SOTERIA is an on-going H2020 project which proposes a comprehensive research approach in order to enable nuclear power plant operators, as well as regulators, to better understand and thereby predict the ageing phenomena occurring in reactor pressure vessels and internals steels to ultimately ensure a safe long-term operation of existing European nuclear power plants.

The SOTERIA approach is based on an end-user perspective and has planned the set-up of simulation-oriented experiments aiming to validate models at different scales.

*The **third edition of the SOTERIA newsletter** focuses on the technical progress of the different work packages, describing among other items of interest, the technical report on microstructural inhomogeneities of reactor pressure vessel steels and their impact on mechanical properties, that was issued within WP3, and the new hybrid kinetic MonteCarlo method for complex alloys that has been developed within WP5. This issue also presents information about the General Assembly meeting held in November, in Madrid.*

A section on upcoming events includes a brief description about the Soteria midterm workshop and the training school which will both take place in 2018. Further information is available on our public website.

Finally, we would like to remind that the SOTERIA End-User Group is still open to equipment manufacturers, vendors, and operators (if interested, please contact Marc Berveiller at marc.berveiller@edr.fr).

The SOTERIA project partners

Progress in radiation effects on microstructural evolution of RPV and internals under different levels of fluence and flux (WP2)

Experimental observation by SANS, PAS and TEM confirm the effect of neutron flux on the radiation induced damage in RPV base metals and welds as well as on model alloys. TEM examination of n-irradiated stainless steels show evidences of void swelling, more experimental work is on-going on the same material irradiated at higher fluences to confirm this observation. PAS (Coincidence Doppler Broadening) results on Ringhals surveillance materials and model alloys (as irradiated and PIA) are already available. Effects of the chemical composition of irradiation hardening has been observed by nanoindentation of ion-irradiated RPV steels.

Progress in evaluating uncertainties in fracture toughness measurement on irradiated RPV steels and mitigation approaches (WP3)

Material samples and components supplied by the consortium are used to quantify the degree of inhomogeneity present in RPV base and weld materials by dedicated examinations of a large coupon section from a forged vessel head of Jose Cabrera plant (MnMoNi steel), a section from Greifswald Unit 8 RPV (CrMoV steel) and other RPV material samples which are already well characterized to avoid large new experimental investigations. Currently, 19 RPV materials which are representative for European Light Water Reactors are being examined by appropriate mechanical tests, chemical analyses and microstructural techniques. All planned manufacturing processes and transportations of specimens to the various European laboratories were finished as a prerequisite for the ongoing experimental work.

A technical report on microstructural inhomogeneities of RPV steels and their impact on mechanical properties at initial state was issued, where the influence of initial macro- to micro-scale heterogeneities on RPV fracture toughness behavior was quantified. Among others, inhomogeneity analyses and initiation sites investigations were performed; primary initiation sites on several fracture surfaces were analyzed by SEM; carbides rich in Mn, Mo and Cr were detected by APT in non-segregated and microsegregated samples; and impact tests showing a dependence of the absorbed energy with the location of the specimens in a forging material were performed.

Impact tests show a dependence of the absorbed energy with the location of the specimens in CIE-1 material.

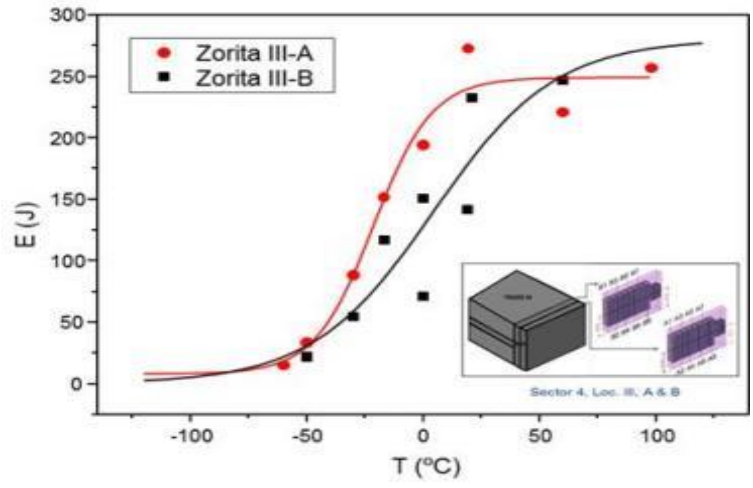

Figure 1 – Charpy V-notch transition curves of material CIE-1 (Zorita, MnMoNi) for same location

It was found that the primary initiation site is not characterized by a specific microstructural feature, such a precipitate or inclusion, at which brittle fracture would have initiated. In general, tensile properties of studied material do not show a significant scatter, whereas the fracture toughness tests show larger scatter than expected that could be attributed to the presence of intergranular fracture areas and to a dependence on the chemical composition, respectively.

Progress in environmental effects on IASCC susceptibility of reactor internals (WP4)

WP4 focuses on understanding the influence played by the environment on reactor internals IASCC susceptibility with a particular focus on: irradiation effects (e.g. neutron, helium), material condition (e.g. cold work) and environmental factors (e.g. water chemistry, hydrogen additions). This work package aims to creating data which can be fed back into fracture models to predict IASCC.

At present, a huge effort has been made securing neutron irradiated material for SCC testing and advanced characterisation. Successful SSRT tests on helium implanted material have been achieved. Proton irradiations have been performed to simulate neutron damage in a short amount of time. Understanding of SCC testing methodology has been progressed in preparation of SCC testing on proton irradiated material. Various experiments and characterisation studying the effect of material condition and the effect of environment have progressed since the beginning of SOTERIA.

Progress in the development, validation and integration of models to assess RPV and internals components under irradiation (WP5)

In task 5.1 dedicated to the nanofeatures modelling, a new hybrid kinetic MonteCarlo method has been developed for complex alloys. A new parameterization (Concentration Dependent Pair Cohesive Model) has been adjusted on large database DFT calculations to describe energies of both pair interaction and solute-vacancy clusters. These developments allow to have a better agreement with experiments for the formation of solute riche clusters under thermal ageing and under irradiation. A DFT based neural network kinetic Monte Carlo for cluster formation studies is also under development for the study of flux coupling effects, including SIAs, in RPV steels. This method was applied on model alloys and industrial RPV steels.

In task 5.2 dedicated to the behavior of material for RPV and internals steels, several numerical implementations of different Crystal Plasticity Laws (CPL) into Mfront code were made for both materials and tested. Concerning internals steels, these laws are used to compute stress fields in large polycrystalline aggregates based on realistic geometries at different temperatures and for different levels of irradiation.

In task 5.3 dedicated to fracture models, some simulation of SENB specimens were made to consider variation in the material initiating particles and their impact on fracture toughness.

Probabilistic assessments considering localized variation in the calibration parameters of the brittle fracture model(s). We had a successful use of Beremin and JFJ LA models in a deterministic and probabilistic methods for materials selected within the programme (ANP2 and ANP4).

The Void Growth and Coalescence is under investigation to provide experimental. These data would also be useful to calibrate constitutive equations for irradiated austenitic stainless steels. Some ion-irradiated thin tensile samples have been obtained by using a Focused Ion Beam (FIB) for the drilling of cylindrical holes. SEM observations of the evolution of void dimensions under tensile loading has been made on these specimens.

In task 5.4 dedicated to the integration of models into a platform, a new version of the platform is available with new features:

- A new interface dedicated to case studies.
- A new module with Charpy impact tests models.
- More interactions with experimental data (tensile curve can be loaded as input of finite element models, identification of constitutive equations form experimental data).

SOTERIA General Assembly 2017

On 7-8th November 2017, SOTERIA held its yearly General Assembly meeting. This year's general assembly took place in Madrid, Spain, and was hosted by project partner CIEMAT. The objectives of this event were to receive an update of the work progress in each of the 6 work packages to check whether the project is on track; to provide the work package teams opportunity for face-to-face work sessions; and to plan the activities until the end of the next official reporting period, which will be reached in August 2018. On the same occasion, the meeting participants did also benefit from a guided tour of the CIEMAT research facilities. The tour was highly appreciated by the partners and allowed for some interesting additional insights regarding the work of CIEMAT.

The meeting went very well. It allowed the partners to discuss in a constructive atmosphere, to find answers to pending questions, and to determine the actions for the months to come as to make sure that the project continues to progress according to plan.

UPCOMING EVENTS

SOTERIA MID-TERM WORKSHOP

9-10 & 12 April 2018, Prague

SOTERIA will hold a workshop as a side event of the NUGENIA Annual Forum & Nuclear Days 2018.

The objective of the workshop is to disseminate the project preliminary results and work progress among the nuclear research and industrial communities, as well as identifying future research needs. The workshop will serve as a forum for regulators, user groups, experts and industry, to exchange information and experiences on the issue of radiation effects on nuclear power plant components.

Technical Programme

RPV – Microstructure
Flux effect
Mechanisms of formation of nano-features
RPV – Uncertainties in determination of RPV fracture toughness
Effect of materials heterogeneities on mechanical properties at initial state
Effect of materials heterogeneities on microstructure and mechanical properties at irradiated state
Effects of additional uncertainties and handling and mitigation of uncertainties
INTERNALS – Microstructure
Flux effect on the radiation damage of austenitic steels
Mechanisms of formation of nano-features and their effect on intergranular cracking susceptibility
INTERNALS – Environmental effects on IASCC susceptibility of internals
Irradiation effects on microstructural evolution
Cold work effects on microstructure
Effects of the environment on the oxide properties
Effects of irradiation on SCC
Effects of He on IASCC susceptibility
Multiscale Modelling tools
Nanofeature models due to irradiation for RPV and Internals
Improvement and validation of the prediction of the hardening and physically-based constitutive equations for RPV and Internals
Fracture models for RPV and for the IASCC of Internals
Demonstration of the modelling platform

A Joint Technical Session, with the objective of exchanging information, building collaborations and enhancing synergies with other NUGENIA projects, will be organized as part of the workshop on 12th April. During this session, presentations by the different projects will be followed by a round table for discussion.

More information and registration available here.

Joint session	
SOTERIA	Every participant will make a short presentation of the project, followed by an introduction of common interest issues. ROUND TABLE FOR DISCUSSION
NOMAD	
ADVISE	
MEACTOS	
INCEFA+	

SOTERIA TRAINING SCHOOL

3-7 September 2018, Valencia

Addressed to early career scientists and engineers, the training school will focus on long-term irradiation effects in structural materials for nuclear reactors.

The SOTERIA consortium includes the following organisations:

COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
WOOD PLC
AREVA NP SAS
FRAMATOME GMBH
ARTTIC
CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
CENTRUM VYZKUMU REZ S.R.O.
ELECTRICITE DE FRANCE
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TECNATOM S.A.
UJV REZ, A.S.
THE UNIVERSITY OF MANCHESTER
UNIVERSITAT POLITECNICA DE CATALUNYA
VATTENFALL AB
ECOLE NATIONALE SUPERIEURE D'ARTS ET METIERS
TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

This project received funding from the Euratom research and training programme 2014-2018 under grant agreement no. 661913.

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