NOMAD

Nondestructive Evaluation (NDE) System for the Inspection of Operation-Induced Material Degradation in Nuclear Power Plants

STATUS REPORT

June 2020

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Editorial

In almost all major industrial countries worldwide, today, nuclear power plants (NPPs) are used to generate electricity. The long-term operation (LTO) of existing NPPs has already been accepted in many countries as a strategic objective to ensure adequate supply of electricity over the coming decades. To estimate the remaining useful lifetime of NPP components, LTO requires reliable tools. This is what NOMAD stands for: the development, demonstration and validation of a nondestructive evaluation (NDE) tool for the local and volumetric characterization of the embrittlement in reactor pressure vessel (RPV) materials.

Consequently, our priority aims are

- to develop and demonstrate a software-based NDE tool for the characterization of RPV embrittlement, accounting for material heterogeneities and exceeding the existing information from surveillance programs.
- to extend the existing database of RPV material degradation by adding correlations of mechanical, microstructural and NDE parameters, including quantification of reliability and uncertainty.
- to apply the developed tool to cladded RPV material.

What's new?

For the first time, a systematic study is carried out on a well-characterized set of multiple sample scales that correlates the microstructure, mechanical properties, neutron irradiation conditions and nondestructive properties. A variety of NDE methods is applied to provide information complementary to those generated by destructive tests which can be performed on surveillance samples only. NOMAD will provide an optional procedure to quantify the neutron-induced degradation additionally to the existing standardized methods and will contribute to the extension of the existing knowledge concerning degradation phenomena and progression of the material properties. NOMAD will foster the development of NDE for the characterization of ageing materials, going along with increasing innovation capacity and integration of new knowledge for the surveillance of a safe operation of RPV. After validation, a credible and reliable tool for the quantification of material degradation from results of nondestructive evaluation becomes available. The proposed concept will furnish supporting information or confirmation, when there is no monitoring of material properties by destructive testing during periodical safety reviews.

With this status report the NOMAD consortium provides an overview of the main outcomes during the first three years. First insights are also being shared via scientific publications, at international conferences and scientific events. To complement this summary, one member of the NOMAD Scientific Advisory Board will share her perspectives on the project development in a short interview.
If you have any general or even specific questions regarding NOMAD, we are happy to receive your feedback. Please find our contact details at the end.

Enjoy reading!

NOMAD – Work progress and main results

In order to reach the objective of the project a complete sample matrix of representative European RPV steels has been set up of multiple sample scales from half Charpy over full Charpy samples to non-cladded and cladded blocks. Samples of Eastern and Western RPV design, base and weld material have been provided in non-irradiated condition and at different neutron irradiation levels (neutron fluence and temperature). One Western RPV material is represented at multiple sample scales with the goal to study neutron-induced embrittlement across a variety of sample geometries reaching from Charpy samples to large cladded blocks simulating an almost realistic RPV condition. Some of the samples are available from previous irradiation programs, some have been irradiated within NOMAD. Currently, the irradiation of Charpy samples, cladded and non-cladded blocks, is completed. To ensure that all defined samples serve the goal of a validated NDE tool, the suitability of the selected materials and sample geometries has been verified successfully. In addition, basic mechanical properties (yield and ultimate tensile strengths) and fracture toughness tests (master curve approach) have been determined for all Charpy samples. Preliminary metallographic analysis on selected samples has confirmed the observations resulting from the mechanical tests.

Moreover, multiple NDE technologies including micromagnetic, electrical and acoustic techniques have been developed and successfully tested on all provided materials and sample geometries. Setting optimization and round-robin tests have been carried out on several sets of non-irradiated Charpy samples and large non-cladded and cladded blocks made from representative Western and Eastern RPV steels. Furthermore, nondestructive tests on neutron-irradiated Charpy samples of five Western and one Eastern RPV steels have been completed and are currently being evaluated. For the first time, irradiated samples have already been characterized nondestructively in as-received condition in order to capture the initial condition of the material before irradiation.

To determine the capabilities of the individual NDE techniques and the performance of the NDE tool regarding the future application in the field a study has been initiated assessing the field conditions as well as their effects on the different NDE techniques. This includes important inspection technique parameters as well as possible difficulties regarding the conduction of inspections in a NPP and in similar environment conditions. The information collected has been analysed and compiled, providing an overview of the most relevant field conditions to be addressed in the validation process. Based on this information and on the assessment of the samples available, the design of experiments was supported by the development of a validation plan.

Work Package 1

Description and delivery of the sample sets and irradiation conditions, sample provision, microstructure characterization and determination of the mechanical properties

- Material: Select and confirm availability of materials and samples (broken/non-broken Charpy, large cladded and non-cladded blocks) and allocate/provide the materials for the project

Charpy samples made from four Western RPV (18MND5-W, 22NiMoCr37, A508-B, HSST-03) steels; that were already available from previous research activities; have been provided to all NDE partners in the non-irradiated state for calibration purposes. The same materials at various fluence and temperature levels from previous irradiation campaigns (CHIVAS) have been recovered from storage. Around ~200 samples were foreseen in this first sample set. A JRQ material was used for round-robin testing for destructive purposes.

The second set of samples contained one Eastern (15kH2NFMA) and one Western (A508 Cl.2) RPV steel (Charpy geometry, non-cladded and cladded blocks) was manufactured specifically for this project. A total of ~220 Charpy samples and ~40 huge blocks (50x50 x115mm²) with and without cladding have been manufactured and send around for round robin tests to all NDE partners. The advantage of this approach was that the exact same samples and blocks were irradiated. Enough non-irradiated material has been provided to develop NDE sensors and optimize NDE methods. Thermally treated material has been prepared from these two steels for the characterization in a round-robin manner by all NDE techniques. A study to evaluate the procedure for heat treatment of A508 Cl.2 steel including a preliminary mechanical testing after the heat treatment procedures was carried out to prove the effectiveness of the thermal treatment conditions.
In total this gave rise to a well-defined sample set representing six base and one weld material of eastern and western RPV design. The matrix of materials selected has been evaluated in terms of validation regarding the representation of common reactor pressure vessel material, resulting in the laboratory approach. This means that there is a huge variety of neutron irradiated materials from base, weld, various fluence and irradiation temperature.

As a final sample set, eight samples with different surface roughness have been manufactured and provided to all partners applying NDE to examine the additional effect on the accuracy of the nondestructive results caused by the surface roughness. Moreover, the effect of manufacturing and removal of the Ni coating for irradiation on the NDE results have been examined by supplying samples before and after Ni coating as well as with Ni coating.

To examine effects caused by the cladding itself, two pieces from A508Cl.2 cladding with the interlayer and heat-affected zone have been manufactured. The whole process has been performed in line with the requirements for the usability in WP4.

This objective has been successfully achieved.

- Microstructure and mechanical properties: Supply detailed information on microstructure and destructively determined mechanical properties for calibration of and correlation with NDE data

To identify and describe common trends in NDE data regarding neutron irradiation-induced embrittlement, correlations between mechanical, microstructural and NDE parameters, including quantification of reliability and uncertainty, are being analysed and documented with respect to non-irradiated microstructure, material variability, irradiation conditions and other influencing factors. Furthermore, a mechanical test study on neutron irradiated small samples was performed at low temperature to determine the hardness and DBTT shift which shall be achieved after irradiation of Charpy samples and large blocks.

The initial condition (before irradiation) has been characterized in detail. Chemical compositions for the various RPV steel grades were determined by means of optical emission spectroscopy. In order to evaluate the ductile-to-brittle transition temperatures (DBTT) of non-irradiated materials several mechanical tests have been performed. Mechanical tests and microstructure analysis have been performed on all materials in non-irradiated condition. All non-irradiated and irradiated Charpy samples from previous irradiation programs have been mechanically tested. Four previously neutron irradiated materials, namely the 18MND5-W, 22NiMoCr37, A508-B and HSST-03 at ten various irradiation conditions (fluence, temperature) were investigated. Approx. 400 mechanical tests were executed. An embrittlement database was built as calibration source for the partners applying NDE.

Moreover, all Charpy samples irradiated within NOMAD were destructively tested and the results are currently being evaluated.

- Neutron irradiation and hot-cell use: Provide neutron-irradiated material for investigations in hot cells regarding embrittlement and hardening relevant for the LTO of existing NPPs

A preliminary neutron irradiation campaign (NOMAD_0) was performed at a temperature of ~280°C in order to determine the optimal procedure for the irradiation of the blocks and Charpy samples. After that, the irradiation of Charpy samples, non-cladded and cladded blocks has been prepared and carried out at BR2. The rigs have been designed and manufactured. Thermal and hydraulic flow calculations as well as final calculations on flux/fluence, anti-reactivity and corrosion in the BR2 cooling water were performed. A study on the adherence and procedure for removal of the Nickel coating on the blocks was carried out. The irradiation of Charpy samples, cladded and non-cladded blocks has been completed in three irradiation campaigns and the samples have been transported from BR2 to the LHMA hot cells at SCK CEN after proper cooling.

Selection and preparation of the hot-cell for the hot-cell campaigns at SCK CEN is finished. An ALARA study (“As Low As Reasonably Achievable" refers to a principle of radiation protection) was performed to allow the modification of the connection feedthroughs for the various cables of all NDE set-ups. Electronic connection requirements have defined for the NDE set-ups needed for the hot cell campaigns on Charpy samples.

The first hot-cell campaign was related to old available Charpy samples that were not yet destructively tested. All NDE measurements on the Charpy samples were successfully completed. All possible contaminated sensors were cleaned and properly stored.

The second hot-cell campaign was related to the newly irradiated A508 Cl.2 and 15kH2NMFA Charpy samples at three different fluence levels irradiated at low temperatures. Also here, NDE measurements were performed successfully. At the moment, destructive Charpy impact testing is going on. Since the material was irradiated at low temperatures, the test temperatures are limited. Therefore, additional hardness and tensile tests are performed as correlation rules for the NDE measurements.
The preparation of the third hot-cell campaign is ongoing. The Ni coating from all 12 huge neutron irradiated blocks (sizes 42.5 x 47 x 115 mm^3) were removed and polished.

Work Package 2

Nondestructive materials characterization (MC) and evaluation of the progression of the material properties

- Qualitative and quantitative nondestructive materials characterization of the embrittlement in Charpy samples of several relevant RPV steels

In order to characterize the neutron irradiation-induced embrittlement of Charpy samples six NDE methods have been optimized or developed where applicable: three micromagnetic, two electrical and one ultrasound-based ones. They deliver different local and volumetric information about the interaction of microstructure with an external magnetic field, with electrical current or with and ultrasonic wave, respectively. Combining this complementary information in terms of material degradation enables a full nondestructive materials characterization across many material properties.

Several probes and devices have been optimized or designed and constructed, where applicable. For an optimal sensor design and setting of measuring parameters non-irradiated samples prepared and thermally treated in WP1 have been used. Additionally, the setting optimization including definition of coupling conditions, design of the sample and probe holders and determination of proper measuring parameters for all approaches have been performed by all partner applying NDE in their own laboratories. To assure that all partners used absolutely the same samples a round robin test has been initiated on one set of thermally treated samples.

After all these activities related to set-ups optimization had been completed NDE measurements have been carried out on neutron irradiated Charpy samples within two hot cell measurements campaigns. For this all partners applying NDE have defined a common procedure to perform the NDE measurements according to requirements for validation and qualification. All partners applying NDE methods have measured several Charpy sample sets of four RPV steels of western design base and weld material at different irradiation conditions: base material 22NiMoCr37, A508 Cl.3, A533-B and weld material 18MND5.

Additionally, two sets of Charpy samples of RPV materials of western and eastern design A508 Cl.2 and 15kH2NMFA, respectively, were investigated in non-irradiated condition in order to capture their initial condition. These Charpy samples have been irradiated in 2019 and, after that, nondestructively examined again. In this way, for the first time the progression of the material properties induced by neutron irradiation has been captured taking into account the initial condition of the materials. All nondestructive measurements have been completed on Charpy samples in October 2019.

For each material 28 measuring quantities generated by six methods were individually collected and depicted against the corresponding irradiation conditions (temperature and fluence level) and the ductile-to brittle transition temperature DBTT. These measuring quantities gives information about different material properties but characterize only partly the materials. However, several measuring quantities show good correlation with the embrittlement. For a full materials characterization all these quantities are combined in WP3. This large amount of data extracted from six NDE methods has been prepared according to requirements for the generation of the database and the tool development in the frame of WP3.

Moreover, to get a raw notion about the influence of different surface conditions on the NDE approaches, an additional set of six Charpy specimens made from RPV steel 22NiMoCr37 with different surface roughness have been provided and investigated by all NDE partners following the same procedure as during first and second hot-cell campaigns.

- Identification and description of the trends and correlation between nondestructively determined parameters and neutron irradiation-induced embrittlement

For this purpose, a classification procedure of the NDE data in terms of unified data format and measurement procedure for all NDE methods (related to the number of repetition/measurements to be performed, measuring positions) and data needed to be documented and collected in the NDE tool (row data or processed in terms of degradation) have been defined. Parameters describing neutron irradiation-induced embrittlement have been provided. Measuring quantities extracted from all NDE measurements have been depicted in terms of irradiation condition and correlated with the corresponding DBTT. All

these quantities show differences between samples of a given material irradiated at the same conditions. A possible explanation is the variations/deviations of the initial microstructure within one group of samples corresponding to the same irradiation condition. Measurements performed on samples made from a given RPV material before irradiation show different results and confirmed this assumption. Detailed examination must be carried out to verify this assumption.
However, trends have been identified in terms of embrittlement. Several quantities extracted from different NDE methods based on the same physical principal show similar results.

Qualitative and quantitative nondestructive materials characterization of the embrittlement in cladded RPV material samples

In order to generate information complementary to the information obtained by tests performed destructively on surveillance samples, which are currently assumed to represent the whole component and do not take into account possible local material variations and to inspect RPV materials through the cladding, considering local material inhomogeneities the micromagnetic, electrical and ultrasonic NDE techniques applied on Charpy samples have been optimized for this sample geometry. Non-irradiated non-cladded and cladded blocks have been provided to allow for the sensor design and optimization of the measuring settings. Additionally, two plates of cladding material with two thicknesses were provided in order to check the origin of signals recorded on the cladded blocks and whether the nondestructively detected signals are originated from the material under the cladding or not. In order to compare the sensitivity and the capability of different NDE methods related to the characterization of the material underneath the austenitic cladding and to avoid different influences on the measurement outcome due to different sets of blocks (in terms of slightly different microstructures, surface conditions, thickness of the cladding, thickness of the interface material between cladding and base material) one single set of thermally treated cladded and non-cladded blocks RPV steels has been investigated by all partners applying NDE in the frame of a round robin test. The results show systematic dependencies between quantities determined nondestructively, the thermal treatment condition and DBTT. In order to verify whether the signals received using the developed probes originate from the cladding or from the material underneath the cladding, cladding material has been investigated too. The results show that all NDE methods are in principle capable to detect the material underneath the austenitic cladding.

In a next step neutron-irradiated blocks will be investigated nondestructively. To assure that the results to be obtained on neutron-irradiated blocks are caused by neutron-irradiated degradation only, all blocks, have been nondestructively tested in non-irradiated condition before irradiation.

Due to COVID-19 pandemic the consortium has been unable to conduct essential measurements to complete this task.

Work Package 3

Advanced nondestructive evaluation tool for demonstration of materials characterization

Evaluation and comparison of measurement techniques optimized in WP2

All the measurement results obtained in WP2 with the different techniques and their respective analyses have been separated in terms of physical principles involved with the measurements, correlating them to the mechanical properties and irradiation condition. A guidance document has been created describing the evaluation procedure of the individual measurement techniques, the evaluation of their capability and determination of overall measurement uncertainty. A comprehensive table and database have been generated. The NOMAD Database consists in a large and unique collection of both destructive and nondestructive data of irradiated Charpy specimens and blocks with and without cladding.

The NOMAD Database is built using relational model. The basic info includes sample identification, material, and irradiation conditions. Measurement data includes all the parameters measured destructively during WP1 and nondestructively during WP2 and their corresponding standard deviations. In a first step this database has been fed with data collected during first and second measurements campaigns on Charpy samples, corresponding irradiation condition and embrittlement data.

In order to perform a comparison of all the techniques and give information of the feasibility of each NDE technique to classify the neutron irradiation-induced embrittlement degree on Charpy specimens, the DBTT have been estimated by the individual NDE technique. DBTT values were estimated by using the data measured in nondestructive fashion. The estimated DBTT were compared to actual DBTT values measured by means of Charpy tests and were also included in the database.

Selection of the measurement techniques

Selection of the techniques being most appropriate for the tool development and the further development of the techniques will be performed after the nondestructive examination of the large blocks will have been completed. Due to COVID-19 pandemic the consortium has been unable to conduct essential measurements to complete this task. The selection will be based on the methods' capability to detect changes between NDE measuring quantities measured before and after irradiation.

Development of an advanced NDE tool for materials characterization

The fundamental concept of the NOMAD Tool is based on regression analysis. At the moment, machine learning and AI is a major research topic. Since regression analysis is seen as a sub-group of supervised learning, the NOMAD project can exploit the state-of-the-art algorithms and implementation methods published by the scientific community. Therefore, the Tool will be written in Python 3.X using open source libraries such as scikit-learn and TensorFlow 2. The NOMAD Tool will be written using 100% open source code.

The state-of-the-art algorithms such as Support Vector Regression (SVR) and Artificial Neural Networks (ANNs) have been applied successfully. The first results show that, with the state-of-the-art regression analysis algorithms, it is possible to estimate DBTT with 20 °C accuracy. In addition, it is possible to add simultaneous USE estimation into the algorithm. The USE can be estimated with accuracy of 10 J.

Work Package 4

Application and Validation

- Determining the reliability of each technique, taking into account the most relevant parameters that might affect the measurement and the application in the field

In close cooperation with WP2 and WP3 the most relevant field parameters affecting the performance of the different inspection techniques have been identified and a procedure has been defined to take them into account for the experiment in the laboratory in terms of performance determination and accuracy estimation of any applied NDE method.

To identify the most relevant parameters affecting the performance and the outcome of each NDE inspection technique, a study was conducted to collect all relevant information regarding the relevant field conditions, the applied NDE methods and the provided samples. This included material, geometry and many aspects of testing environment. The matrix of materials selected in WP1 has been evaluated regarding the representation of common reactor pressure vessel material, resulting in the laboratory approach. Also, different geometries as well as different surface conditions and thickness ranges will be applied in the laboratory study. The suitability of the cladded blocks has been ensured regarding the validation requirements.

Possible circumstances interfering with the measurement in the field have to be well-described and simulated in the laboratory. A general NOMAD approach has been created. The necessary information was extracted from the study and merged with the information concerning materials available for NOMAD. After compiling the information assessed, an overview about the most relevant field information and how it will be addressed in the laboratory approach was obtained. Together with the simulated environmental parameters affecting the NDE performance, such as temperature and coupling, the degradation mechanism of neutron-induced embrittlement, represented by different fluence levels and irradiation temperatures, can be applied to the different specimens. Additional object parameters in the field, such as material imperfections, were identified within the study. Potential concepts for the assessment of the individual parameter influence on the measurement result have been investigated. The approach applied within NOMAD is the integral analysis of the measurement results, which follows an empirical concept. It has advantages in assessing the overall uncertainty complementary. Another advantage is to adapt this idea to the current experimental conditions and take into account the limited number of samples as well as the predefined irradiation conditions. It is implemented in NOMAD by a procedure guiding each NDE team through the evaluation of their measurement results. After entering the sample ID and the measurement values for each sample investigated, the related absolute DBTT-value has to be provided. These steps have to be repeated for all samples investigated in a predefined measurement campaign. As a result, the mean values and the expanded standard deviations will be calculated for each inspection technique in the same way and automatically displayed in a specific correlation curve between the absolute DBTT-values and the values obtain from nondestructive measurements. Based on this analysis, the correlation between the true destructively determined absolute DBTT-values and the DBTT-values obtained from the NDT-measurements will be established in a second step. This integral procedure ensures that the overall uncertainty of the predefined experiment will be calculated for all inspection techniques in exactly the same way. In addition, all uncertainty sources will be considered in one overall budget. Also with the application of this approach it is ensured, that the input values for the NDE tool were determined according to the same procedure for each inspection technique. Together with WP3, WP4 is currently investigating to what extent this procedure for characterizing each inspection technique fits in with the basic concept of the NDE tool and how both concepts can be merged.

- Provide recommendations for the application of the (developed) NDE tool (consisting of various reliable and validated NDE techniques) in the field

First recommendation in pursuit of this objective can be given after starting the demonstration of the NDE tool with regard to realistic field conditions.

Interview with NOMAD Scientific Advisory Board member

The Scientific Advisory Board (SAB) provides additional advice to help ensure that the NOMAD consortium can successfully disseminate and exploit project findings. With that it is an essential part of the extended project team, giving valuable scientific input for strategic decisions.

The NOMAD SAB consists of renowned scientists from international institutions or leaders of industry in the field of NDE in nuclear research. With that Marta Clelia Ruch (National Atomic Energy Commission of Argentina - CNEA), Sarmishtha Palit Sagar (National Metallurgical Laboratory - CSIR-NML) and James Wall (Electric Power Research Institute - EPRI) are bringing different expertise to the project.

Providing an insight into her experiences and feelings about NOMAD, we had a short interview with Marta Ruch:

1. In your opinion, what is unique about NOMAD's approach?

There are three aspects of NOMAD's approach, which I consider unique:

- The multidisciplinary approach to the problem of assessing aging of RPVs in NPPs. The project has put together a consortium of R&D institutions and laboratories with many different capabilities, combining experts in the irradiation of material for the surveillance programmes of many active NPPs, material scientists and researchers in the field of nondestructive material characterization, experts in tool design, systems and data management, validation, end users.

- The procuring and/or manufacturing of different and diverse sets of samples, ranging from tiny Charpy samples to large cladded blocks of RPV material. The study of different alloys, steels used in Eastern and Western RPVs. The huge amount of samples prepared and tested, starting from the as-received material, thermally heat treated, irradiated. This approach allows for a very careful separation of variables, in order to understand the effect of each of these on the particular material characterization technique. Measurements are being made at different facilities, including hot cell laboratories.

- The effort to assure at every step that the tool can be validated for its future use in NPPs.

2. What is the main impact of NOMAD for the nuclear community and which main need is addressed?

The main need addressed refers to the construction, testing and validation of a tool which through the cladding can search for defects and for material properties related to aging of RPVs.
The main impact for the nuclear research community lies in the large scale study of properties of RPV material. In this item I am including: (i) the preparation of the study samples, characterized by many laboratories in the round robin tests and which later on will constitute a very precious collection of calibration samples; (ii) the data bases with signal features; (iii) data fusion and the discussion of the performance and scope of the different NDT methods and techniques.

3. For you personally, what is the most exciting result of NOMAD?

There are some general aspects of NOMAD, which I find particularly promising and exciting:

- the promising results from some of the techniques, hence suggesting guidelines for further development.
- the data fusion approach to the problem.
- the interactive platform for information management. The effort towards dissemination of results to a wide public.

Scientific Publications

Even though the data generated in NOMAD is still being produced and evaluated, the partners have already been committed to disseminating their results openly (OpenAccess) to the scientific community. Some examples are highlighted below.

INSPECTION OF REACTOR STEEL DEGRADATION BY MAGNETIC ADAPTIVE TESTING

Degradation of nuclear pressure vessel steel materials, 15Kh2NMFA type and A5 08 Cl2 type (definition is given in the text) were investigated by a novel magnetic nondestructive testing method, so-called Magnetic Adaptive Testing (MAT), which is based on systematic measurement and evaluation of minor magnetic hysteresis loops. The measured samples were thermally treated by a special step cooling procedure, which generated structural changes in the material. It was found that this type of degradation can be easily followed by magnetic measurements. Charpy impact test were also performed and the results were compared with the magnetic parameters. In case of 15Kh2NMFA steel, a good, reliable and closely linear correlation was found between magnetic descriptors and transition temperature.

G. Vértesy, A. Gasparics, I. Szenthe, F. Gillemot and I. Uytdenhouwen

materials

https://www.mdpi.com/1996-1944/12/6/963

MAGNETIC NONDESTRUCTIVE INSPECTION OF REACTOR STEEL CLADDED BLOCKS

Degradation of nuclear pressure vessel steel material (15H2NMFA) was investigated by a novel magnetic nondestructive testing method, so called Magnetic Adaptive Testing (MAT), which is based on systematic measurement and evaluation of minor magnetic hysteresis loops. The measured samples were thermally treated by a special step cooling procedure, causing embrittlement of the material. It was found that this type of degradation can be easily followed by magnetic measurements. Results of Charpy impact tests were compared with the magnetic parameters. A good, reliable and nearly linear correlation was found between magnetic descriptors and transition temperature. Some results suggest that MAT testing of cladded block samples is possible even through the relatively thick cladding.

G. Vértesy, A. Gasparics, I. Szenthe, F. Gillemot

gjaets

http://www.gjaets.com/Issues%20PDF/Archive-2019/June-2019/1.pdf

INFLUENCE OF THE SIZE OF SAMPLE IN MAGNETIC ADAPTIVE TESTING

Magnetic adaptive testing is a nondestructive method, based on systematic measurement and evaluation of magnetic hysteresis loops, to characterize the degradation of ferromagnetic materials. Magnetic parameters in general depend on the size of the samples to be measured, and results of measurements, performed on different size samples cannot be compared with each other. In this work it is shown, that by proper choice of the size of magnetizing yoke, the degradation of the material can be correctly determined even in that case if different size of samples are measured.

G. Vértesy, B. Bálint, Sz. Gyimóthy, J. Pávó

gjaets

https://www.gjaets.com/Issues%20PDF/Archive-2019/September-2019/1.pdf

CHARACTERIZATION OF Β-SILICON CARBIDE AND POTENTIAL USE AS IRRADIATION TEMPERATURE MONITOR

Post-irradiation data on the neutron-induced swelling behaviour and resistivity changes in silicon carbide often does not show a clear trend. This makes a quantitative comparison between different studies difficult. To address the diverging results after irradiation in different studies, a thorough reference study is performed on high quality β-silicon carbide. The results show the response to neutron irradiation may be significantly influenced by structural defects present before irradiation. These findings open a way to improve the accuracy of silicon carbide irradiation temperature monitors.

J.V. Pitte, C. Detavernier, J. Lauwaert, I. Uytdenhouwen, A. Gusarov, J. Wagemans

Scientific.Net
Publisher in Materials Science & Engineering

https://www.scientific.net/MSF.963.362

NONDESTRUCTIVE INVESTIGATION OF NEUTRON IRRADIATION GENERATED STRUCTURAL CHANGES OF REACTOR STEEL MATERIAL BY MAGNETIC HYSTERESIS METHOD

The neutron irradiation embrittlement of four different types of nuclear pressure vessel materials (three base metals and one weld material) were investigated by a magnetic nondestructive testing method, magnetic adaptive testing (MAT). The method is based on the measurement of minor magnetic hysteresis loops on Charpy specimens irradiated by neutrons in the BR2 reactor. Due to the neutron irradiation, the structure of the material was modified. The Charpy impact method is suitable for destructive characterization of material embrittlement. The results of Charpy impact test measurements at SCK CEN Belgian Nuclear Research Centre were compared with the nondestructively measured magnetic parameters. A definite correlation was found between magnetic descriptors and the ductile-to-brittle transition temperature (DBTT), regardless of the type of material or irradiation condition. The results suggest that this "calibration curve" can be used to estimate the DBTT from nondestructive measurements.

G. Vértesy , A. Gasparics, I. Uytdenhouwen, I. Szenthe, F. Gillemot and R. Chaouadi

metals

https://www.mdpi.com/2075-4701/10/5/642

Past & Upcoming Events

2019

JANUARY

MO	TU	WE	TH	FR	SA	SU
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FEBRUARY

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NUGENIA TA4 Meeting
Madrid, ES

MARCH

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NUGENIA Annual Forum
Paris, FR

APRIL

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MAY

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DMIUT 2019
Gdansk, HU

JUNE

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BALTICA XI 2019
Helsinki (FI) &
Stockholm (SE)

NOMAD
2nd Progress
Meeting

NDE in Nuclear 2019
Charlotte, US

JULY

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ASME Pressure Vessels
& Piping Conference
San Antonio, US

AUGUST

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58th British Conference
on Nondestructive
Testing
Telford, UK

OCTOBER

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XII. Országos Anyagtudományi
Konferencia 2019
Balatonkenese, HU

NUGENIA TA4 Meeting
Petten, NL

NOVEMBER

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2020

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FEBRUARY

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Physics Days 2020
Kuopio, FI
!cancelled due to COVID-19!

MARCH

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APRIL

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WCNDT 2020
Seoul, KOR
!cancelled due to COVID-19!

JULY

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PVP conference
Minneapolis, US

AUGUST

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SNETP Forum 2020
Rome, IT

SEPTEMBER

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NOMAD
3rd Progress Meeting

OCTOBER

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NOVEMBER

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DECEMBER

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The NOMAD Consortium at a Glance

FRAUNHOFER INSTITUTE FOR NONDESTRUCTIVE TESTING (FhG-IZFP)

The Fraunhofer-Gesellschaft (FhG) undertakes applied research of direct utility to private and public enterprises and of wide benefit for society. The Fraunhofer Institute for Nondestructive Testing (Fraunhofer IZFP) was founded in 1972 under the lead of FhG with the mission "Research and Development for NDT for Nuclear Safety", and dealt with more than 50 projects on that topic.
The institute has competence in a wide range of services: evaluating new inspection procedures, staff training as well as executing on-site inspections and tests.

Besides the project coordination and overall monitoring, the main tasks of FhG-IZFP within NOMAD is the nondestructive material characterization by means of micro-magnetic and ultrasound methods.

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THE BELGIAN NUCLEAR RESEARCH CENTRE (SCK CEN)

The Belgian Nuclear Research Centre is a foundation of public utility under the supervision of the Belgian Secretary of State for Energy. With laboratories in Mol and a registered office in Brussels, it is one of the largest research centres in Belgium.
SCK CEN aims to be a leading research institution and a centre of excellence at an international level. Driven by inspired scientists and engineers, in combination with a unique infrastructure, we aim to develop innovative technologies that provide solutions for the social issues and requirements in the field of nuclear energy and ionising radiation. Safety and durability are always the key priorities.

Within NOMAD, SCK CEN is dealing with the description of sample sets (including cladded material), the microstructure characterization and determination of the mechanical properties. SCK CEN provides knowledge and expertise to identify a suitable test matrix, conducts neutron irradiation of relevant RPV materials and cladded blocks in their BR2 reactor and provides relevant samples needed for NDE and destructive testing.

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VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD.

VTT is a state owned and controlled non-profit limited liability company established by law and operating under the ownership steering of the Finnish Ministry of Employment and the Economy. VTT's activities are focused on three areas: Knowledge intensive products and services, Smart industry and energy systems, and Solutions for natural resources and environment. As an impact-driven organisation it takes advantage from its wide multitechnological knowledge base to strengthen Finnish and European industrial competitiveness. VTT's expertises include e.g. structural integrity of nuclear reactor materials and nondestructive evaluation.

Within NOMAD VTT is leading the work package which focuses on the development of a software-based NDE tool to characterize neutron-irradiation induced embrittlement and conducted the development of electrical resistivity measurement techniques.

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SWISS ASSOCIATION FOR TECHNICAL INSPECTION (SVTI)

SVTI is a private, independent institution within Switzerland that monitors around 50,000 technical installations and equipment, more than 2,000 kilometers of natural gas and oil pipelines and 12,000 transportation tankers for both, rail and road. SVTI/ASIT is a not-for-profit organization whose primary purposes are the prevention of accidents, the elimination of hazards in connection with the transportation and storage of dangerous goods and the elimination of hazards in the manufacturing and operation of various types of technical equipment.
The Nuclear Inspectorate, one of four main departments, supervises the manufacturing, installation, operation and testing of pressure-bearing installations in Swiss nuclear power stations. It reviews the design approval documentation for components and systems, supervises their manufacturing, installation and documentation and supervises the periodic testing (Nondestructive In-service inspections) within the framework of the annual revision outages of the nuclear power stations.

SVTI's main task within NOMAD is the validation of the inspection system. It steers the validation process in the focus of existing qualification standards on the one hand, but also applies latest evaluation techniques to quantify the performance of the system.

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EUROPEAN RESEARCH AND PROJECT OFFICE GMBH (EURICE)

EURICE provides comprehensive support services for the planning, initiation, and implementation of international collaborative research and innovation projects. EURICE ranks among Europe's largest project management offices, with a dedicated team of >40 staff members and has been successfully involved in the coordination of 50 collaborative projects within Horizon 2020. It offers backbone services for a successful project management approach by providing fair, transparent and neutral decision support information. EURICE is specialised in managing impact and innovation in all areas of research and innovation projects and provides expert knowledge to several 'Innovation Support Actions' aiming at maximising values of Horizon 2020 and focusing on the exploitation of Horizon 2020 results.

Within NOMAD EURICE assists the coordinator in all aspects of project management, including project monitoring, progress management, and decision making. Furthermore, it supports all partners in communication and networking activities as well as innovation-related activities such as dissemination and exploitation of results to maximise the project impact.

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COVENTRY UNIVERSITY (CU)

CU is the UK's top modern University having a reputation for excellence research, business engagement, innovation and entrepreneurship. Its Manufacturing and Materials Engineering Research Centre (MME) located within the Faculty of Engineering and Computing builds on historic research strengths at Coventry. It's core themes of Materials, Products and Processes support collaborative research with key industrial sectors including aerospace, automotive, and nuclear power generation. The Structural Integrity team is developing advanced methodologies for the study of damage processes in materials for critical structural applications.

Within NOMAD CU focuses on the NDE measurements for material characterization by employing electromagnetic equipment for the nondestructive testing. CU applies the MIRBE technology where magnetization amplitude and frequency have to be optimised.

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HEPENIX TECHNICAL SERVICE LTD

HEPENIX is experienced supplier in the automotive, consumer and nuclear industries. Its services include the full range of the development, production, installation and maintenance of tailor-made automated specialty equipment and industrial machinery.
Building on its matter-of-fact experience and expertise, incorporating the latest developments in management techniques HEPENIX deploy full-scale solutions of the highest standards.

HEPENIX is involved in the engineering tasks. Its main task within NOMAD is to develop and demonstrate an NDE tool for the quantitative characterization of the most relevant degradation phenomena.

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CENTRE FOR ENERGY RESEARCH (EK)

The Centre for Energy Research (EK) was established on the basis of two former independent institutions, the Institute of Isotopes (IKI) and the KFKI Atomic Energy Research Institute (AEKI). The Centre is part of the research network of the Hungarian Academy of Sciences.

In 2015 the Institute of Technical Physics and Materials Science also joined EK and is active in multidisciplinary research on complex functional materials and nanometer-scale structures targeting the exploration of physical, chemical and biological principles, and their exploitation in integrated micro- and nanosystems. The focus is on multidisciplinary research, whereas the possibilities of analytics, characterization and system integration can be exploited by effective cooperation. The Institute has competence in a wide range of services including material testing, evaluating new inspection procedures and executing on-site inspection and tests.

Within NOMAD EK's main task is to collect and provide differently aged material samples for the nondestructive testing. EK provides its expertise by applying nondestructive material characterization by means of magnetic hysteresis measurements (Magentic adaptive testing).

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PAUL SCHERRER INSTITUT (PSI)

PSI is the largest multi-disciplinary research center for natural sciences and technology within Switzerland. It has a long tradition in energy research. With respect to nuclear energy, the Department of Nuclear Energy and Safety (NES) has a unique position in Switzerland thanks to its heavy infrastructure, namely the Hot Laboratory with well–equipped hot cells and shielded zones for work and investigations on radioactive material.

Within the NES department, the Laboratory for Nuclear Materials (LNM) is the principal research unit and national center of excellence in Switzerland in the domain of radioactive material behavior and ageing in nuclear installations. The LNM addresses material-related, scientific issues with regard to safety, lifetime (extension), performance and sustainability of current and future nuclear reactors.

Within NOMAD PSI mainly contributes to the magnetic and thermoelectric NDT methods (Thermoelectric power measuring method – TEPMM).

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TECNATOM S.A.

TECNATOM is a Spanish company that operates in the field of engineering and specializes in guaranteeing operation and high levels of safety in the industrial setting, most especially at nuclear power plants. Its main activities are centred on the inspection of components by nondestructive testing, the manufacturing of inspection equipment, the training of plant operating personnel and the rendering of services supporting plant operation. Main expertise areas of TECNATOM are plant operation support, inspection services, structural integrity, execution and assessment of RPV surveillance programmes and training of NPP operations and maintenance personnel.

TECNATOM participates in NOMAD as a final user of the technology. It mainly contributes by specifying the requirements of the inspection equipment for application under real condition on the reactor pressure vessel of NPPs and reviews the applicability of the techniques and equipment developed in the project.

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Editorial Board

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For further information on the project, please visit the project website

www.nomad-horizon2020.eu

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