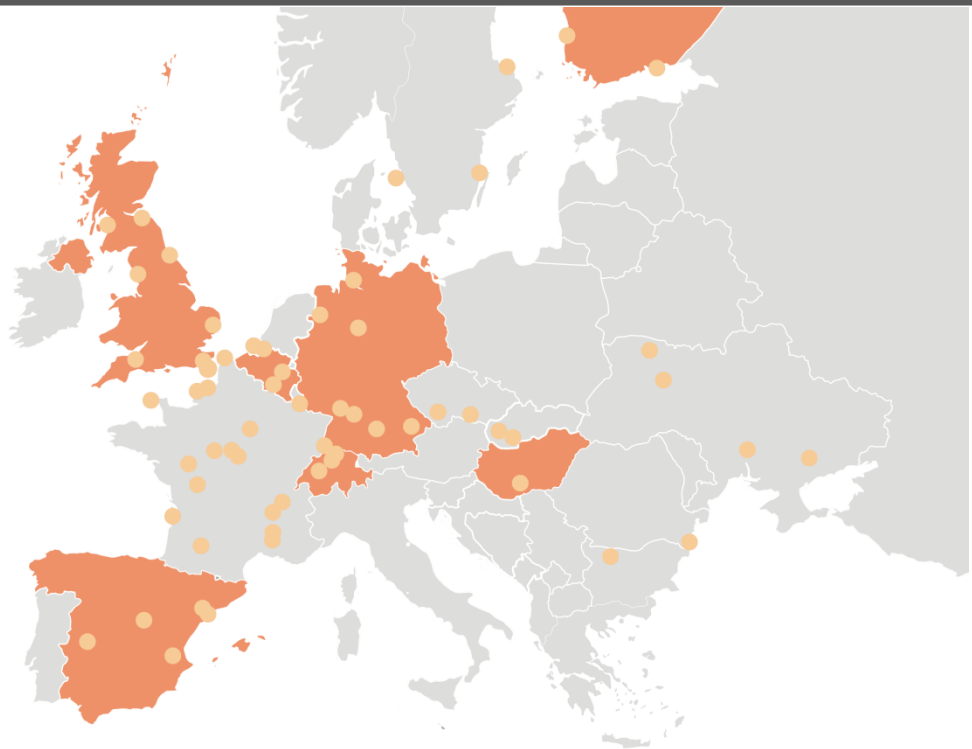
NOMAD

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



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www.nomad-horizon2020.eu

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The project at a glance

Aim
NOMAD aims to develop a non-destructive evaluation (NDE) system for nuclear power plants to assess the embrittlement in reactor pressure vessel (RPV) materials

Methods
NOMAD partners will implement different NDE methods including electrical, ultrasonic, acoustic and micromagnetic techniques

Vision
NOMAD will contribute to ensuring a secure electricity supply for the societies in Europe in the next decades

Partners
10 Partners from 7 European Countries

Duration
01/06/2017–31/05/2021

Provision and reference characterization of materials

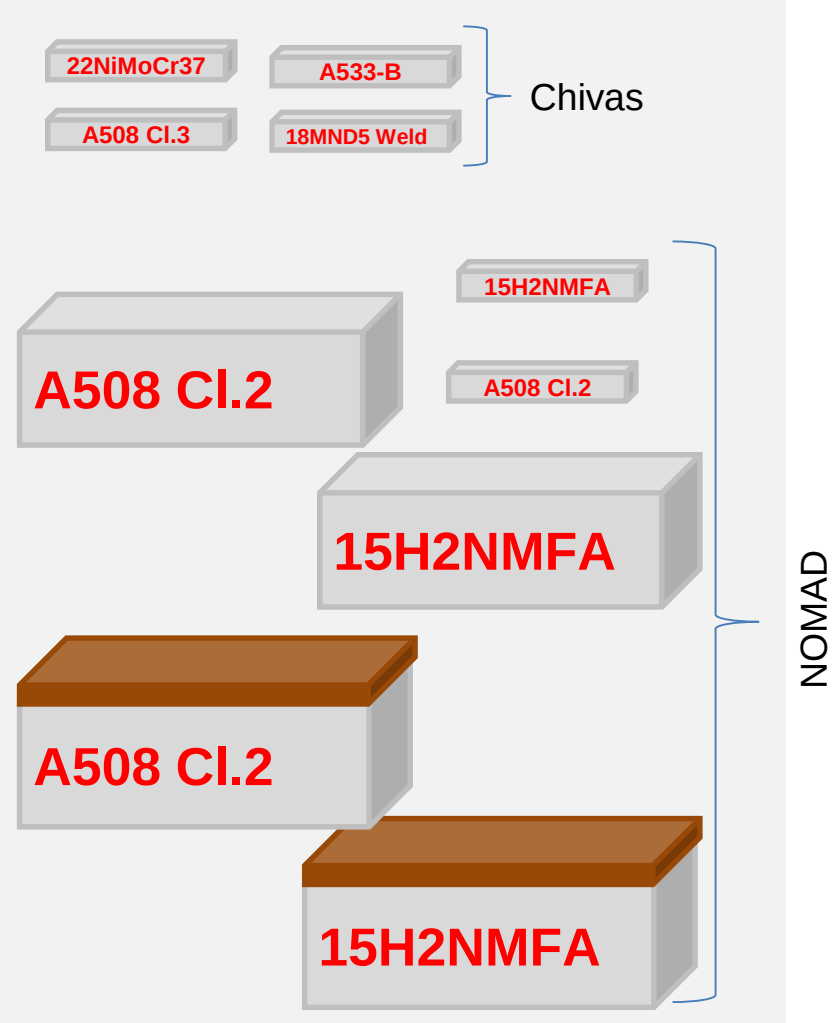
- Different relevant RPV materials
- Weld and base materials
- Western and eastern RPV design materials
- Different samples geometries
- Similar realistic operation conditions

Thermal treatment – „step cooling procedure“
- temperature
- time

Neutron irradiation
- high neutron flux
- four fluences
- low temperature

Microstructure characterization
- Metallographic analysis (optical microscopy)

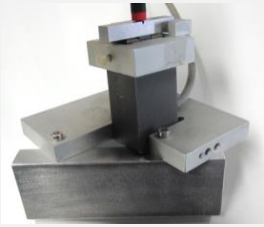
Mechanical tests
- yield and ultimate tensile strength
- Mechanical hardness
- Charpy impact properties



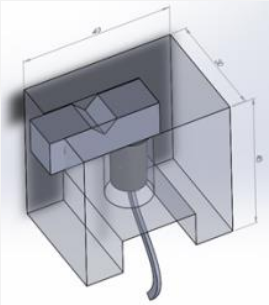
NDE methods development

Design / construction of 7 NDE setups

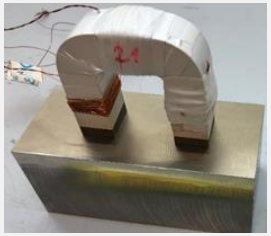
Charpy's | **Blocks**



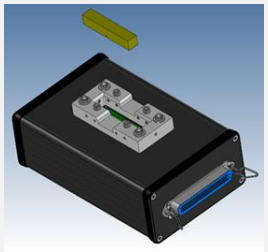
3MA



MAT



Piezo-US



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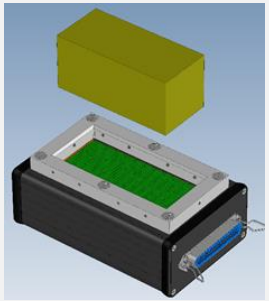
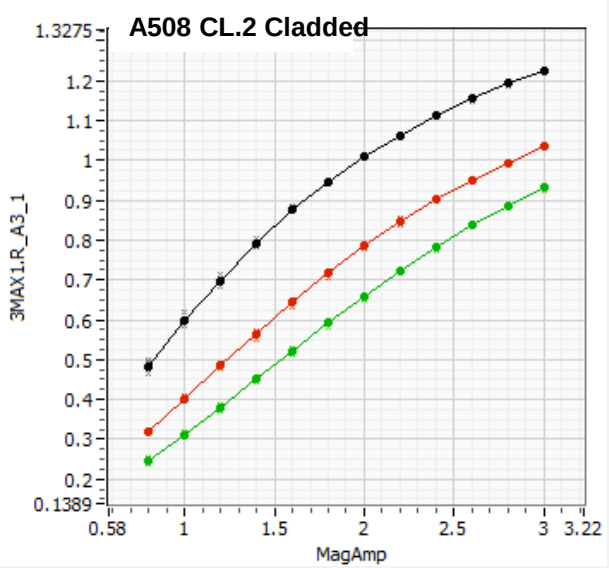


Settings optimization

- Coupling conditions
- Probes geometries
- Samples holders
- Measuring parameters



Provision of Charpy samples – CHIVAS + NOMAD

NOMAD: irradiated Charpy samples

Chivas

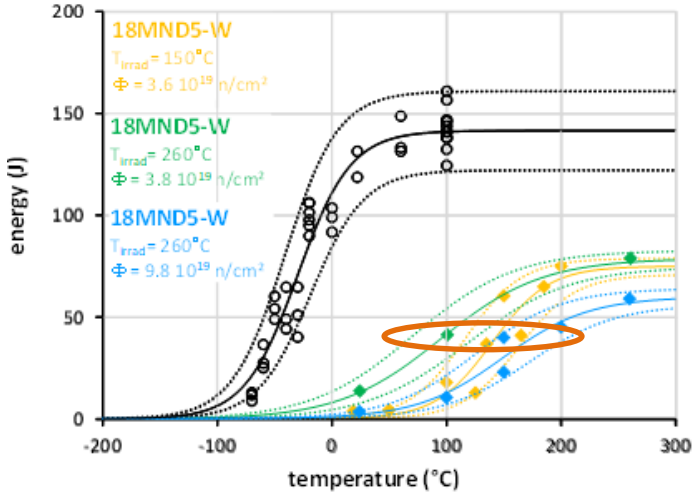
CHIVAS T_{irrad} [°C] Material	150	260	260	290	305
18MND5-W	3.5	4.8	9.4		
22NiMoCr37		3.4	5.7		
A508-B	4.1				4.2
HSST-03	2.7			4.6	4.1

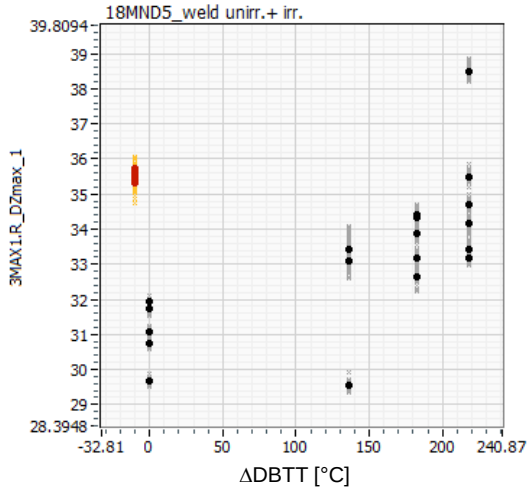
NOMAD

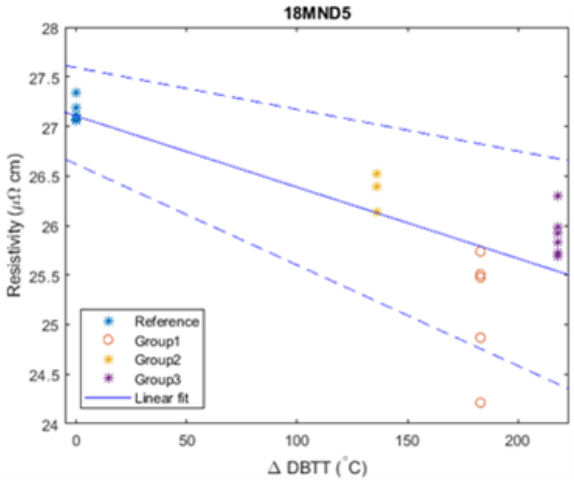
NOMAD T_{irrad} [°C] Material	100	100	100
A508 Cl.2	2.8	4.38	7.04
15kH2NMFA	2.78	6.83	7.9

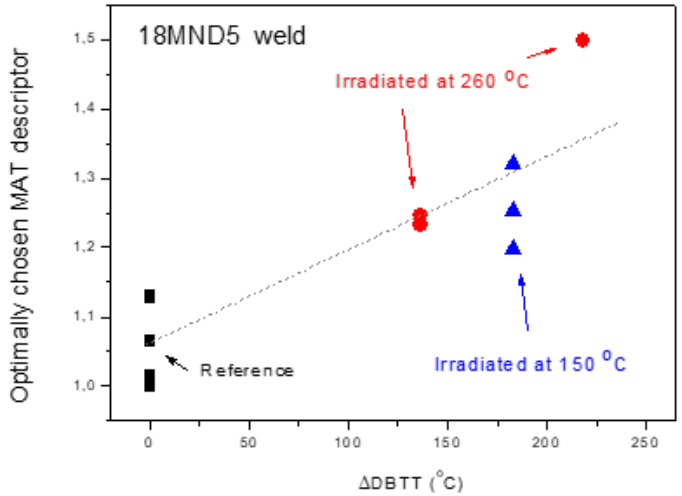
Irradiation temperature (T_{irrad} in °C) and fast fluence (in 10^{19} n/cm², E>1MeV)

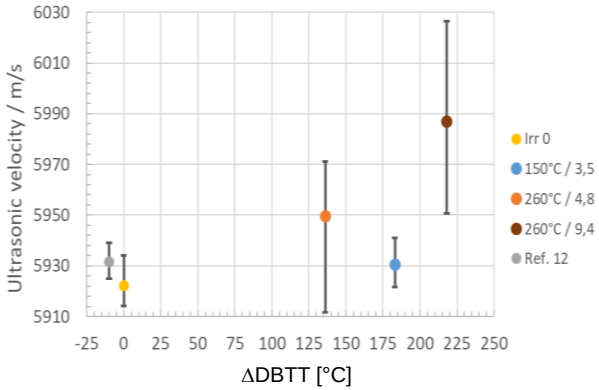
NDE – CHIVAS 18MND5 W

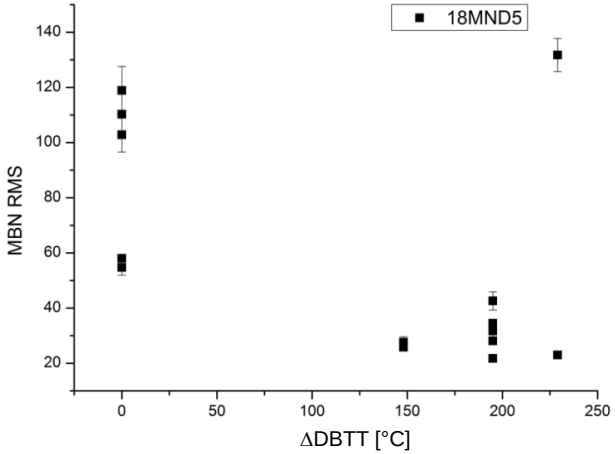




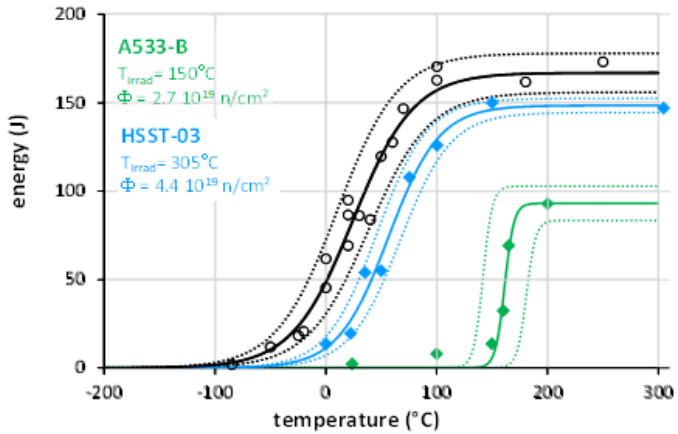


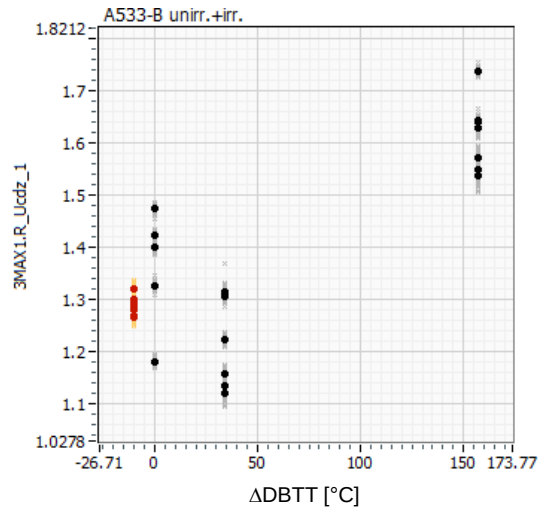


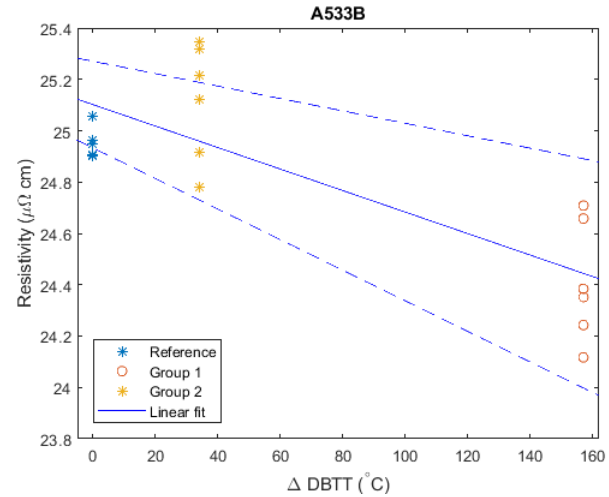


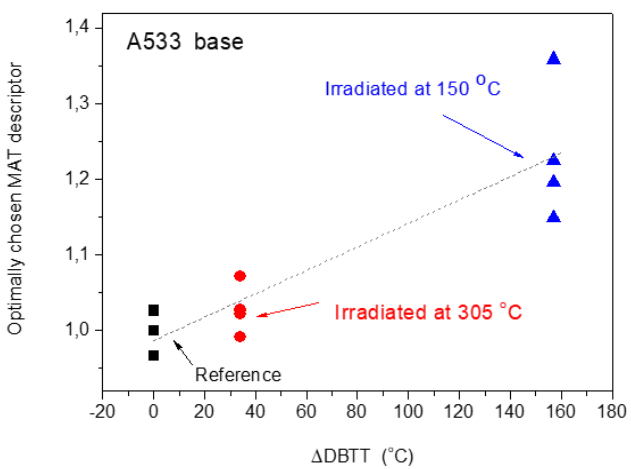


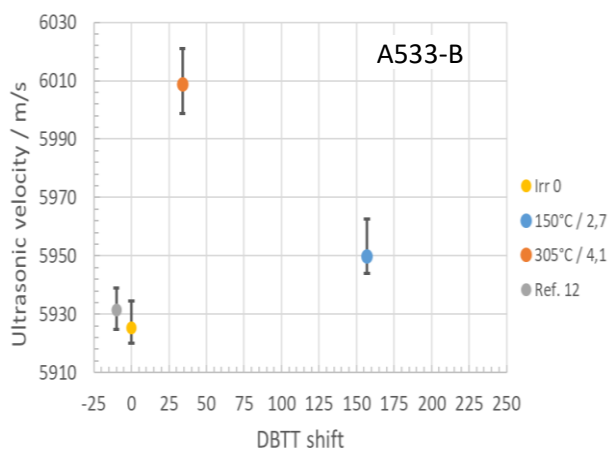
NDE – CHIVAS HSST-03(A533-B)

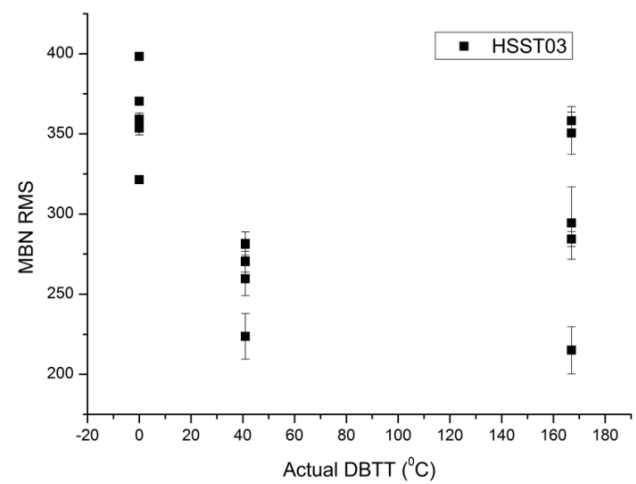




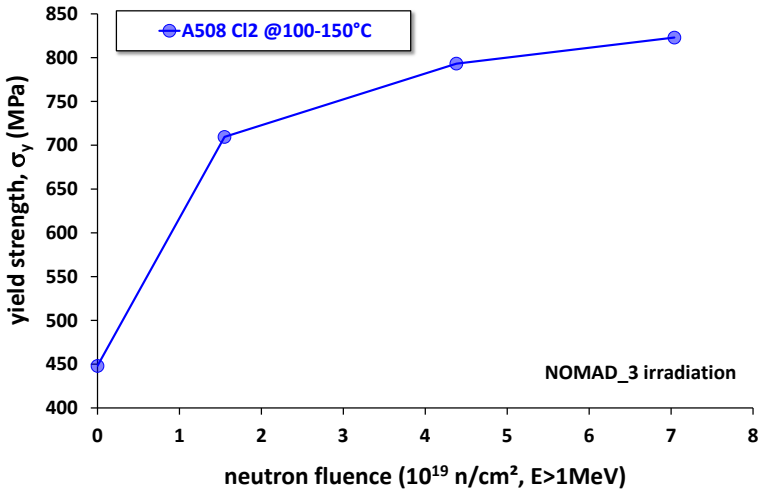


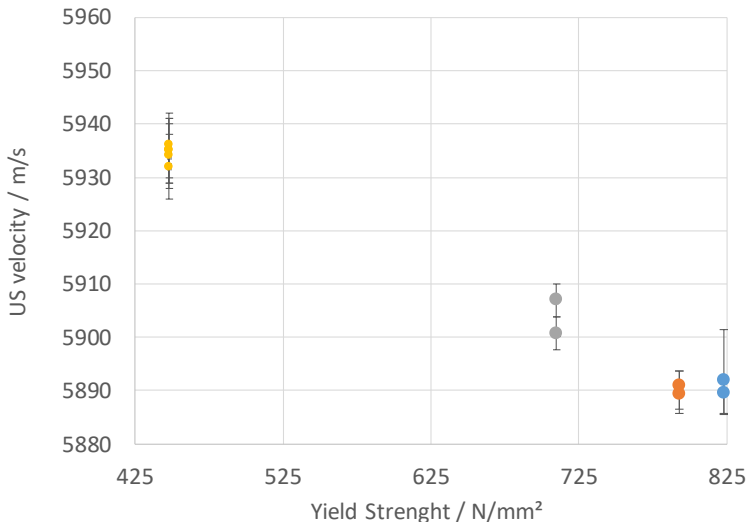


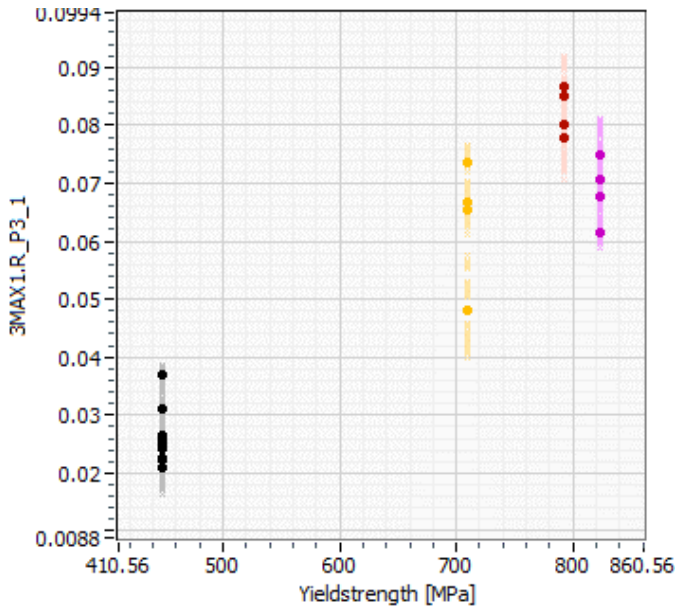


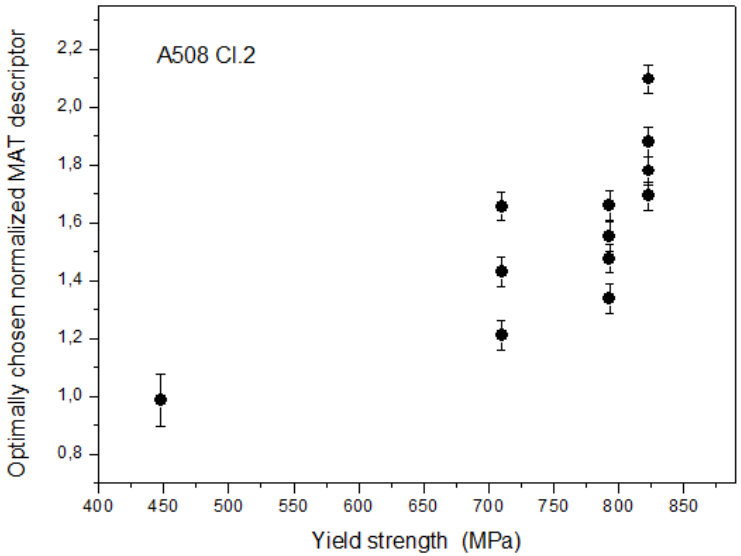


NDE – A508 Cl.2 NOMAD irradiation



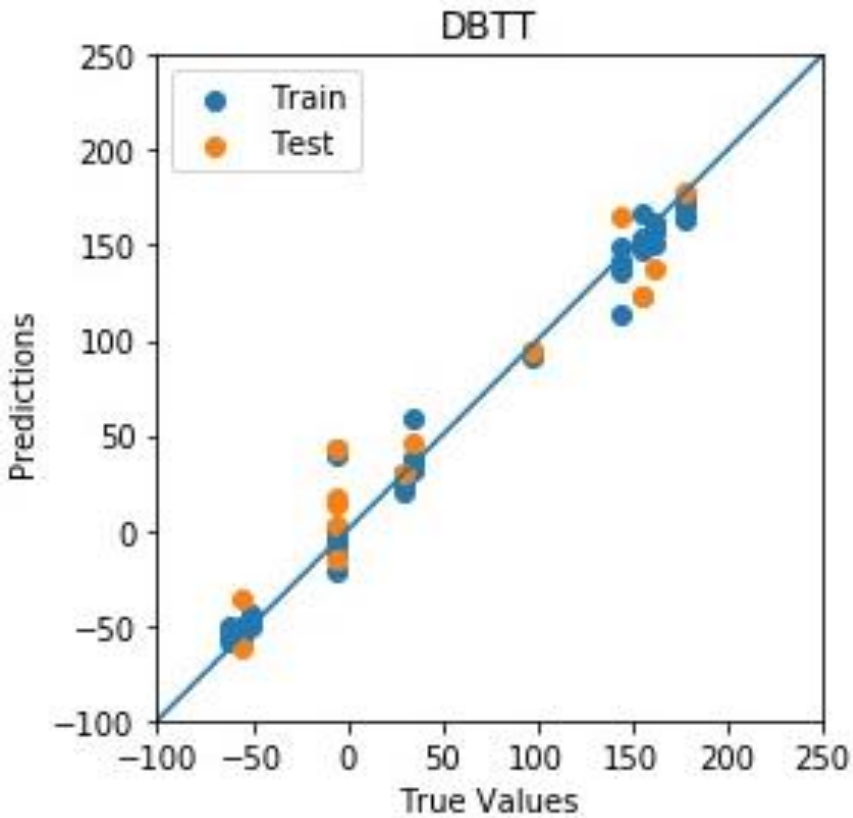


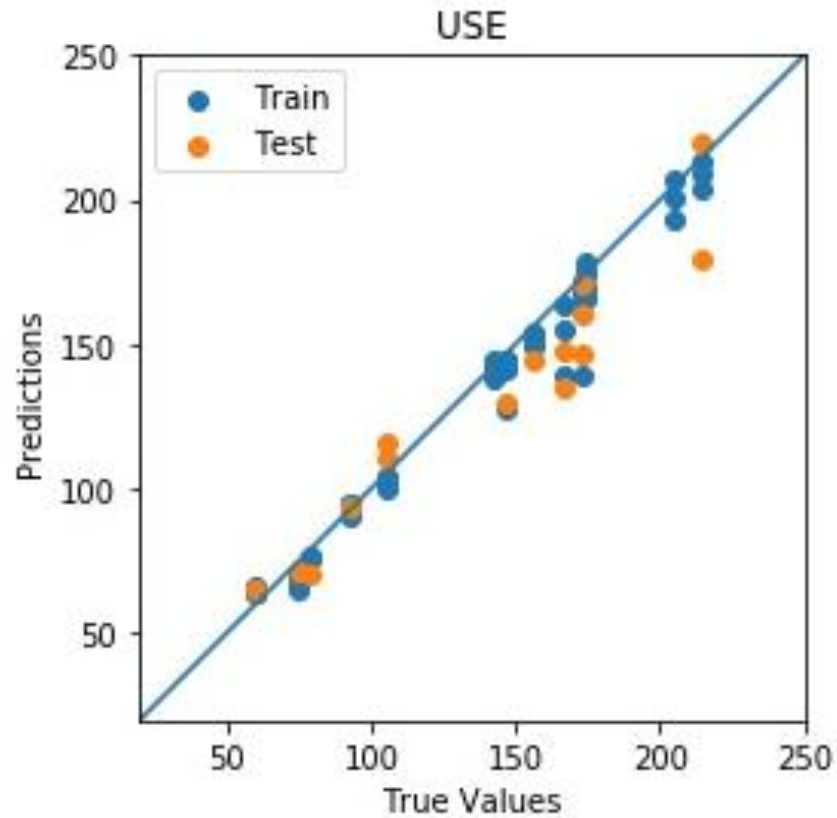




NDE tool development

First results obtained using deep neural network regression – Charpy samples





Provision and irradiation of large blocks –NOMAD

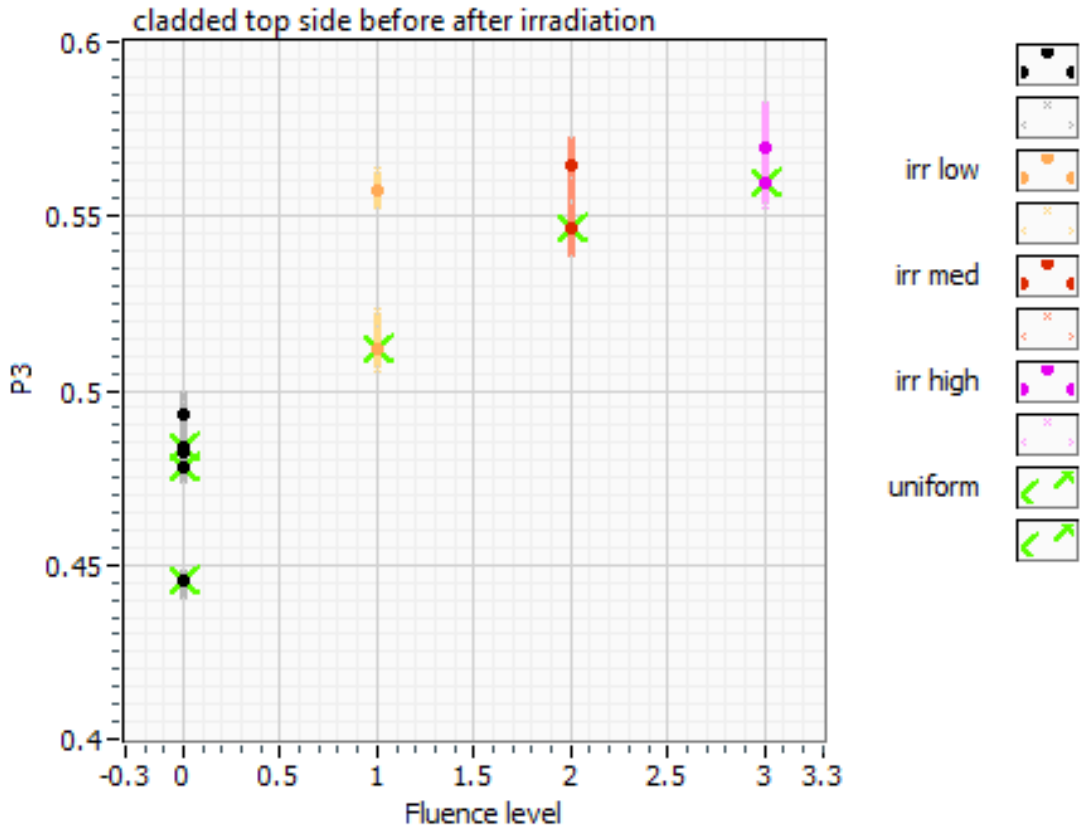
NOMAD: irradiated blocks

NOMAD T_{irrad} [°C] A508 Cl.2	100		100		100	
	top	bottom	top	bottom	top	bottom
Non-cladded att.	4.99	4.90	18.54	9.94	21.42	10.71
Non-cladded unif.	6.07	8.55	13.80	16.58	16.58	18.23
Cladded att.	4.55	1.48	11.23	5.12	17.41	8.86
Cladded unif.	2.09	1.72	6.93	6.76	12.67	12.57

Irradiation temperature (T_{irrad} in °C) and fast fluence (in 10^{19} n/cm², E>1MeV)

NDE – irradiated cladded blocks

- Micromagnetic characterisation of irradiated RPV material A508Cl2 under the autenitic cladding



Conclusion & Future activities

- Irradiation of large blocks to simulate the RPV condition
- Stability of NDE systems against activated material
- Different NDE results on individual samples vs. one DBTT value for one group of samples due to different initial material properties
- Suitability of individual NDE methods for characterization of the progress of material properties if preliminary NDE of the initial condition
- Combination of physically different NDE methods → non-destructive prediction of the damage condition

- Correlation of the NDE results on blocks with mechanical properties
- Data fusion from NDE and mechanical tests → model building to predict DBTT for blocks

NOMAD Follow-up

- Optimisation of the model for DBTT prediction – best practice model
  - NDE on Charpy's cut out from blocks
  - Comparison between NDE on Charpy's from different depths in blocks and NDE on original Charpy
    - representativeness of Charpy for blocks?
    - homogeneity of the blocks?
  - Additional input data for irradiated cladded material
    - modelling,
    - augmentation
  - Extended study of affecting parameters of NDE – real inspection situation
- Transfer of model for DBTT prediction of A508 Cl2 to further relevant RPV materials
- Hardware design for the NDE tool

Thank you very much for you attention on behalf of NOMAD consortium