on experimental characterization techniques, multiscale modelling methods and their application on metallic and ceramic structural materials of fission and fusion reactors, as well as nuclear fuels.

In addition, participants worked in groups on case studies with support of lecturers and presented the results in front of their fellow students. This increased active participation and interactions, enabled them to work on applications and show the contribution of materials science to the investigation of various issues concerning the behaviour of nuclear materials.

After a first online edition in 2020, this 2nd edition enabled the participants to exchange live with other students and lecturers and start their network

OPERAHPC EVENTS (2/2)

NuFuel 2023 workshop

The NuFuel workshop series aims at gathering the research community working on nuclear fuels and fuel elements for all reactor generations. The series was initiated by CEA and JRC-Karlsruhe under the auspices of the EERA-JPNM to establish stronger and more-lasting collaborative links between European institutes, to provide a forum where dialogue between experts is fostered and to give students and young scientists the possibility to present their work and discuss with experts in the field

The fifth edition of Nufuel (NuFuel 2023 took place in Marseille. (France). It was chaired by CEA IRESNE (France), JRC (EC) and RATEN (Romania) and sponsored by OperaHPC and FREDMANS Horizon Europe projects. 80 participants attended the workshop, including more than half-early career researchers (MS, PhD and post-docs). The main research topics on fuels were represented: multiscale modelling, thermodynamic modelling, separate effect studies, fuel synthesis, fuel element performance simulation, post-irradiation experiments, and to a smaller extent irradiation design.

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