SINDRI: Synergistic utilisation of INformatics and Data centRic Integrity engineering

Business Lead: EDF | University Lead: University of Bristol | Grant reference: EP/V038079/1

Summary

This Prosperity Partnership, entitled Synergistic utilisation of INformatics and Data centRic Integrity engineering (SINDRI), is developing powerful digital tools that will radically transform how the nuclear industry designs and conducts in-service assessments of materials and components. SINDRI exploits the opportunity of digital technologies to accelerate the implementation of novel designs, fabrication, and structural performance assessments. So far, these processes have been largely accomplished through manual iteration in the industrial environment, resulting in slow progress. SINDRI will take advantage of new materials modelling frameworks and high-fidelity validation experiments to replace these manual processes with a virtual environment.

Introductions and Background

Even with significant development, nuclear industry manual procedures are limited in their ability to meet the demands of a carbon-neutral economy by 2050. Disruptive technologies, accepted by the regulator, are needed to accelerate construction and reduce the cost of operation. SINDRI will develop open-source, inter-connected, multi-physics, modular digital tools, eliminating significant time-consuming and cumbersome human interventions. This will be done building on EDF's in-house open-source finite element software Code_Aster and the Salome_Meca platform. The project supports the cost reduction of a key low-carbon energy technology crucial to the UK's future carbon-neutral economy. The programme is being delivered collaboratively by academia and industry and provides EDF with important components of their multi-physics plant digital twin. It also adds value to several national initiatives, including the Nuclear Virtual Engineering Capability and the BEIS Nuclear Innovation Programme in which members of the partnership lead or participate. It will enable collaboration with the Small Modular Reactor Programme led by Rolls-Royce (through Jacobs and NNL) and the UKAEA's STEP programme.

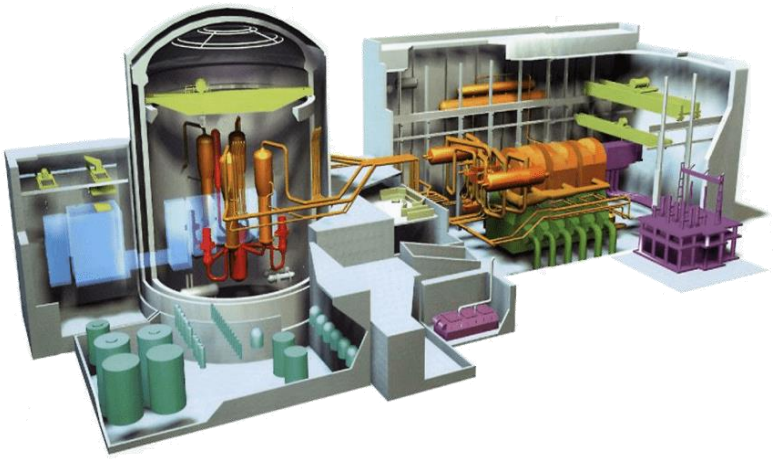

Image Credit EDF: Cutaway of nuclear power plant showing components

Objectives

- Determine the effects of fabrication and in-service degradation on the material's microstructure using a programme of high-fidelity experiments. Metallic systems of interest are: stainless steel, low alloy ferritic steels, and eventually, ferritic-martensitic steels.
- Develop microstructurally informed, multi-physics models to simulate the fabrication and in-service behaviour of representative alloy systems.
- Implement data-based methods and models (such as model reduction, data assimilation, uncertainty quantification and other machine learning techniques), support and complement physics based meso-scale models, create surrogate models that can be applied to engineering-scale components.
- Update current procedures used in the nuclear industry to underpin a robust probabilistic approach distinct from the current expensive and over conservative deterministic methods.

Project achievements: outputs, outcomes and impact

In its first 6 months SINDRI has made significant progress in establishing the research framework of the partnership and building the project teams. The project has delivered several, key, initial deliverables and participated in stakeholder engagement activities. These include:

Crystal Plasticity Model Integration

In an effort to standardise the way of working between the different partners, the crystal plasticity framework developed by the partnership has been reshaped. Tangible outcomes have been achieved, including (i) the development of a standard and automatized procedure to generate crystal-plasticity models from experimental data, saving significant set-up time, and (ii) compatibility of the micro-mechanistic models developed by Bristol with EDF tools and very encouraging benchmark results. The unified process significantly reduces the time needed for training on different platforms and allows the industrial user to utilise the tool with ease.

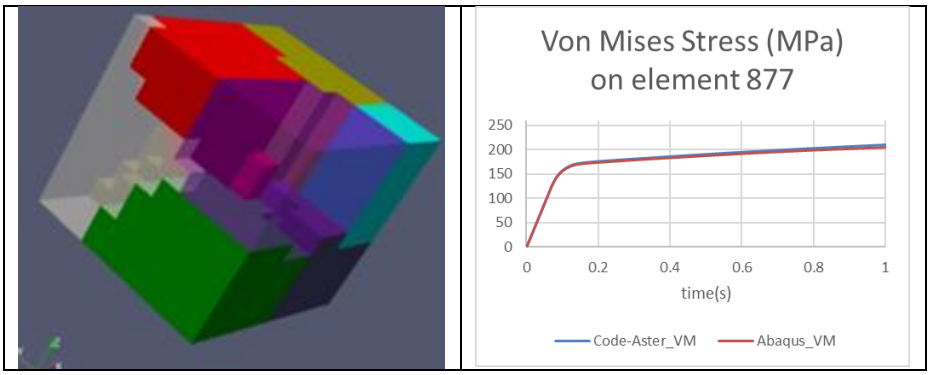

Image: Left - crystal plasticity modelling in EDF's Code_Aster following the project's framework. Right - the benchmarking shows that for a simple case, the academic and industrial codes yield identical results

This standardisation and automatization effort is important as it will enable a community of researchers to evolve in a common environment and benefit seamlessly from each other's work whilst being able to focus on their individual research topics. In addition to saving a significant amount of time, it paves the way for a direct exploitation of the results in R6 procedures of ultimate interest to assess the structural integrity of EDF's nuclear components. This common framework also facilitates the systematic deployment and use of data centric methods, such as data assimilation, uncertainty quantification and machine learning, which will be looked at during the second part of the project.

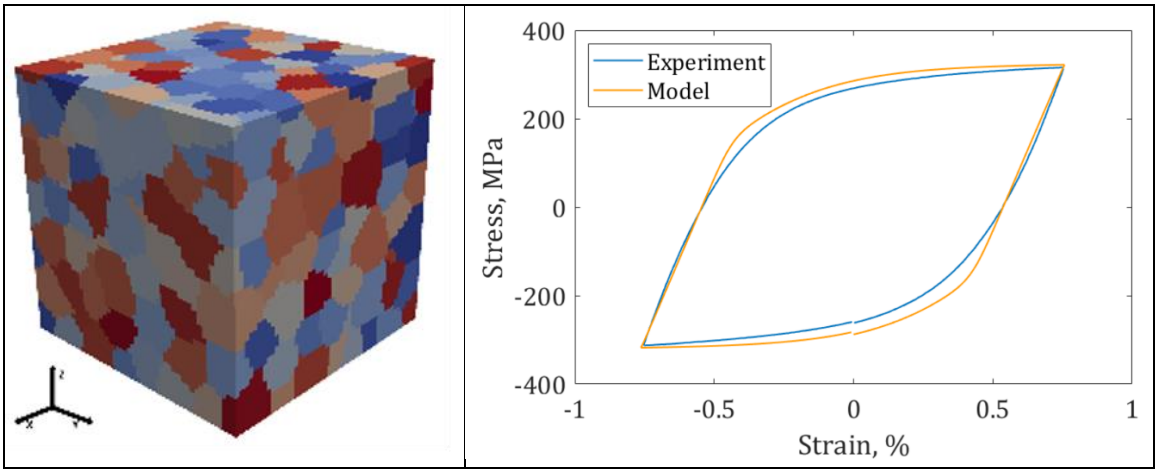

Image: Left – representative microstructure of stainless steel 316L Right – simulation of cyclic behaviour after 10 cycles.

The University of Bristol's Jean Golding Institute Data Week 2021

The University of Bristol's Jean Golding Institute Data Week 2021 brought together industry and academia to help tackle data-related challenges. The South West Nuclear Hub hosted two sessions led by SINDRI researchers Professor David Knowles and Professor Mahmoud Mostafavi. These were "*The Nuclear Industry/Data Science Experts: Challenge Collaboration Workshop*" and "*Nuclear Structural Integrity & Data Automation: A Roadmap*". The sessions provided an opportunity to collaborate with the data science-community and define and discuss key areas driving data automation in nuclear structural integrity. A follow-up workshop is being organised by industry.

New collaborations

The team has grown their collaborative relationships and has worked with new stakeholders both internal and external to the consortium, this includes:

Rolls-Royce

Rolls-Royce aiming to provide support for three, new PhD studentships in the SINDRI project.

French Alternative Energies and Atomic Energy Commission (CEA)
Cécile Petesch, from the CEA, has over a decade of experience in nuclear equipment design and manufacture and has joined the SINDRI Technical Advisory Board.

Staff Highlights

This project brings together the UK's foremost experts in materials, manufacturing and data science for the nuclear sector. This past year, the SINDRI project and several members of the team have been awarded or recognised for their achievements and impact.

Awards

- **Dr Emilio Martínez-Pañeda, Imperial College London**: UKRI Future Leaders Fellowship (Sept 2021) and one of five winners of the RAEng Engineers Trust Young Engineer of the Year competition (July 2021).

- **Dr Ed Pickering, University of Manchester**: IOM3 Grunfeld Memorial Award & Medal (June 2021).

Press Recognition

- **Professor David Knowles** - Interviewed for Reuters on SINDRI (August 2021)
- **SINDRI Project** – Funding announcement on Business Live. Featured on UKRI blog on realising the potential of digital twins. Included in BEIS-led announcement in April 2021 of new Prosperity Partnerships.

Conference Recognition

- **Dr Emilio Martínez-Pañeda** - Invitation to give a plenary lecture at the annual conference of the UK Association for Computational Mechanics (UKACM 2022).
- **Professor Mahmoud Mostafavi** – Invitation to present at the 15th International Conference on Fracture, Atlanta Georgia, 2022
- **Professor Paul Wilcox** - Plenary talk at the SPIE Smart Structures and Non-Destructive Evaluation conference, Long Beach, California, 2022.

New Team Members

Since the project launched 6 months ago, we have welcomed several new members to the team including: 15 Co-Investigators, 3 Post-Doctoral Research Associates and 15 PhD Students. The programme has also benefitted from 2 additional interns within the EDF UK Centre team, speeding up progress and strengthening the collaboration with the different partners.