IMPROVING SAFETY ANALYSIS METHODOLOGIES AND MOVING FROM TRADITIONAL TO HIGH-FIDELITY SAFETY ANALYSIS TOOLS FOR SMALL MODULAR REACTORS

MCSAFER - NEWSLETTER 08/2021

Dear Colleagues,

welcome to the first edition of the McSAFER project newsletter.

McSAFER represents a consortium consisting of 13 partners including universities, research centres, manufacturers, and utilities located in Europe and Latin America. The project is funded by the Horizon 2020 EURATOM Research and Training Programme 2019-2020 under the topic “Support for safety research of Small Modular Reactors” (NFRP-2019-2020-05. It brings together experts in SMR technology, reactor safety analysis, core analysis, and high-fidelity numerical tools to contribute to the safety research (methods improvement and experimental investigations) for SMR licensing.

On September 28th-30th, the McSAFER consortium assembled for an online Kick-off Meeting. Almost a year later, we are looking back on a busy and successful first year.

We thank all partners working on and associated with McSAFER and look forward to an exciting and productive collaboration.

Victor Hugo Sanchez Espinoza,
coordinator of McSAFER

McSAFER AT A GLANCE

The aim of the McSAFER project is to advance the safety research for Small Modular Reactors (SMRs) by combining safety-relevant thermal hydraulic experiments and numerical simulations of different approaches for safety evaluations.

Start date: 01/09/2020

Duration: 36 months

Consortium: 13 partners located in Europe and Latin America

Coordinator:
Dr. V. H. Sanchez Espinoza, Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR)

Funding: 4.045.133,75€

Learn more about McSAFER on the project website

McSAFER MOBILITY PROGRAMME

The McSAFER project has launched a mobility programme for PhD students, postdoc researchers and staff members of its partner organizations. The mobility programme funds temporary stays in McSAFER partners' labs and research facilities.

In order to support education in the field of SMR, safety analysis and multi-physics simulations, the McSAFER project offers a mobility programme for PhD students, postdoc researchers and staff members. The goal of the programme is the promotion of mobility between the McSAFER partners to create synergies between the organizations and to disseminate knowledge to the next generation of nuclear experts. The McSAFER project will grant up to 10 mobility grants with a total budget of 18.000€ during the runtime of the project.

The mobility programme offers funding for research focused exchange stays at the McSAFER organizations. The mobility programme will fund the temporary stays in McSAFER partners' labs and research facilities. The programme is now open for applications and applications can be submitted at any time.

Learn more about the programme

THERMAL HYDRAULIC TEST FACILITIES

In McSAFER, researchers and industrial partners will perform experiments on existing European thermal hydraulic test facilities. The goal is to develop and improve simulation tools for SMRs and to validate the applied simulation tools with the experimental data generated within McSAFER.

COSMOS-H (Karlsruhe Institute of Technology, Germany)

The experimental test facility COSMOS-H (“Critical Heat Flux on Smooth and Modified Surfaces – High Pressure Loop”) is developed and set up for the detailed investigation of thermohydraulic phenomena like boiling and complex flow phenomena that can occur in (nuclear) power plants.

Figure 1: First trial setup of the COSMOS-H test track in McSAFER

The facility consists of a high-pressure loop in which experiments can be carried out with demineralized water at pressures up to 17 MPa and temperatures up to 360°C. In addition, there are two cooling loops connected in series working with thermal oil and cooling brine. The entire system has a heating capacity of almost 2 MW for heating and evaporating the working medium. The test section accounts for 600 kW of this.

The experiments conducted within McSAFER focus on heat transfer in different SMR concepts. In particular, boiling flows under forced convection up to the critical heat flux will be investigated.

For this purpose, two different experimental setups will be fabricated. Detailed investigations will be carried out on a single heated tube made of Zircaloy-4 surrounded by an annular gap through which the flow passes, also using optical measurement methods. These will be supplemented with investigations on a rod bundle consisting of 5 heated tubes. Similar to a small section of a fuel element, one tube is surrounded by four other tubes in the periphery.

HWAT (Kungliga Tekniska högskolan, Sweden)

HWAT (“High-Pressure Water Test Loop”) is a high-pressure, high-temperature water loop for investigation of two-phase flows and heat transfer relevant to nuclear applications. In particular, the loop has been used for intensive studies of Critical Heat Flux (CHF), bringing about one of the largest experimental databases in this area in the world. The loop is constructed to withstand high pressures, up to 25 MPa, and high temperatures (up to 375°C) to enable experiments involving supercritical water.

In McSAFER, the HWAT experimental programme aims to develop experimental data for the calibration and validation of thermal-hydraulic codes with the focus on natural circulation transients, specifically transition from forced-to-natural circulation and transition from natural-to-natural circulation in conditions relevant for novel SMRs.

MOTEL (Lappeenrannan-Lahden teknillinen yliopisto LUT, Finland)

The next-generation multifunctional large-scale test facility MOTEL (“Modular Test Loop”) has been constructed at LUT University nuclear safety research laboratory in Lappeenranta in 2019-2020 for studies on nuclear reactor safety related thermal hydraulic phenomena. The principal idea of the MOTEL facility is modularity: the facility comprises interchangeable components, modules, and the facility design enables adding new components when needed. By replacing individual modules, MOTEL is thus able to represent several different types of nuclear power plants as needed.

In McSAFER, the MOTEL experiments will produce SMR-specific data for the validation of system, CFD and subchannel codes. The experiments are divided into two test series. The first series will focus on the behaviour of the helical coil steam generator. The aim is to study heat transfer from the primary side to the secondary side by performing several steady state periods with different core power levels. The second test series will comprise core crossflow experiments especially for the studies on mixing between core subchannels. This test series will be divided into two parts: experiments with an even radial core power distribution and experiments with a skewed radial core power distribution.

PROJECT PROGRESS

Work Package 3 – Multiphysics core analysis methodologies for SMR applied for safety case REA

The Work Package 3 of McSAFER focuses on evaluating the differences in the predictive capabilities of different fidelity reactor core solvers in core level transient scenarios. Transients are modelled at the core level of four different SMR concepts using solvers at three levels of fidelity:

1. Traditional low-order methods based on nodal diffusion neutronics and one dimensional thermal hydraulics.
2. Advanced low-order methods with direct pin-level resolution of the neutronics coupled with subchannel level thermal hydraulics.
3. High fidelity methods using Monte Carlo neutronics solution coupled with advanced thermal hydraulic solvers.

During the first year of the project, the openly available specifications for the four SMR concepts were supplemented using expert judgment in order to produce comprehensive and consistent specifications at the reactor core level that can be utilized in constructing the calculation models for the wide range of reactor core analysis codes applied in the project.

The construction of the calculation models for traditional and advanced low-order methods has been proceeding well with the largest effort going into establishing a proper group constant generation methodology for both the nodal neutronics and pin-level neutronics solvers for each of the different SMR concepts.

Furthermore, an investigation has been made into advanced transient heat deposition models that could account for both the prompt part of transient heating and also accurately model the development of the decay heat distribution in the reactor core during and after transient scenarios.

Work Package 4 – Multiscale RPV analysis methodologies for SMR

Within WP4 we will perform thermal hydraulic analyses of reactor pressure vessel behaviour for two SMR designs, NuScale and SMART. This WP is divided into four Task, in which the same problems are analysed both by the traditional 1D or 3D (coarse mesh) approach and by using multiscale coupling of system-TH codes with subchannel codes and system-TH codes with CFD codes. The work in WP4 is closely coordinated with WP5, as the models developed in WP4 serve as input for WP5.

At the beginning of the project, NuScale and SMART databases were created from open literature, on the basis of which input models for computer codes are prepared. This approach will ensure comparability of the results of individual participants.

In the current phase of the project, efforts are mainly focused on the development of 1D and 3D models for system programs (eg. TRACE) - see Figure 2.

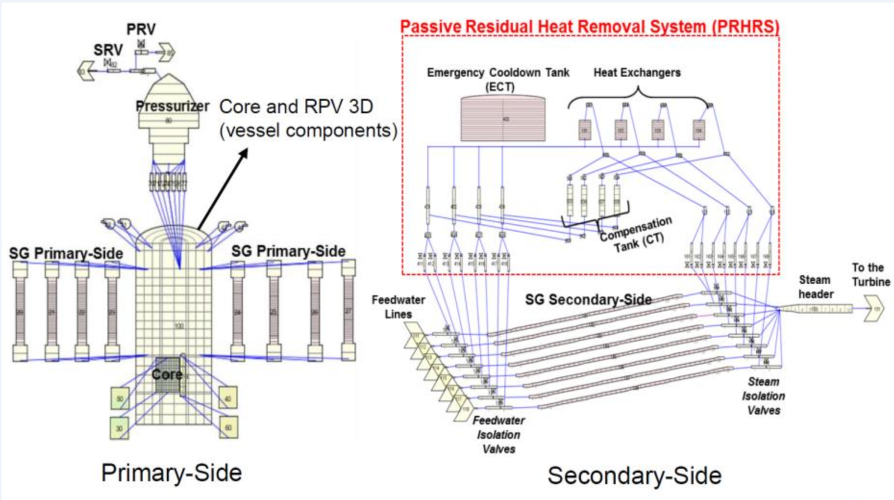

Figure 2 SMART Facility TRACE Model (KIT)

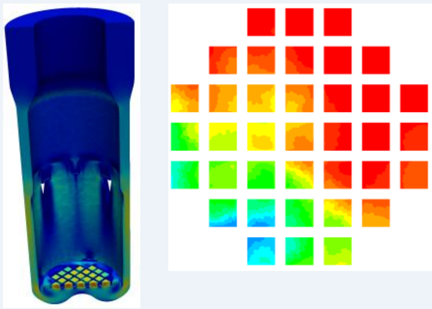
Figure 2 NuScale Mixing Scalar Test Fluent calculation (ÚJV)

Work Package 5 – Multi-scale plant analysis methodologies for SMR applied postulated accident scenarios

WP5 deals with the modelling of the whole plant of two SMR designs, NuScale and SMART. It continues the work of WP4, where the reactor pressure vessel of the same two designs is modelled and different accident scenarios are analysed. In the first phase of the project, efforts are naturally concentrated on vessel modelling.

Beside this, the system code models for the NuScale and SMART reactor designs are prepared to be equipped with components outside the reactor pressure vessel. This concerns the decay heat removal system (DHRS), the feedwater system and the main steam lines (Fig. 1).

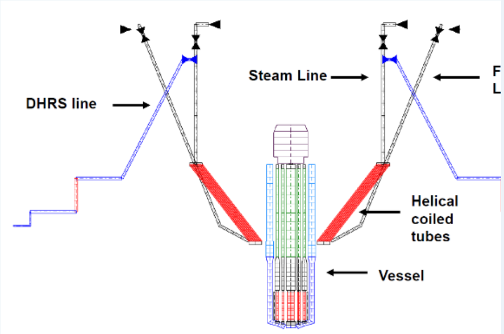

Fig. 1: ATHLET NuScale model with feed water, steam and decay heat removal system lines

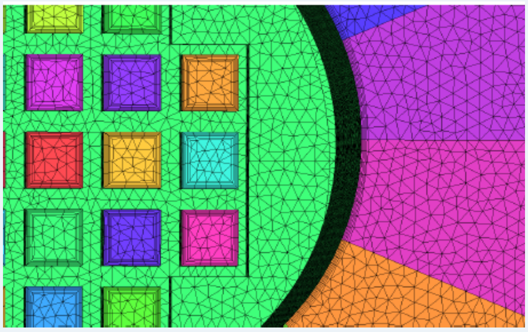

Fig. 2: Preparation of coupling interface for a 1:1 channel coupling between CFD and system code

In addition, the modelling efforts are directed towards the coupling of the system code model with those from the CFD code. For the NuScale model a 1:1 coupling of each fuel assembly is being implemented (Fig. 2).

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