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Validation of CIVA ultrasonic simulation in canonical configurations

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Abstract
The ultrasonic simulation tools gathered in the CIVA software include beam and defects computations. The calculations apply propagation and scattering models based on semi-analytical kernels and numerical integration. Over the years a large amount of experimental comparisons have been carried out using CIVA in the framework of studies dedicated to different industrial applications, either at CEA or by CIVA users. In parallel CEA has participated to various international modeling benchmarks in particular organized by WFNDEC (World Federation of NDE Centers). To go further a long-term validation work is being done at CEA in order to precisely quantify the level of reliability of the predictions, and accurately define the domain of applicability of the models. This work is mainly based on comparisons between CIVA simulation results and experimental measurements. In this communication we present the validation procedure which is been adopted. We report the results obtained on various canonical configurations: reference reflectors SDHs, FBHs, corner echoes on notches. The validations are complemented by theoretical considerations about hypotheses and approximations of the models allowing drawing conclusions on the models validity.

Keywords: Ultrasonic; simulation; experimental validation; CIVA.

1. Introduction

The CIVA-UT modules allow calculating the echoes from postulated defects during a postulated NDT inspection, the CIVA output being the result of the inspection i.e. C-scan or B-scan images (built from all the elementary A-scans, one isolated A-scan being the electrical signal of the probe in reception at one probe position). The calculations are based on different inter-connected semi-analytical models depending on the physical phenomena involved in the inspection.
When using the code, it is important to evaluate the level of reliability of its predictions in the studied inspection. This evaluation can be done by considering the models (physical basis, domain of applicability and approximation made for their implementation), the list of code inputs and their values (it helps to check which aspects are taken into account by the code: does it account for the influence of the essential parameters of the inspection? Is it a 2D or a 3D model? ...) and also data related to the validation of the code in similar situations (data from literature, data from other codes, experimental validation data…)
Over the years a large amount of experimental comparisons have been carried out using CIVA in the framework of studies dedicated to different industrial applications. In parallel CEA has participated to various international modeling benchmarks in particular organized by WFNDEC (World Federation of NDE Centers). To go further a long-term validation work is being done at CEA in order to precisely quantify the level of reliability of the predictions, and accurately define the domain of applicability of the models of the CIVA-UT code by comparing its predictions to results obtained by experiments. In this paper the notion of

reliability/accuracy and the means of evaluating it will be quickly addressed and some validation results are presented and discussed.

2. CIVA-UT experimental validation procedure

The objective of experimental validation is to test the capability of the code to reproduce experimental results for one given application. The process of validation includes the simulation plus the representation of reality in terms of qualifying characteristics and essential parameters and consists of three main steps: define and perform experiments, perform the corresponding computations with CIVA, interpret the results of comparisons between experiment and simulation**.**

2.1 Experiments

A first scope of validation has been defined dealing with very classical "canonical" configurations like direct echoes of reference reflectors, SV and P corner echoes of back-wall breaking notches (i.e. notches detected with a probe generating transversal or longitudinal waves in the specimen), specular echoes from the specimen geometry, The measurements were carried out in homogeneous isotropic planar specimens with various NDE "conventional" 2MHz and 5MHz planar contact or immersion probes functioning in pulse-echo mode. The parameters under investigation were chosen by physical considerations. For example, when studying the corner echoes of back-wall breaking notches, the parameter "notch height" was considered (because corner echoes are specular echoes and because of the known small defect limitation of the Kirchhoff model used in CIVA for their computation). The parameter "divergence of the probe" was also investigated (because of the creeping wave contribution depending on the incidence angles contained in the beam). Other parameters like notch orientation or extension were not considered in this study. We tried to isolate the effect of each parameter in order to study slow variations of one parameter at a time. For example the mock-up designed to study the notch height effect contained 11 notches of same extension and of a height changing very slowly (figure below).

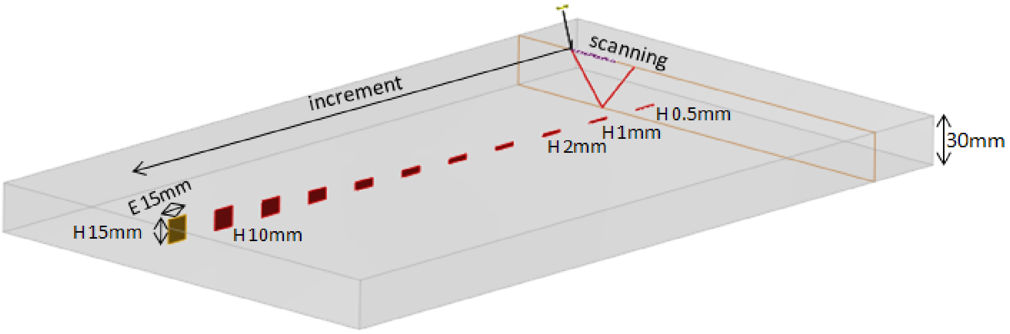

Figure 1 : validation steel mock-up, 30 mm height, back-wall breaking notches of height 0.5mm, 1mm, 1.5mm, 2mm, 3mm, 4mm, 5mm, 7.5mm, 10mm, 12.5mm and 15mm (15 mm extension).

Controlled experimental protocol has been followed in order to minimize the sources of un-accuracies. The reproducibility of the results has been checked and the confidence interval of the experimental data presented in this paper has been evaluated to +/-2dB.

2.2 Computations

Civa10.0 was used to carry out the simulations presented in this paper.

A systematic computation protocol is followed: all the input parameters are listed and checked in order to avoid any uncontrolled effect due to erroneous input. The correspondence between the output of the code and the data provided by experiment was checked (see [1] for more complete information).

2.3 Comparisons

The validation is done by comparing experimental measurements with the output of the computations. For the cases presented in this paper, the physical quantity considered for the comparisons is the echo amplitude. Nevertheless, the interpretation of the results may involve echo-dynamic curves or A-scan shapes

If a good agreement is obtained, it provides useful information about the domain of applicability and accuracy of the CIVA predictions. When discrepancies are observed, their possible origin has to be studied. It can be due 1) to experimental uncertainties (measured by the reproducibility of experimental results), 2) to simulation uncertainties (due for example to numerical noise), 3) to inaccuracy on the definition of essential inputs, 4) to bugs (abnormal behavior of the code) or 5) to a possible error on the reference reflector amplitude (that introduces a constant gap in the comparisons results) 5) to inaccuracy of the models. The final goal of the validation is to quantitatively determine the component of the discrepancy actually due to the simulation itself. Such evaluation constitutes a measure of the “reliability” of the simulation.

In the cases presented here: Point 1) the experimental reproducibility has been evaluated, the discrepancies between experimental and simulated amplitudes are compared to the confidence interval of the measurements (+/-2dB). Point 2) had no effect (deterministic models), Point 3) the characteristics of the specimen and probes have been checked Point 4) the consistency of the computed results have been checked.

3. Results on Side Drilled Holes (SDHs)

The experimental validation of the ultrasonic responses of SDHs is crucial because it concerns not only the validation of the SDH responses but also a check of the probes characteristics which are inputted in the code and will be used for future validations on other defects and specimens. In addition the reference for the comparisons of amplitudes obtained on other reflectors and parts is quite often the amplitude of one SDH echo.

The model used in CIVA10 to compute SDH echoes is the SOV (Separation Of Variables model) [2], [3] and [4].

3.1 Case of SDH of diameter (Ø) 2mm

We displayed in Table 1 and Table 2 the amplitude gaps obtained between the measure and the Civa10 simulated echo amplitudes of SDHØ2mm positioned at different depths in a steel specimen and inspected with various planar probes functioning in pulse echo mode.

The SDHØ2mm chosen as a reference for the amplitudes is located at the depth “Reference depth” (indicated line 1) and obtained for the mode “Reference mode” (indicated line2).

In the tables the discrepancies greater than 2dB are highlighted (black colored)

Table 1. Gaps in dB between the measured and the CIVA10.0 simulated maximal amplitude of the SDH direct echoes, contact probes

Ref. mode	SV45°	P45°	P60°	SV45°	SV45°	SV60°	P45°	P60°	SV45°
Ref. depth (mm)	8	8	4	20	52	32	4	4	36
Probe dim. (mm)	6,35	12,7	12,7	12,7	22x20	22x20	6,35	6,35	12,7
fc (MHz)	2,25	2,25	2,25	2,25	2,00	2,00	5	5	5
SDH depth / Mode	SV45°	P45°	P60°	SV45°	SV45°	SV60°	P45°	P60°	SV45°
4	1,2	1,3	0,0	3,7	5,1	3,5	0,0	0,0	2,1
8	0,0	0,0	-0,3	2,6	4,3	2,3	-0,4	-0,8	1,8
12	-0,3	-0,6	-0,4	1,4	3,5	1,2	-0,4	-0,3	1,3
16	0,6	-0,7	-0,4	0,6	2,3	0,2	0,0	-0,5	1,2
20	0,9	-0,9	-0,3	0,0	1,7	0,1	-0,4	-0,7	1,1
24	1,5	-0,7	0,1	-0,1	2,5	0,2	-0,2	-0,5	0,4
28	1,1	-0,6	0,4	-0,4	2,2	0,2	-0,6	-0,5	0,2
32	-1,8	-0,6	0,5	0,0	1,5	0,0	pb exp	-0,1	-0,8
36	0,5	-0,7	0,6	0,1	1,1	-0,2	-0,5	-0,5	0,0
40	-0,1	-0,6	0,5	0,3	0,7	-0,1	-0,1		-0,6
44	0,5	-0,6	0,3	0,3	0,5	-0,3	-0,2		-0,1

Ref. mode	SV45°	P45°	P60°	SV45°	SV45°	SV60°	P45°	P60°	SV45°
Ref. depth (mm)	8	8	4	20	52	32	4	4	36
Probe dim. (mm)	6,35	12,7	12,7	12,7	22x20	22x20	6,35	6,35	12,7
fc (MHz)	2,25	2,25	2,25	2,25	2,00	2,00	5	5	5
	SV45°	P45°	P60°	SV45°	SV45°	SV60°	P45°	P60°	SV45°
48	0,2	-0,6	0,7	0,3	0,6	-0,2	-0,1		-0,2
52	-1,4	-0,2	1,3	0,2	0,0	-0,3	-0,9		0,0
56	-1,0	-0,5	1,0	0,2	0,1	0,0	0,1		-0,3
60	-1,1	-0,7	1,0	0,1	-0,1	0,2	-0,4		-0,2
64					-0,2				
68					0,0				
72					0,2				
76					-0,2				
80					-0,3				
84					-0,1				
88					-0,3				
92					-0,7				

Table 2. Gaps in dB between the measured and the CIVA10.0 simulated maximal amplitude of the SDH direct echoes, immersion probes

Reference mode	P0°			P0°				P0°	P45°		SV45°						P0°	SV45°				
Reference depth (mm)	8			12				20	4		4						8	32				
Water path (mm)	20			50				50	25		25						50	20				
Probe dimension (mm)	6,35	6,35	6,35	12,70	12,70	12,70	12,70	19,00	6,35	6,35	6,35	6,35	6,35	6,35	6,35	6,35	6,35	12,70	12,70	12,70	12,70	12,70
fc (MHz)	2,25	2,25	2,25	2,25	2,25	2,25	2,25	2,25	5	5	5	5	5	5	5	5	5	5	5	5	5	5
SDH depth / Mode	P0°	P45°	SV45°	P0°	P45°	P60°	SV45°	P0°	P45°	P60°	SV40°	SV45°	SV50°	SV55°	SV60°	SV65°	P0°	SV45°	SV50°	SV55°	SV60°	SV65°
4		-0,4	1,0		-0,7		1,2	1,0	0,0	1,0	0,1	0,0	-0,5	-0,6	-0,6	-1,1	-2,2	2,5	1,5	1,4	1,1	0,0
8	0,0	-0,2	0,9		0,0	-1,1	0,6	1,1	0,2	0,7	0,0	-0,1	-0,3	-1,1	-0,9	-0,9	0,0	1,3	0,7	0,3	-0,3	-0,3
12	0,0	0,0	1,4	0,0	0,3	-0,1	0,7	0,6	0,5	1,1	0,1	0,7	-0,5	-0,9	-0,2	-0,8	0,6	0,6	0,1	-0,1	-0,3	-0,3
16	0,1	0,4	1,8	-0,6	0,2	0,4	0,4	0,3	0,4	0,7	0,1	0,3	-0,2	-0,8	-0,1	-1,1	0,0	0,5	-0,1	-0,1	0,0	0,0
20	0,4	0,1	1,8	-0,3	0,4	-0,2	0,6	0,0	-0,1	0,7	0,9	0,7	-0,6	-0,4	-0,5	-0,8	-0,2	-0,2	-0,1	0,0	0,0	-0,2
24	0,1	0,1	2,1	-0,5	0,6	-0,2	0,8	-0,2	-0,1	0,8	1,0	0,6	-0,2	-1,1	-1,0	-1,1	0,0	-0,2	-0,1	-0,1	0,1	-0,4
28	1,4	0,8	2,1	-0,4	0,5	0,0	0,9	-0,2	0,3	1,5	1,1	-0,2	-1,4	-1,2	-1,3	-1,4	-1,0	0,0	-0,3	0,1	-0,1	-0,3
32	0,8	0,5	2,1	-0,1	0,6	-0,3	1,0	-0,2	0,0	1,8	1,2	-1,0	-1,4	-1,4	-1,3	-1,7	-0,2	0,0	0,0	0,0	-0,2	-0,4
36	1,1	0,7	2,1	0,2	0,3	-0,2	1,0	-0,4	0,5	1,4	1,8	-0,9	-0,5	-1,9	-1,7	-1,9	-0,5	0,1	-0,2	-0,1	-0,7	-1,0
40	-0,2		2,3	-0,1	0,6	-0,4	1,2	-0,3	0,4	1,7	0,9	-0,9	-1,6	-2,0	-1,3	-2,2	-0,6	-0,4	-0,3	-0,1	-0,8	-0,9
44	0,7		2,2	8,0	0,6	-0,1	1,3	-0,4	0,2	1,6	1,5	-1,0	-1,5	-2,1			-0,8	-0,1	-0,6	-0,3	-0,6	-1,3
48			2,4	0,1	1,0	0,4	1,8	-0,3	0,5	1,5	1,1	-1,4	-1,0	-1,5			-0,5	-0,4	-0,7	-0,5	-0,8	-1,3
52	1,0		2,4	-0,1	0,7	0,3	1,1	-0,3	1,2	2,1	0,3	-1,9	-0,5	-1,6			-0,8	-0,3	-0,6	-1,0	-1,0	-1,3
56	1,5			0,2	0,6	0,2	1,0	-0,2	1,1		0,3	-0,6	-1,1	-1,6			-0,9	-0,7	-0,9	-1,0	-1,3	-1,8
60	1,6			0,1	0,7	0,5	0,8	0,1	0,5		0,4	-1,1	-0,9	-1,8			-0,9	-0,8	-1,2	-0,8	-1,1	-2,0

3.2 Discussion

The comparisons show a very good agreement: the discrepancies between the measured and simulated amplitudes are less than 2 dB in most cases. They also allow concluding that the relative amplitudes of the P and SV specular echoes of the SDHs are in very good agreement. For example, in the case of the Ø12.7mm, 2.25MHz immersion probe (Table 2) the P0° direct echo of the SDH at 12mm depth is chosen as reference echo for the amplitudes of the SDH echoes obtained with the same probe used with another incidence and generating P60° waves or also SV45° waves in the specimen. In all the cases a very good agreement is observed.

The depth of the SDH used as a reference for the amplitudes has to be greater than the "near field length" in order to avoid the uncertainties of the modelling in the near field. For example, in the case of the 20x22mm, 2.25MHz contact probe, the SDH reference depth is 52mm, a greater depth than the near field length while in the case of the Ø 12.7mm, 2.25MHz contact probe, the SDH reference depth is 8mm (see Figure 2). Indeed, the strongest discrepancies between the measured and CIVA simulated SDH responses occur for the SDH at the smallest depths, when the SDHs are positioned in the near field (see for example table 1, contact probe 22mmx20mm) and are due to an approximation in the model: to compute the SDH echo, the incident beam on each point of the sampled SDH surface is approximated by a given wave form (the same for each point) and a given time of flight (depending on the point position). This beam description is not valid in the near field which presents strong variations due to wave interferences as it is illustrated on Figure 3. Work is in progress in order to overcome this approximation

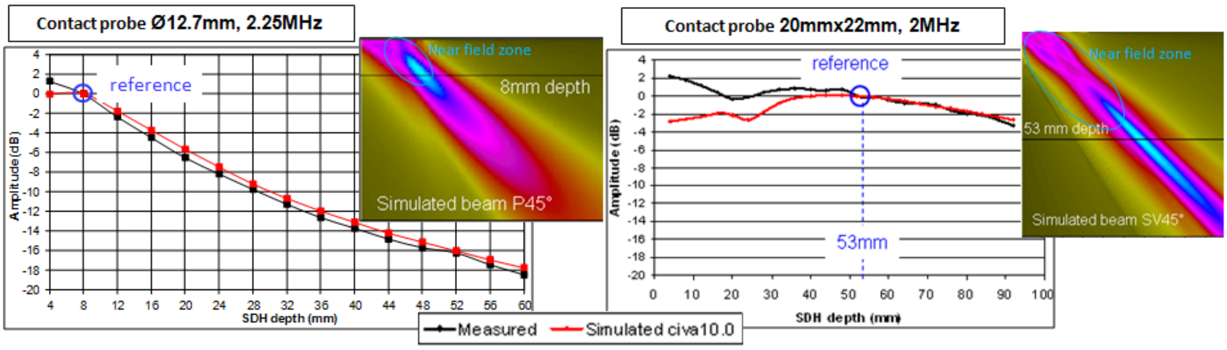

Figure 2: Comparison of measured and simulated responses of SDH Ø2 mm at different depths from 4 mm to 60 mm (step 4mm). Contact probe Ø12.7mm, 2.25MHz, P45° inspection (left) and contact probe 22mmx20mm, 2MHz, SV45° inspection (right). Beams radiated by each probe in the specimen.

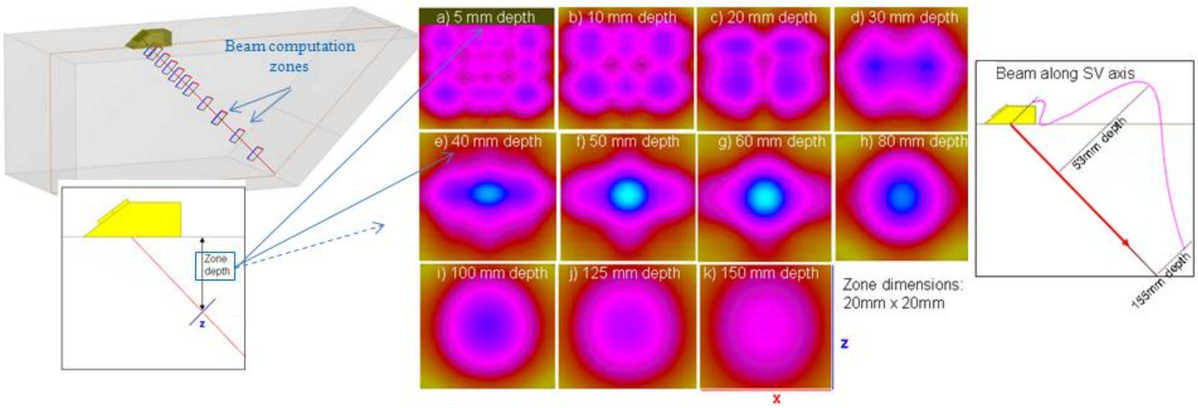

Figure 3: Result of SV45° CIVA beam computation (displacement module) in the zones defined on the figure (zones perpendicular to the SV refracted axis in the specimen and positioned at different depths, dimensions: 20mm x 20mm). The reference amplitude is the maximal amplitude obtained in the zone at 50mm depth (which is about the maximal amplitude of the beam computation).

Small deviations, just over 2dB, have been observed for the probes of greatest apertures (see Table 2). These discrepancies are low, and they occur for weak echoes outside of the focal area (see Figure 4). The interpretation of this phenomenon is still under study.

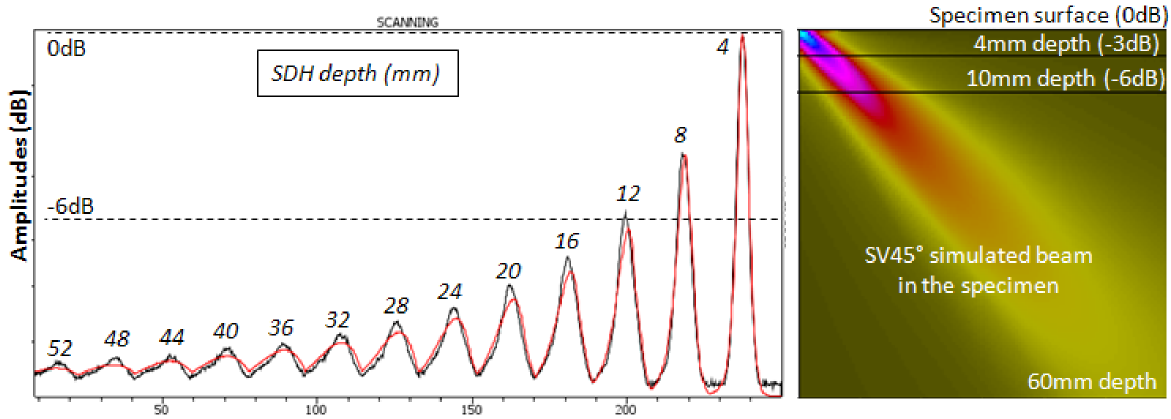

Figure 4: Superposition of the measured and CIVA10.0 simulated scanning echo-dynamic curves and simulated refracted beam. Immersion probe, Ø6.35mm, 2.25MHz, water path 20mm, SV45° inspection.

3.3 Case of SDHs of "small" diameter

For the SDH Ø2mm and the 2.25MHz and 5MHz probes considered up to now, the circumferential creeping wave and the specular reflected wave responses are separated. The relative amplitude of the two contributions is well reproduced. The next point is to check the CIVA predictions when the two contributions interfere. In this purpose, we compare the measured and simulated echoes of SDHs of decreasing diameters obtained with a Ø6.35mm, 2.25MHz immersion probe generating SV45° refracted waves. Again, a very good agreement is observed for the amplitude, the amplitude discrepancies obtained between measure and simulation are less than 1.5dB for all the diameters (the reference for the amplitude is the SDH Ø2mm) and also for the A-scans (Figure 5).

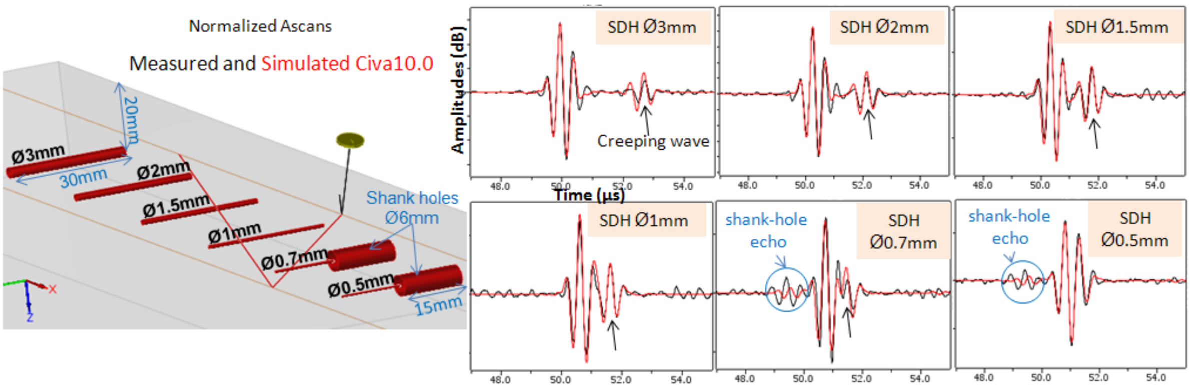

Figure 5: Measured and simulated normalized A-scans superposition. SDHs of different diameters positioned at 20mm depth. Immersion probe, Ø6.35mm, 2.25MHz, water path 25mm, SV45° inspection.

It has to be noticed on this figure that the first recorded echo is due to the edge of the shank hole. While not important for our purpose this echo has been simulated.

The SDH direct echo validation data presented, and others not shown here, allow to conclude that, in the case of 2MHz and 5MHz planar probes functioning in pulse echo mode, the SDH echo computed with CIVA can be used with confidence, even when specular and creeping waves are merged in time, if the SDH is positioned at a depth greater than the near field depth.

4. Results on SV45° corner echoes of back-wall breaking notches

Corner effect is commonly used in UT inspection procedures for the detection of back-wall breaking defects. Corner effect corresponds to the double reflection of an obliquely incident bulk wave on the back-wall and on the defect.
A campaign of experimental validation has been carried out on SV45° back-wall breaking notches corner echoes. Data have been collected with several probes and steel specimen. In all cases the specimen is planar, the material isotropic and homogeneous, the notches are vertical (normal to the surface). In the following we present results obtained on the specimen shown Figure 1 for various notch heights (varying from 0.5 mm to 15 mm) , has frequencies (2 and 5 MHz) and probe apertures (Ø6.35mm and Ø12.7mm).
The model used in CIVA10 to compute notches corner echoes is the Kirchhoff model [4], [5] and [6].

4.1 Results

We present Figure 6 some of these comparison data obtained for 3 probes.

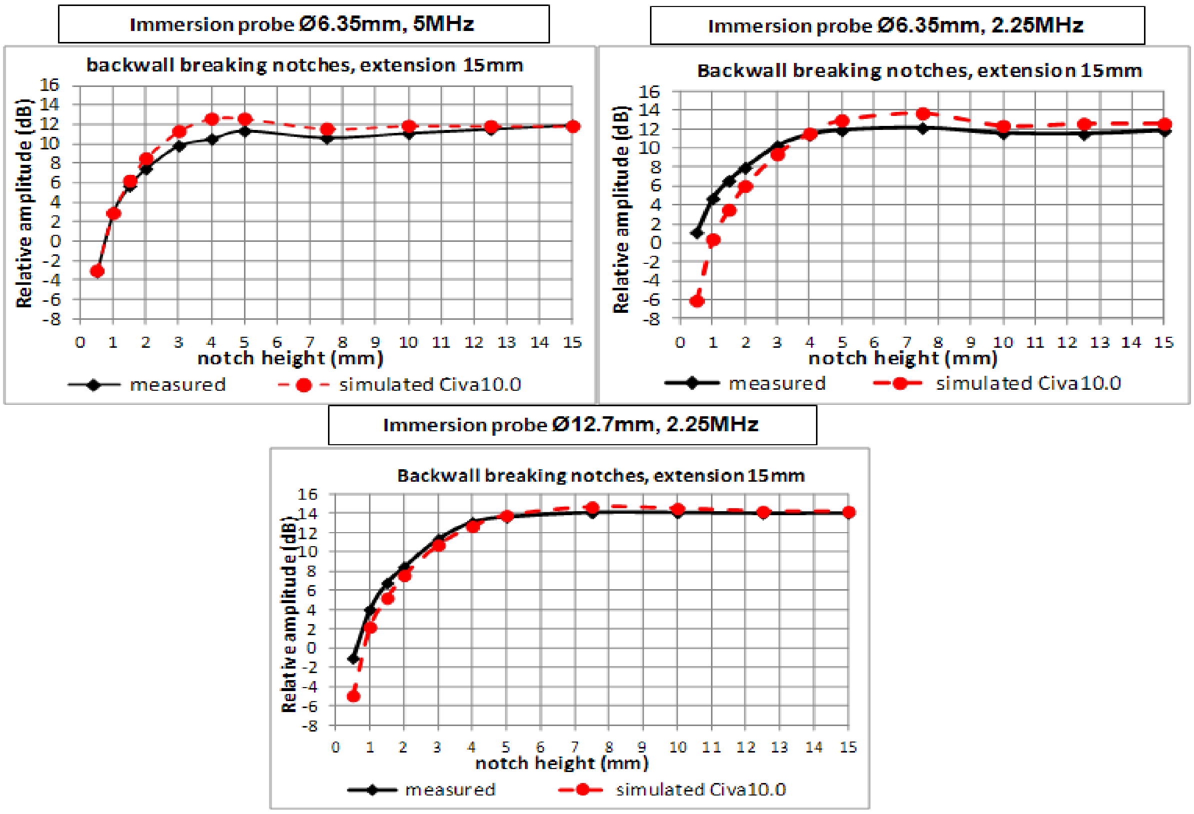

Figure 6: Comparison of measured and simulated amplitudes of the corner echoes of the back-wall breaking notches of different heights at 30 mm depth. The probes are indicated on the figure, the water path is 25mm, for each probe the reference for the amplitudes is the amplitude of the SV45° direct echo of a SDH Ø2mm at 20mm depth obtained with the same probe, SV45° inspections.

At 5MHz, (immersion planar probe, Ø6.35mm, 5MHz), the agreement is very good for all notches (0.5mm to 15mm height).
At 2.25 MHz with the second probe of same diameter (immersion planar probe, Ø6.35mm, 2.25MHz) we obtain again a very good agreement for the highest notches (15mm to 4mm height), but strong deviations occur for the smallest ones (up to 8dB for the 0.5mm notch).

Reducing the central frequency keeping constant the probe aperture leads to an increase of the beam divergence. In order to separate the effect of the central frequency and the effect of the beam divergence, measurements have been done with a third probe having the same central frequency but a greater diameter (immersion planar probe, Ø12.7mm, 2.25MHz).. We can see a significant decrease of the discrepancies on the smallest notches (about 4dB for the 0.5mm notch) while the good agreement for the highest notches is kept.

4.2 Discussion

The previous results (Figure 6) and other results (Table 3) show the reliability of CIVA predictions of SV45° corner echoes inspections. In most cases, the observed errors between simulation and measure are below the experimental uncertainties (around +/- 2dB)).
Nevertheless higher discrepancies are observed on very small notches (0.5mm height notably) inspected at low frequency relatively to the notch height (Ø6.35mm and Ø12.7mm, 2MHz probes) or/and examination with divergent probes (Ø6.35mm, 2MHz probe). The strongest errors are obtained when these two limitations are combined.

Table 3. Gaps in dB between the measured and the CIVA10.0 simulated maximal amplitude of SV45° corner echoes, contact and immersion probes.

Probe type			C	C	I	I	I	I	I	I	I
Ref. mode			SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°
Ref. depth (mm			30	30	4	20	20	15	15	32	20
Water path (mm					20	25	25	10	20	20	25
Probe dim. (mm			6,35	22x20	6,35	6,35	12,7	6,35	12,7	12,7	6,35
H	E	P Fc (MHz)	2,25	2	2,25	2,25	2,25	5	5	5	5
0,5	2	5			4,1			-2,0			
0,5	5	5			3,5			-0,7			
0,5	15	5			3,4			-0,8			
0,5	15	30				7,2	3,9				0,3
1	15	30				4,3	1,8				0,8
1,5	2	5			2,1			-2,0			
1,5	5	5			1,1			-0,9			
1,5	15	30				3,1	1,6				0,3
1,5	15	5			1,4			-1,2			
2	2	20							-0,1	-0,7	
2	5	20							0,0	-0,4	
2	5	50	3,8	1,6							
2	15	20							0,2	0,6	
2	15	30				1,9	0,9				-0,6
2	40	50	2,8	1,0							
2,5	2	5			1,7			-1,7			
2,5	5	5			1,5			-1,2			
2,5	15	5			1,3			-1,4			

			C	C	I	I	I	I	I	I	I
			SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°	SV45°
			30	30	4	20	20	15	15	32	20
					20	25	25	10	20	20	25
			6,35	22x20	6,35	6,35	12,7	6,35	12,7	12,7	6,35
			2,25	2,00	2,25	2,25	2,25	5	5	5	5
3	15	30				0,9	0,6				-1,1
3,2	40	30									
4	15	30				-0,1	0,4				-1,4
5	5	50	-0,2	0,9							
5	15	30				-1,1	-0,2				-1,2
5	40	50	0,7	-0,2							
6	15	20							0,5	0,3	
7,5	15	30				-1,6	-0,6				-0,3
10	5	50	-0,1	0,5							
10	15	30				-0,8	-0,4				-1,3
10	40	50	-0,4	-0,2							
10	40	30									
12,5	15	30				-1,1	-0,2				-0,4
15	15	30				-0,7	-0,2				-0,6
20	40	50	0,4	-0,5							
20	5	50	1,7	0,2							

Different effects can explain the observed discrepancies between CIVA and measure:

4.2.1 Small notch sizes

The discrepancy between simulation and experiment increases when the ratio of the notch size to the wavelength decreases. This is coherent with well-known limitations of the Kirchhoff approximation which is a high frequency approximation valid for large *ka*, where *k* is the wave number, and *a* the characteristic dimension of the flaw. These limitations explain the discrepancies observed for small flaws or/and small inspection frequencies (problem called thereafter "small defect effect"). In the case of the 0.5mm height defect and the 2MHz probes, the *ka* is 1 (*a* is the half height of the defect).

4.2.2 Probe divergence

As already mentioned, if we compare the results obtained with the Ø12.7mm, SV45°, 2.25MHz probe and with the Ø6.35mm, SV45°, 2.25MHz probe, we can see that the strong deviations observed for the smallest defects in the case of the Ø6.35mm probe are significantly reduced with the Ø12.7mm probe. And the same way, a good agreement is obtained between the measured and simulated scanning echo-dynamic curves for the Ø12.7mm probe (Figure 7) while important deviations are observed for the Ø6.35mm probe (Figure 8).

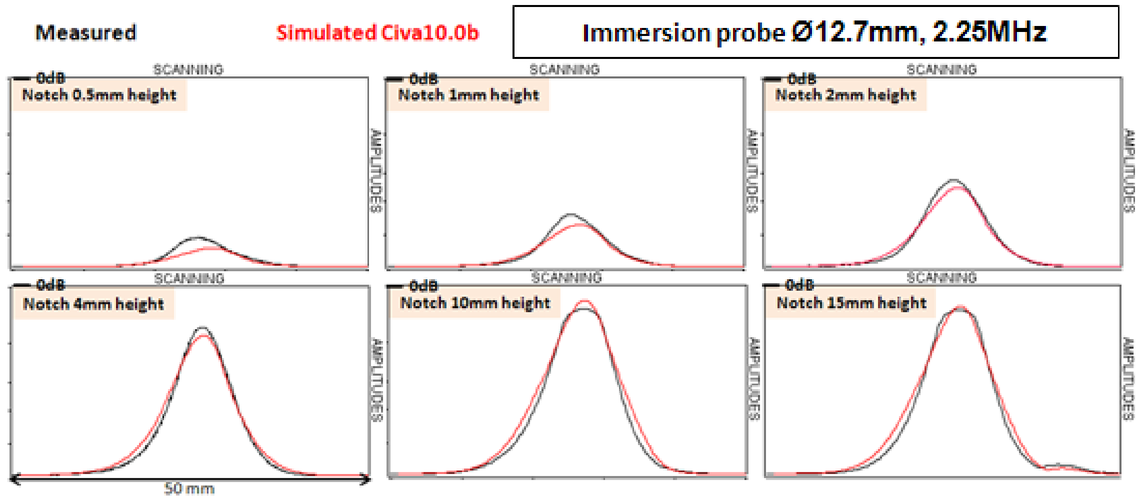

Figure 7: Comparison of measured and simulated echo-dynamic curves of corner echoes of back-wall breaking notches of different heights at 30 mm depth. Immersion probe Ø12.7mm, 2.25MHz, water path 25mm, refracted SV45° waves.

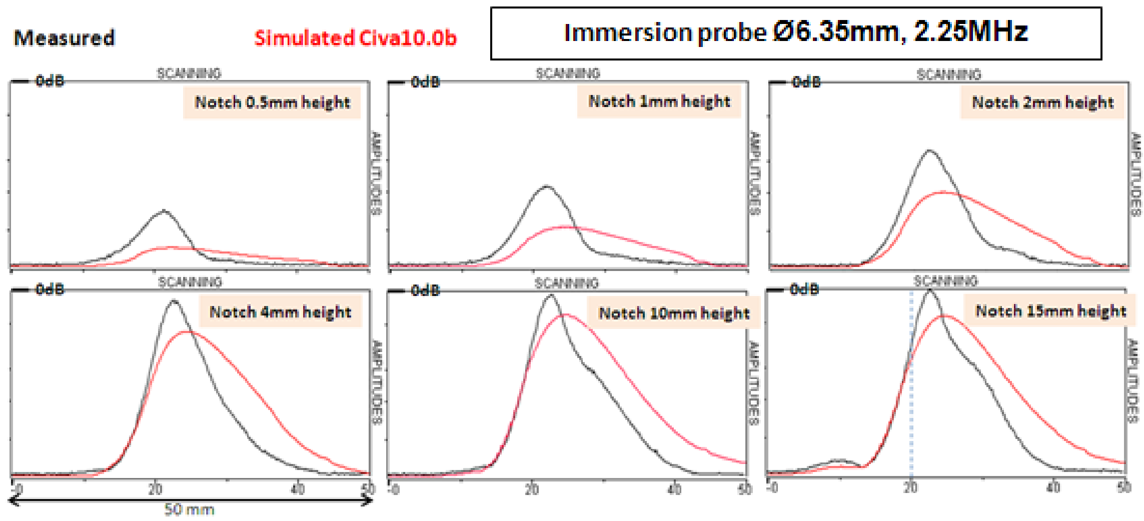

Figure 8: Comparison of measured and simulated echo-dynamic curves of corner echoes of back-wall breaking notches of different heights at 30 mm depth. Immersion probe Ø6.35mm, 2.25MHz, water path 25mm, refracted SV45° waves.

We can interpret these deviations as being due to the combination of the beam divergence and the small defect effects. Indeed, the influence of the beam divergence can be explained as following. In the most divergence beam, waves impinge the back-wall and the notch at incidences higher than the critical incidence possibly inducing the generation of surface waves. It is recalled that the critical incidence for steel corresponds to 33° on the back-wall and to 57° on a vertical notch. Creeping waves and head waves contributions are probably at the origin of the discrepancies observed on the echo-dynamic curves for the smallest notches. Work is in progress in order to confirm this interpretation.

6. Conclusion

In this communication we have reported results of a validation study aiming at quantifying the reliability of CIVA UUT predictions on canonical cases. We have briefly described the protocol adopted for experiments and computations and presented a selection of cases concerning SDH reflectors and SV45° corner echoes of back-wall breaking notches at 2MHz and 5Mhz. These results show that the CIVA predictions are very reliable in most cases and indicate also cases of discrepancies. Work is in progress at CEA LIST in order to improve the models in these cases. Other CIVA validation studies are in progress. The data are made available on the web site of EXTENDE (distributor of CIVA) when they are obtained.

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