CIVA in NDT qualification processes in the Czech Republic and results of CV REZ’s project for CIVA validation for the Phased Array technique

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CIVA Users Community Event, 3rd – 4th April 2025

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Research Centre Řež

- R&D organization focusing on development of technologies and technical support for power generation industry
- since 2002 /1955
- 370 employes

Research Centre Řež a Member of UJV Group

Nuclear Research Institute (ÚJV Řež) provides a wide range of services such as safety analyses, calculations of reactor core landfills, design of conventional and nuclear power engineering, production and delivery of radiopharmaceuticals, reactor surveillance programmes, disposal of radioactive waste and many others.

The mission of the company Research Centre Řež is research, development, and innovation in the field of energy, especially nuclear energy. The research infrastructure SUSEN (Sustainable Energy), two research reactors and a set of experimental equipment (probes and loops) form the backbone of the research infrastructure of the company.

Research and Testing Institute Plzeň deals mainly with research, development and sophisticated diagnostics of power plants. It provides a range of services for manufacturing companies in the metallurgical, energy and transport industries as well as for operators of power plants

ŠKODA PRAHA is an EPC contractor of power plants on turnkey basis. Over many years ŠKODA PRAHA has built excellent experience with the construction of power plants that are proven by extensive list of international reference projects.

CVŘ Company Activities

Our vision is to be a leading research and development organization in energy research, playing an important role in international research community and ensuring continuity in nuclear technologies knowledge in the Czech Republic.

- services for safe and long-term operation of energy technologies
- support for the operation of current nuclear units
- research and development in the field of GEN IV and small modular reactors
- processing and storage of hazardous waste
- microstructural and microchemical analyses
- advanced chemical and analytical methods
- development of new NDT methods and robotic manipulators
- basic and advanced materials research
- design and system diagnostics
- evaluation of condition and qualification of components
- reactor irradiation services
- design, construction, manufacture
- hydrogen and fusion technologies
- modern technologies for energy storage
- publishing activities in the field of nuclear energy
- training and education

Department Diagnostics and Qualifications

The goal of the department is the applied development of diagnostic methods and the provision of research services in the field of advanced diagnostic methods and development od manipulators.

NDT laboratories

- Ultrasonic Testing
- Eddy Current Testing
- 3D Scanning
- Basic Surface Methods
- Pulse Thermography
- Nonlinear methods
- NDT Qualifications
- Potential Methods

Development of diagnostic equipment

Design, construction and manufacture of manipulators for non-destructive testing

Content

- ❑ History of using CIVA in ČEZ/UJV Group

- ❑ Qualification of UT and test blocks

- ❑ CIVA validation project 2019 - 2020
  - ❑ Test block made by „wire EDM“
  - ❑ Validation of SW CIVA for „wire EDM“ test blocks
  - ❑ Application of „wire EDM“ test blocks in NDE

- ❑ Use of CIVA in NDT qualifications

History of CIVA Application in Czech Republic

CIVA Users

- UJV, CVR, CEZ

- Application in UJV

2003 – 2004: First application of CIVA SPIQNAR V6 - verification of developed tools for correction of real ultrasonic signals (filters, derivation, deconvolution, etc.)

2004 – 2009: CIVA 7.0, CIVA 8.0 – Application for modeling of UT beam and response for qualification areas (pulse echo)

2010 – 2013: CIVA 9.x, CIVA 10.0 – Application in the design of ultrasonic probes and verification of defect detectability during UT qualification (pulse echo and phased array technique)

2014 – 2016 – application by old CIVA version

2020 – 2022 – CIVA ADVISE – cooperation on this project, verification of the developed CIVA tools on real measured data

History of CIVA application in Czech Republic

CIVA Users

❑ Application in CVR

2016 – now: CIVA v11, CIVA 2020, CIVA 2023 - use in probe design, parameter selection and response prediction within UT qualification, during verification of real UT results interpretation (UT module, Analysis)

2019 – 2020: CIVA v2020 – The validation of CIVA SW by using of wire EDM test blocks

❑ Application in CEZ

2021 – now: CIVA 2021

UT Qualification and Test Blocks

UT qualification

- used to verify the inspection procedure, the equipment and also the personnel - the aim is achieved the required accuracy (criteria) when performing the in-service inspection
- part of the qualification is verification of the proposed procedure using theoretical and laboratory tests and practical tests
- practical trials – verification of the testing procedure on a model/maquette of the tested area = test blocks/specimens

UT Qualification and Test Blocks

Test blocks

❑ Inspected area as realistically as possible

- geometry
- material – microstructure

❑ Manufacturing of defects

- presumed damage according to DM, stress in component
- As realistic as possible X manufacturability, price

UT Qualification and Test Blocks

Test blocks with defects

artificial X realistic

- holes
- EDM defects

- real cycling crack
- crack produced by thermal heating

EDM defects
- SDH
- semi-elliptical groove

An initiation notch from which a cycled fatigue crack originates

Intermedial level = defects manufactured by wire EDM

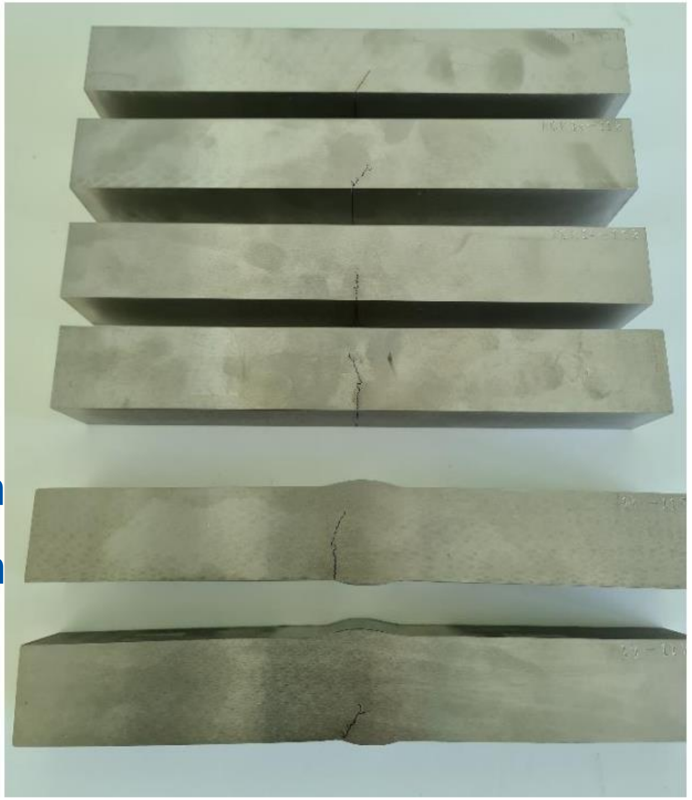
The Validation of SW CIVA Using Wire EDM Test Blocks

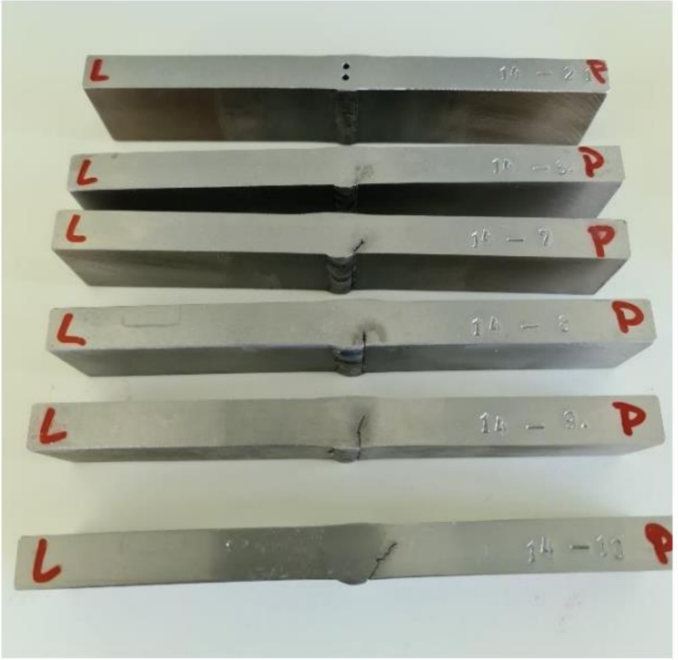
Validation of CIVA by Wire EDM TB

Wire EDM Test blocks

Manufactured 44 test blocks

- Ferritic and austenitic steel
- With and without welding joint
- Dimension of TBs : 250 (260) x 30 x 12 mm
  250 (260) x 40 x 35 mm





Examples of TBs

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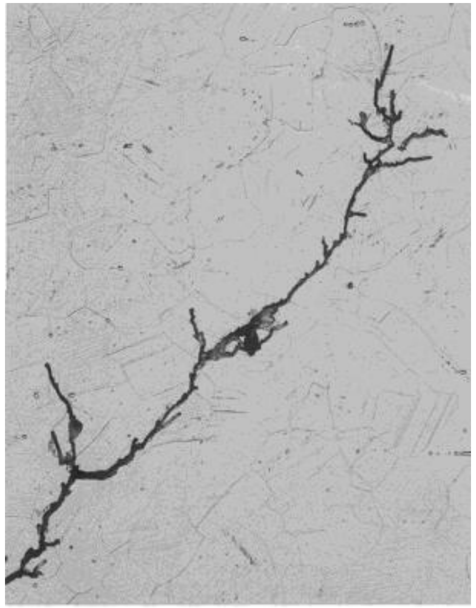
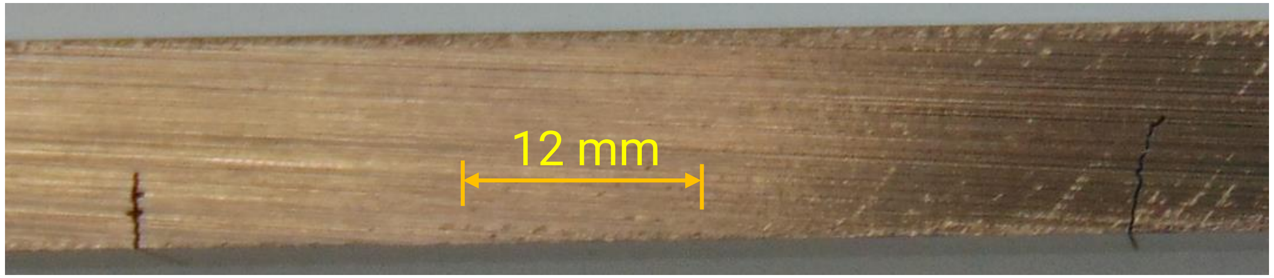
Wire EDM test blocks

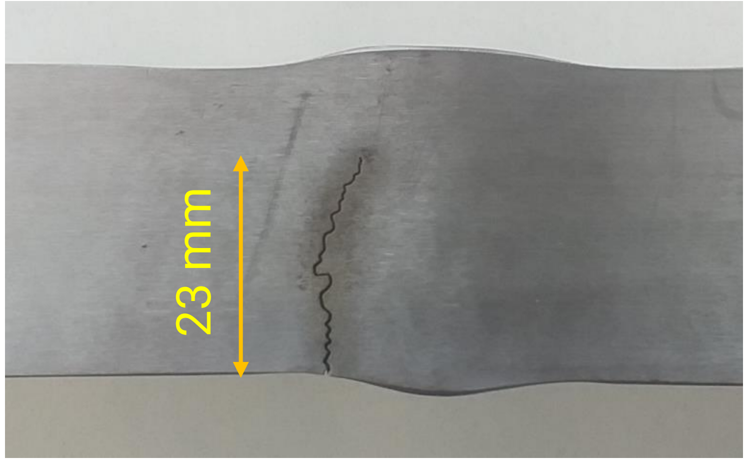
Wire EDM Test blocks

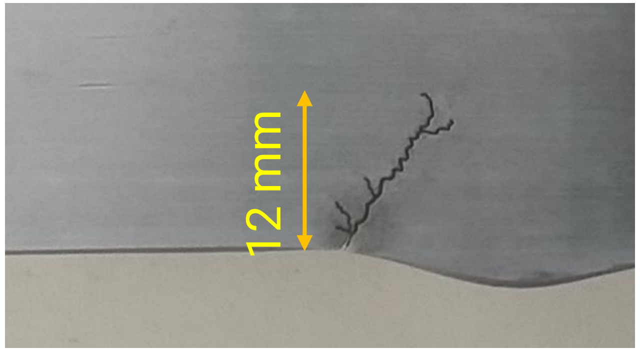
produced using EDM with wire - Ø 0.2 mm



Real crack







Examples of defects

Validation of CIVA by Wire EDM TB

❑ Procedure of UT

- technique Phased array – sector scanning from 40 – 70°
- probe AM5 MHz (ferrite material) and probe AM3.5 MHz (aust. material)
- scanning by rectilinear movement (including the weld) over the entire block

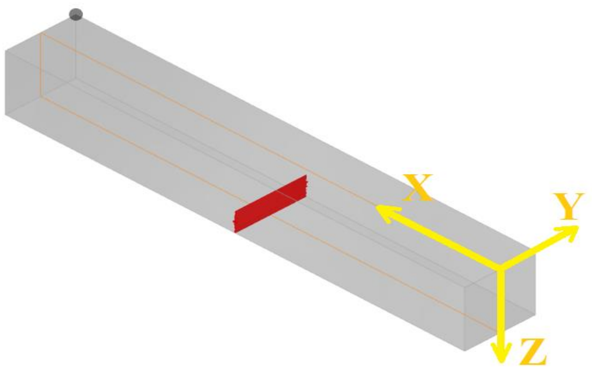
❑ Evaluation

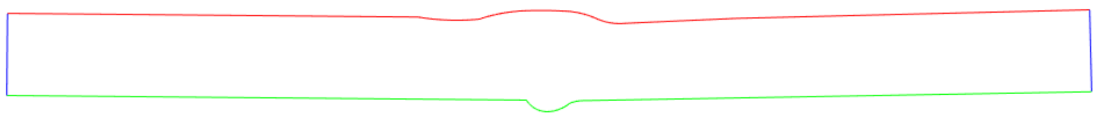
- **comparison of response characteristics (echo shape and peaks)**
- **comparison of maximum response size (comparison of response size relative to SDH response)**

A total of approx. 200 measurements were evaluated and a similar number of calculations were performed in the CIVA v2020 program.

Validation of CIVA by Wire EDM TB

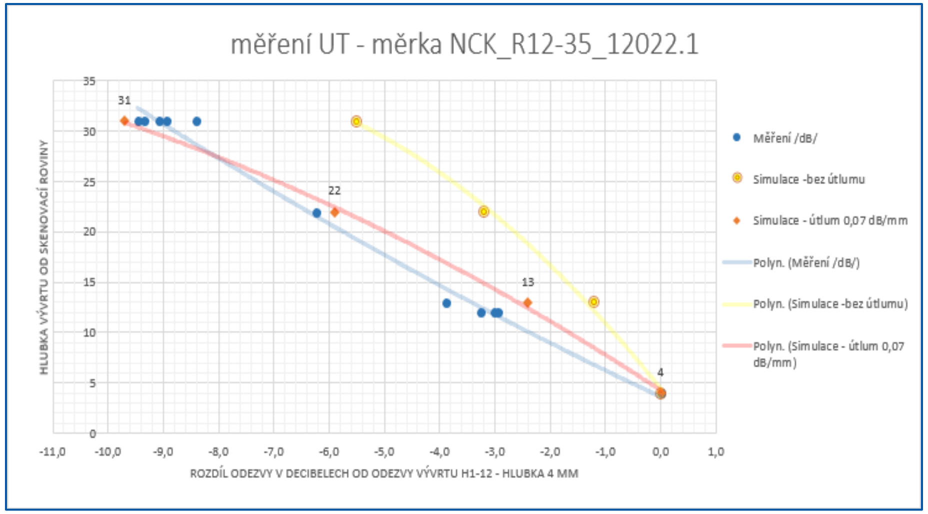
Optimalization setting





Profile correction according to the actual design of the TB

Calibration test block



Attenuation setting for used materials

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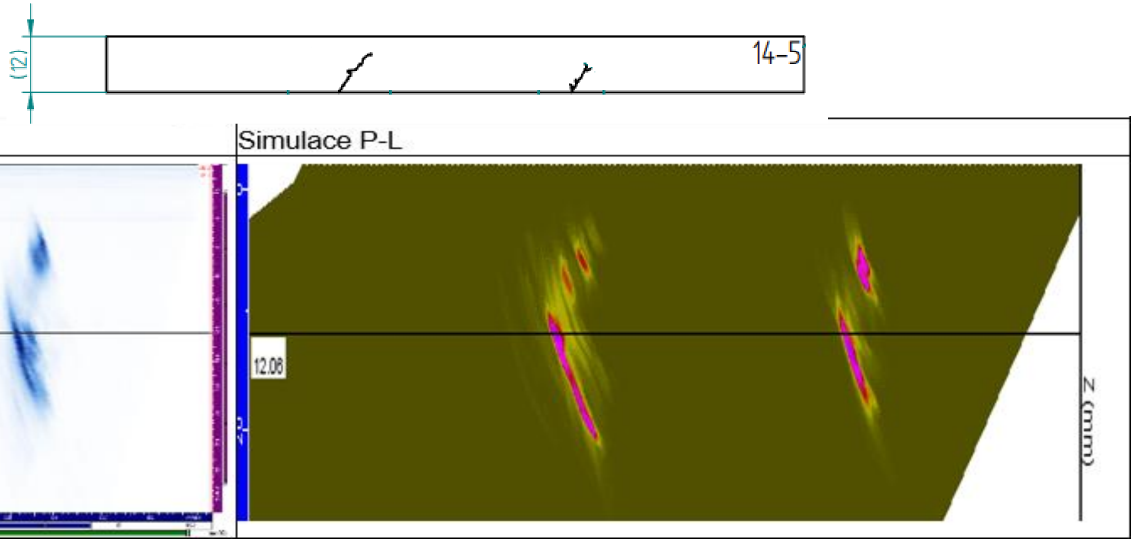
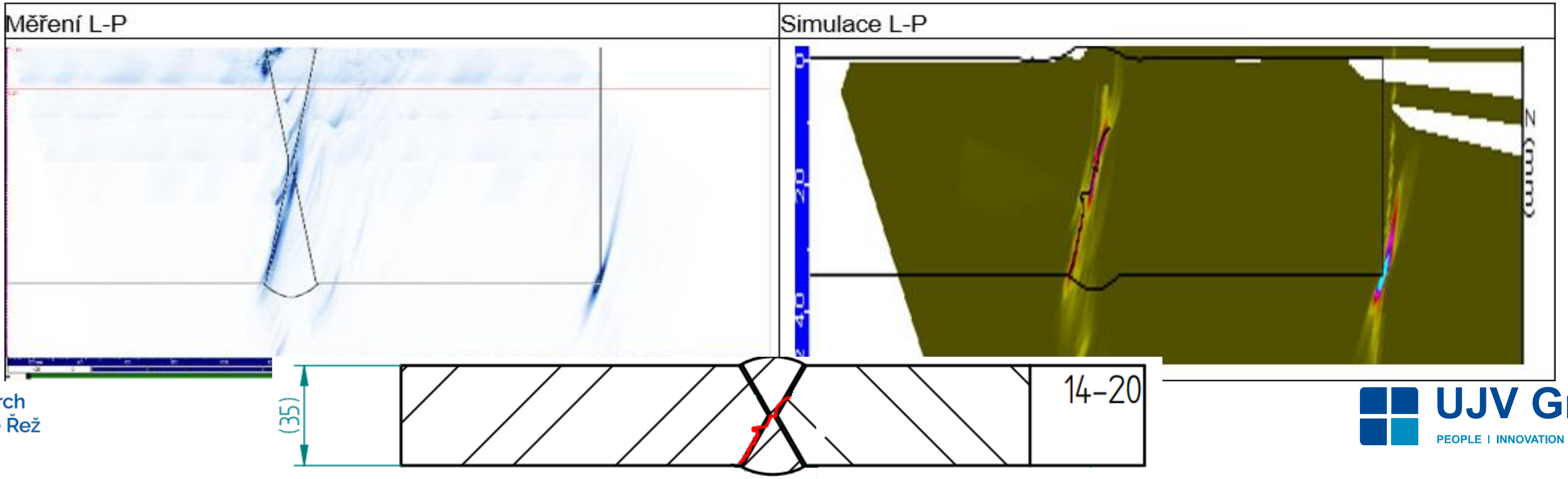
Validation of CIVA using Wire EDM TB

Results of feritic steel TBs

TB No. 5
thickness 12 mm
Without weld



TB No. 18
thickness 35 mm
With weld



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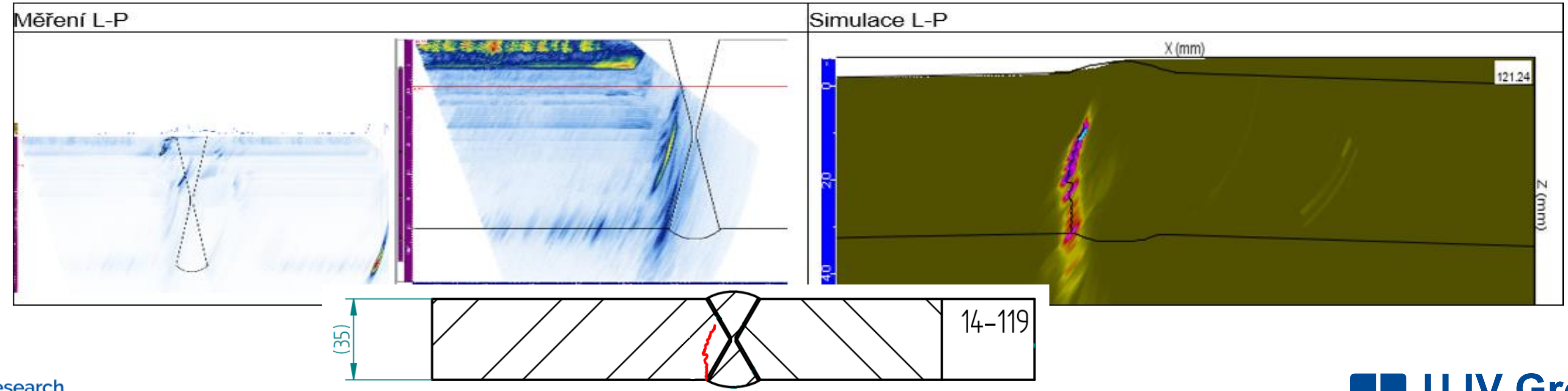
Validation of CIVA using Wire EDM TB

Results of austenitic steel TBs

TB No. 105
Thickness 12 mm
Without weld

TB No. 119
Thickness 35 mm
With weld

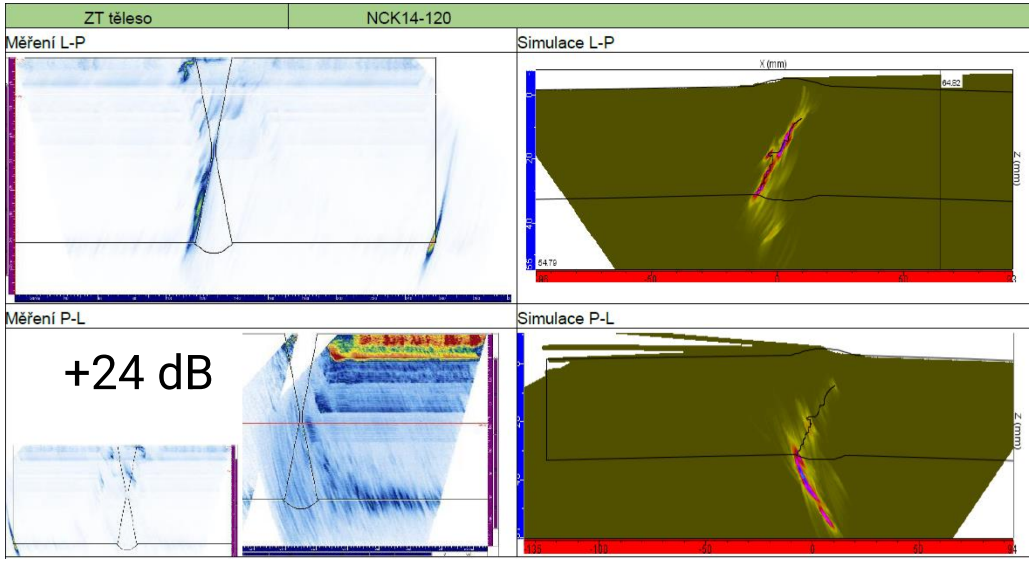


Validation of CIVA using Wire EDM TB

Results of austenitic TBs with weld

- when testing through the weld, most defects were not detected, or only weakly
- the weld profile (crown/root) was not precisely modified
- inhomogeneous base material was also detected

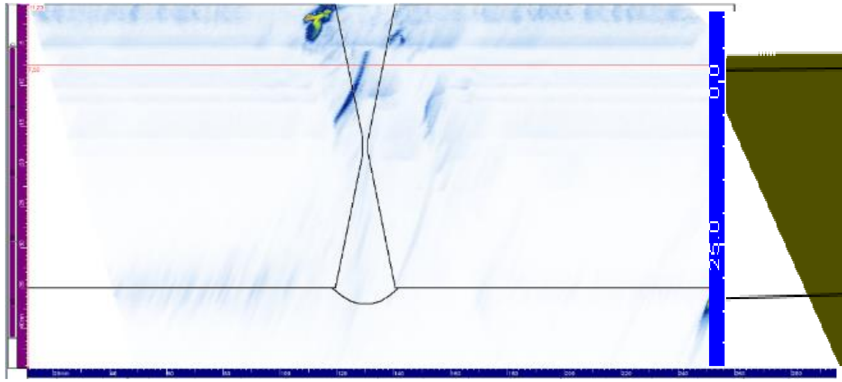
Test Block		Simulation		Measurement		Comparison	
	Defect	L-P /dB/	P-L /dB/	L-P /dB/	P-L /dB/	Diference L-P	Diference P-L
NCK14-116	vada A	8,2	9,1	9,7	without detection	-1,6	-
NCK14-117	vada A	3,0	4,4	-0,3	without detection	3,3	-
NCK14-118	vada A	6,5	3,4	-13,0	-21,9	**19,5**	**25,3**
NCK14-119	vada A	6,8	7,1	-11,5	-15,9	**18,0**	**23,0**
NCK14-120	vada A	4,1	2,3	6,6	without detection	-2,5	-

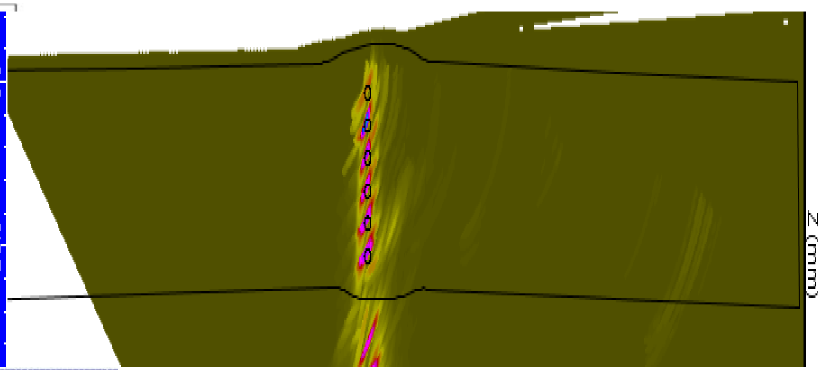


Validation of CIVA using Wire EDM TB

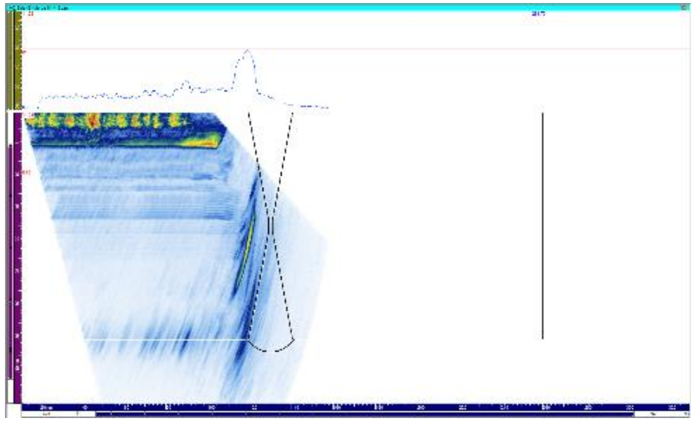
Results of austenitic TBs with weld

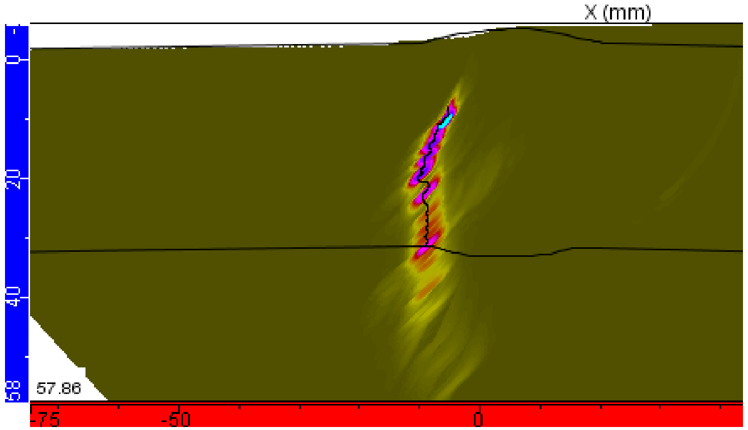
Test Block		Simulation		Measurement	
	Defect	L-P /dB/	P-L /dB/	L-P /dB/	P-L /dB/
NCK14-122	vývrt A	-7,6	-6,1	No detection	No detection
	vývrt B	2,6	0,3	No detection	No detection
	vývrt C	0,9	0,7	No detection	No detection
	vývrt D	-0,2	-2	No detection	No detection
	vývrt E	-0,1	-1,8	No detection	No detection





ZT NCK 14-119 – left side





Max. amp.: -13 dB

Max. amp.: 6,5 dB

Validation of CIVA using Wire EDM TB

Summary of result – comparison of the response agreement

- agreement in the case of testing ferritic materials
- agreement for austenitic material without weld
- TBs with austenitic welds - the effect of inhomogeneous structure and geometry on the result

Material	Thickness	Type	Number of evaluations (N. e.)	Match		Permissible deviation		Justifiable deviation		Impermissible deviation	
				N.e.	%	N.e.	%	N.e.	%	N.e.	%
12022	12	hom	20	20	100	0	0	0	0	0	0
12022	12	weld	10	8	80	2	20	0	0	0	0
12022	35	hom	10	6	60	3	30	1	10	0	0
12022	35	weld	10	9	90	1	10	0	0	0	0
X6CrNiTi18	12	hom	20	16	80	4	20	0	0	0	0
X6CrNiTi18	12	weld	10	5	50	1	10	0	0	4	40
X6CrNiTi18	35	hom	10	6	60	3	30	1	10	0	0
X6CrNiTi18	35	weld	10	3	30	0	0	0	0	7	70
Celkem			**100***	**73**	**73**	**14**	**14**	**2**	**2**	**11**	**11**

Agreement - up to a difference of ±3 dB; permissible deviation - up to a difference of ±6 dB; justifiable - up to a difference of ±12 dB, unacceptable - a difference of 12 and more

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Conclusions

Conclusions from SW CIVA validation on wire EDM TBs

- UT simulation procedure in sw. CIVA makes it possible to obtain results corresponding to real testing – very good agreement
- the accuracy of the result corresponds to the accuracy of the input of the testing parameters (geometry, defects, material heterogeneity)
- modelling UT of aust. welds requires a modified weld joint model than was used in the project
- the results were verified on TBs with defects corresponding to the profile of real cracks

Conclusions

Wire EDM test blocks

- Wire EDM TBs expand the set of test blocks for verification of NDE methods.
- Very beneficial in NDE software tool validations.
- The possibility of use in UT qualification as a supplement to existing procedures for verifying the testing procedure, in verifying the competence of personnel, etc.
- Use for as a data source for virtual defects.

Use of CIVA in NDT qualifications

CIVA in NDT qualifications

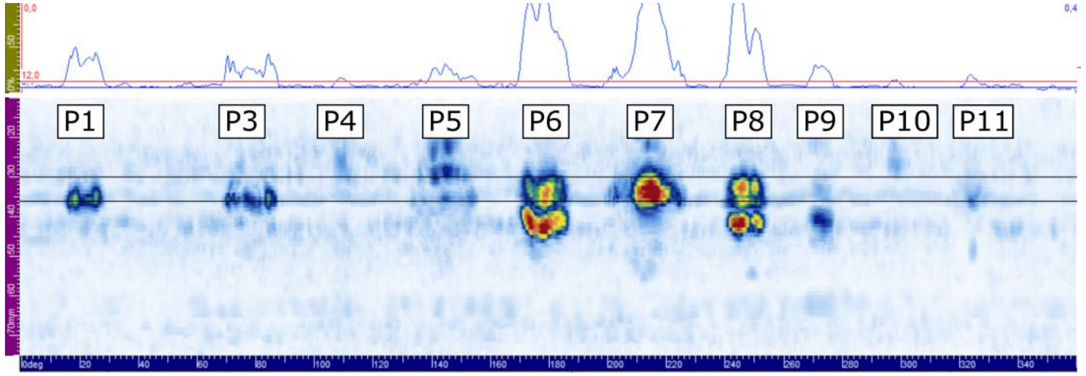
In order to overcome the limitations of the test piece and demonstrate compliance with the requirements of the technical specification, ultrasonic testing simulations are performed in CIVA SW. The simulations are carried out in several phases:

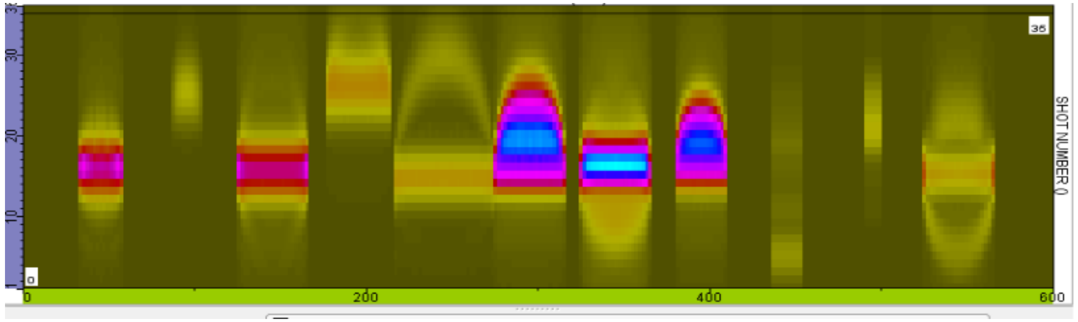
1) Creation of a model representing the test body - A validation of SW CIVA for the test area is performed on the model.
2) Performing parametric studies within the scope of the qualification criteria and determining the theoretical sensitivity of the ultrasound system.

Validation of the model

Model validation in CIVA SW is performed by comparing the simulations of ultrasonic testing and the results of ultrasonic testing on the test body.

During the validation of the ultrasonic model, the sensitivity is assessed against the sensitivity criteria specified in the inspection procedure, which describes that the deviation should not be greater than 4 dB during the validation of the setup.





Measurement	Simulation	Deviation
50	47,5	0,4
-	-	-
42,9	44,5	-0,3
16,3	19,8	-1,7
31,4	19,7	4,0
80,7	93,1	-1,2
100	100	0,0
86,5	89	-0,2
8	9,44	-1,4
14	15,3	-0,8
20	18	0,9

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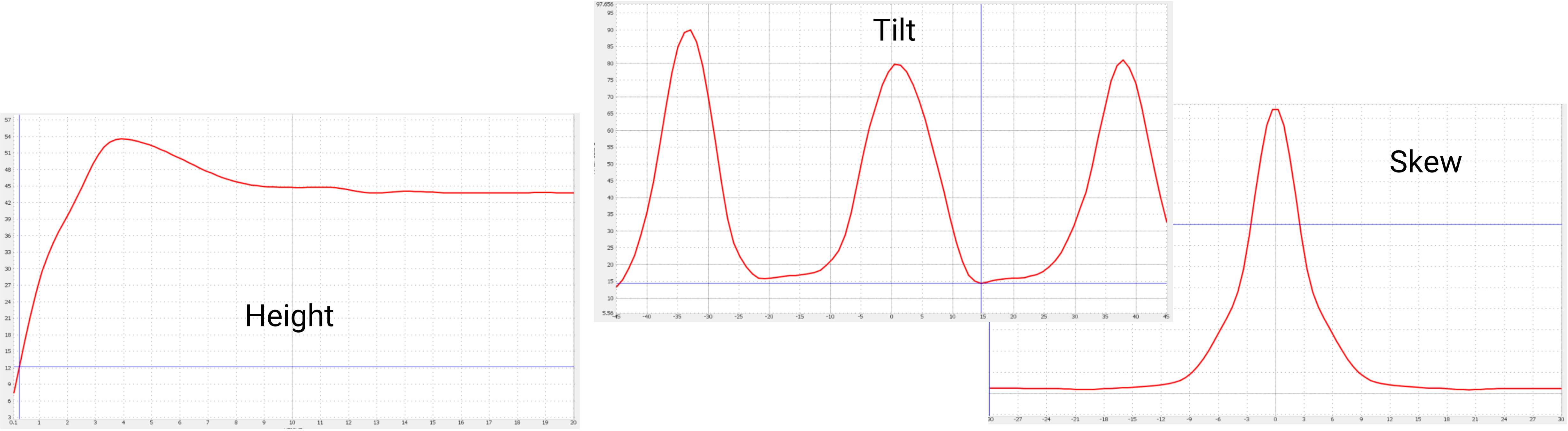
Parametric studies

Only certain types of defects (e.g. on the bevel and in the weld axis) are always selected for parametric studies. For these selected defects, studies are carried out on a few selected parameters, most often height, tilt and skew of the defect.



Conclusions

The history of CIVA use in the Czech Republic is long and it was/is used in many different projects

Validation on wire EDM test pieces gave very interesting results and significant agreement between simulations and real measurements

In the frame of NDT qualifications, the use of NDT simulations helps to overcome the limitations of test pieces and is a mandatory part of the technical justification

Thank you for your attention

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