

A TOOL FOR INSERTION OF SIMULATED FLAWS ON REAL ACQUISITION FILES

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Abstract. Training people to analysis and interpretation of ultrasonic data may be challenging and costly especially when dealing with complex components. Several mock-ups including various defects (real and machined flaws) are necessary to trainees in order to prepare them to the different scenarios they may face later. Simulation is a major cost reduction asset. The ability to vary the parameters of an inspection (having control over them) enables to anticipate the inspection of a component from the design stage but also to minimize the number of mock-ups to demonstrate the performance of an inspection. Most of the time, simulation allows to obtain signals (Ascans) and images (Bscans, Cscans...) very similar to the ones that would have been obtained experimentally. However accurate simulation needs the knowledge and understanding of the limits of the modeling algorithms. This may be beyond the skills required for a NDT technician trainee. Because analysis training is more efficient on realistic data, EXTENDE has developed a tool that allows including signals simulated with CIVA in experimental data. Insertion in acquisition files of simulation signals obtained on virtual defects located inside a component similar to the one used for experiment is possible with this tool. Therefore, EXTENDE's team can propose infinity of possibilities for the choice of defect, their size, orientation and location. The modified files can be opened in CIVA Analysis where several tools can be used to ease the study of the file. In this paper, we present an application of the "simulation on acquisition tool" on a realistic application case.

1. Context

The raw results provided by NDT systems are not always easy to interpret due to the numerous input parameters and the complex physical phenomena involved in an NDT inspection. Training operators to analysis and interpretation of ultrasonic data may be challenging and costly especially when dealing with complex components. Several mock-ups including various defects (real and machined flaws) are necessary to trainees in order to prepare them to the different scenarios they may face later. Limited time and material and specimens may also make training inefficient and expensive.

The simulation plays an increasing role in NDT, allowing to help the design of inspection methods, their qualifications or the analysis of inspection results. It is also a tool to help teaching the "physics behind NDT", to highlight the main phenomena and to understand typical NDT results in a visual and comprehensive environment. Furthermore, simulation is a major cost reduction asset. The ability to vary the parameters of an inspection, the nature and location of the flaws etc... enables to anticipate the inspection of

a component from the design stage but also to minimize the number of mock-ups to demonstrate the performance of an inspection or for training.

CIVA is a well-known versatile software for the modelling of NDT process that includes different simulation modules for various inspection methods: Ultrasound testing (UT), Guided-wave Testing (GWT), Eddy-Current Testing (ET), Radiographic Testing (RT) and Computed Tomography (CT). Along with its latest version CIVA 2016, this platform includes now an analysis module for UT acquisition data. The main objectives of this analysis software are to display acquisition data in an easy and understandable way, to extract advanced information in an efficient manner, to put this data into a dynamic report and to avoid repeatable and time consuming operations. The connection with the simulation part of CIVA provides to the user the possibility to compare easily real data and simulated trials. This helps to understand some phenomena or to highlight the need for an improvement in detection and characterization methods especially when the current results are ambiguous or lead to imprecise diagnosis.

2. A tool for insertion of simulated flaws on acquisition files

In this context, realistic simulation seems to be the solution for a complete and efficient training at low costs. The only thing to do is to make sure that the simulations used for training are sufficiently representative of real conditions and results. Accurate simulations allow obtaining signals (Ascans) and images (Bscans, Cscans...) very similar to the ones that would have been obtained experimentally. However, it is necessary to know and understand the limits of the modeling algorithms. This may be beyond the skills required for a NDT technician trainee. Because analysis training is more efficient on realistic data (realistic geometry echoes, noise...), EXTENDE has developed a tool that allows including in experimental data defect responses simulated with CIVA.

Thanks to this tool, it is possible with a single acquisition to train people analyzing real experimental data augmented by the insertion of the acoustical signature of virtual defects. CIVA offers a wide type of flaws and specimen geometries (including 2D and 3D CAD) to simulate. Therefore, training may be efficient and performed on infinity of realistic cases at low costs. The tool allows the trainee to learn on realistic data and allows the training organization to overcome the manufacturing and machining of several mock-up and defects. Several configuration cases may be created from a single acquisition. On demand, one or several realistic flaws responses at different locations in the specimen may be embedded to the real data. Then, the augmented file shows realistic simulated echoes, real structural noise and real geometry echoes. The training is then very realistic and much less expensive.

Up to now, the tool can only be used with Olympus and M2M files that can be opened in CIVA. The tool uses the knowledge of how are constructed the experimental files and allows to copy and modify them. From an acquisition file and a simulation file, the tool creates a third one containing all the original experimental data plus simulation results. Three operations are available when inserting simulation on acquisition. The user can add or subtract simulated data from acquisition but he can also substitute a sample of the acquired data with simulated ones. The extension of the new file is no more the one of the acquisition. It is a ".civa" file which can be then analyzed only in CIVA Analysis.

On the GUI of the executable program, the user defines the acquisition and the simulation files. The name of the output file i.e. augmented experimental file is specified by the user who must specify also information about the parameters of acquisition and simulation (number of increments, shots, scans, sampling frequency, time gate...). Once all input data are defined, the user chooses where exactly on the acquisition the simulated

signals should be embedded and which operation will be used during the process. After fast computation, a window allows displaying the original, simulated and augmented A-Scan for the increment, sequence and shot of the user's choice.

3. Application of the tool

In order to illustrate the advantages of the use of the “simulation on acquisition” tool developed by EXTENDE, let's consider a cylindrical welded specimen (OD 850mm) made of homogeneous stainless steel. The dimensions of the component are 297mm×186mm×18mm. Figure 1 shows pictures of the specimen from different views.



Figure 1 : Picture of the inspected specimen

In this component representative of classical NDT configuration, several defects are machined (Figure 2): three notches (one breaking the surface, one breaking the backwall and one on the welding bevel) and a set of two Side Drilled Holes (SDHs).

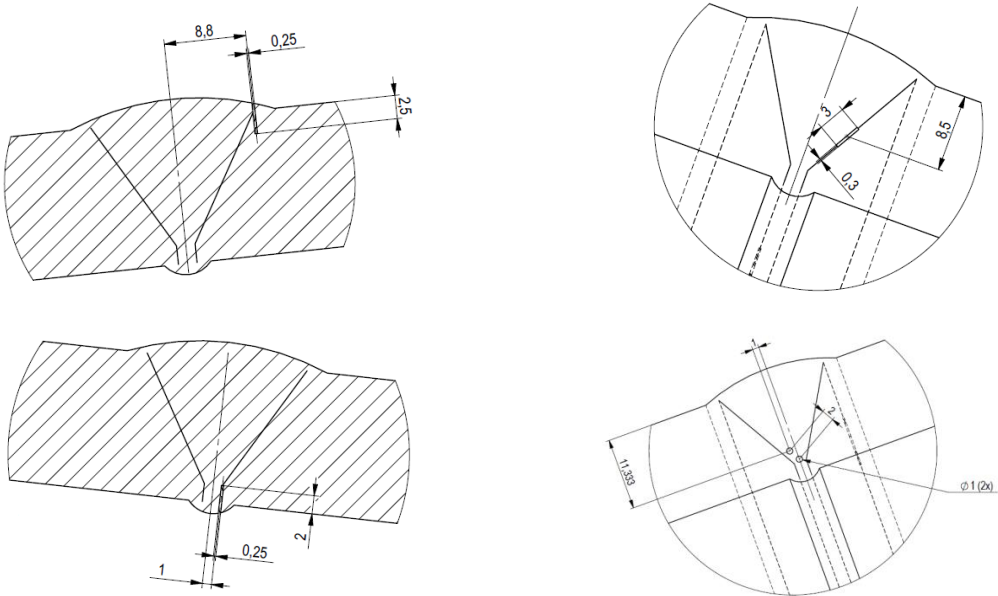


Figure 2 : Schematic representation of the machined defects

In order to ensure an optimal coupling, the inspection has been performed in immersion with a phased-array probe mounted on an articulated robot arm. The number of active elements, the incidence angle and the delay laws were adjusted in order to generate

SW45° or SW60° in the component. To do so, the complex profile (surface and backwall) of the specimen has been acquired by laser profiling.

3.1. Application on the inspection a surface breaking notch

Figure 3(a) and (b) show respectively experimental and simulated C-Scan obtained with SW45° inspection. On them, it is possible to identify the defect n°1 (surface breaking notch). Figure 3(c) and (d) show respectively the experimental and simulated Bscan of the same defect. It can be noticed that the simulated echoes look like very much the experimental ones (same size, same time of flight, same amplitudes). However the texture of the Cscans and the geometrical echoes changes in amplitude due to imperfect knowledge of the geometry are not exactly the same. Simulation does not take into account for amplitude variation due to changes of the specimen geometry along its extension. This is not realistic that is why EXTENDE developed the “simulation on acquisition” tool. Adding realistic simulated flaws signatures obtained by simulation in an acquisition allows the trainee working on realistic signals taking into account of the specificities of the specimen (geometry, noise,...).

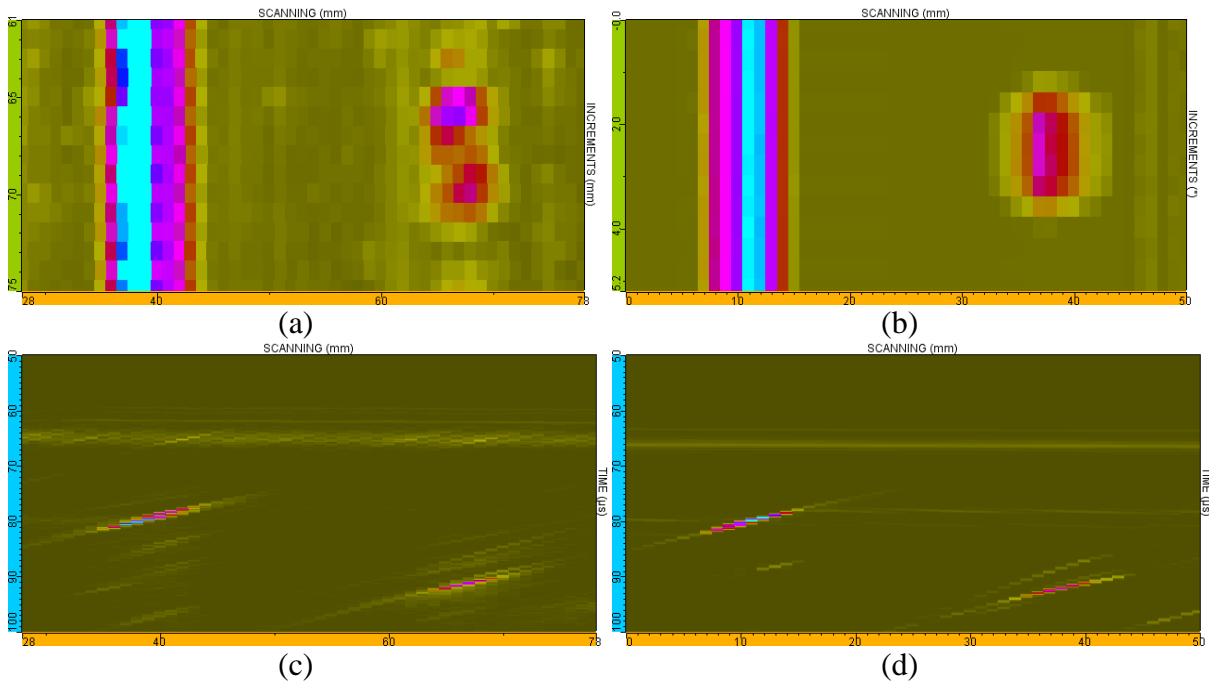


Figure 3 : Comparison of experimental and simulated Cscans : (a) experimental SW45° Cscan, (b) experimental SW45° Bscan, (c) simulated SW45° Cscan, (d) simulated SW45° Bscan

It is easier to realize that the simulated echoes are very similar to the real ones when adding the simulation result into the acquisition. Figure 4 shows that after addition of the simulated data, a very realistic C-Scan is obtained where two similar flaws next to each other can be identified. It is almost impossible to make the difference between the real echo and the simulated one. Furthermore, the geometry echo and the texture of the noise is identical to the experimental one.

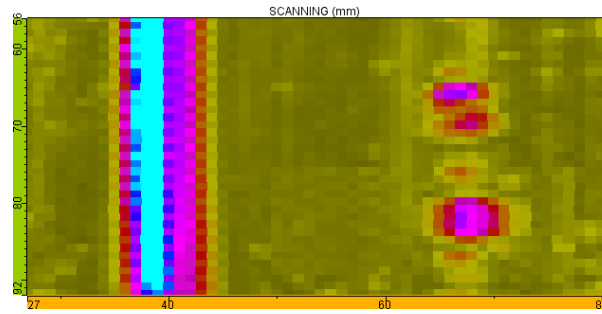


Figure 4 : Augmented Cscan – The simulated echo of the same defect than experiment has been added to the acquisition data at another increment.

The Ascans extracted at the maximum of the response of the simulated and real flaws are displayed on Figure 5. It can be seen that the amplitude and the signal shape of the simulated response are very close to the real ones. The widths of the envelopes are also in very good agreement (Figure 5(c)). These comparisons shows that the simulated data included in acquisition are very realistic and can be used for an efficient training at low cost (less machined defects, less mock-ups...).

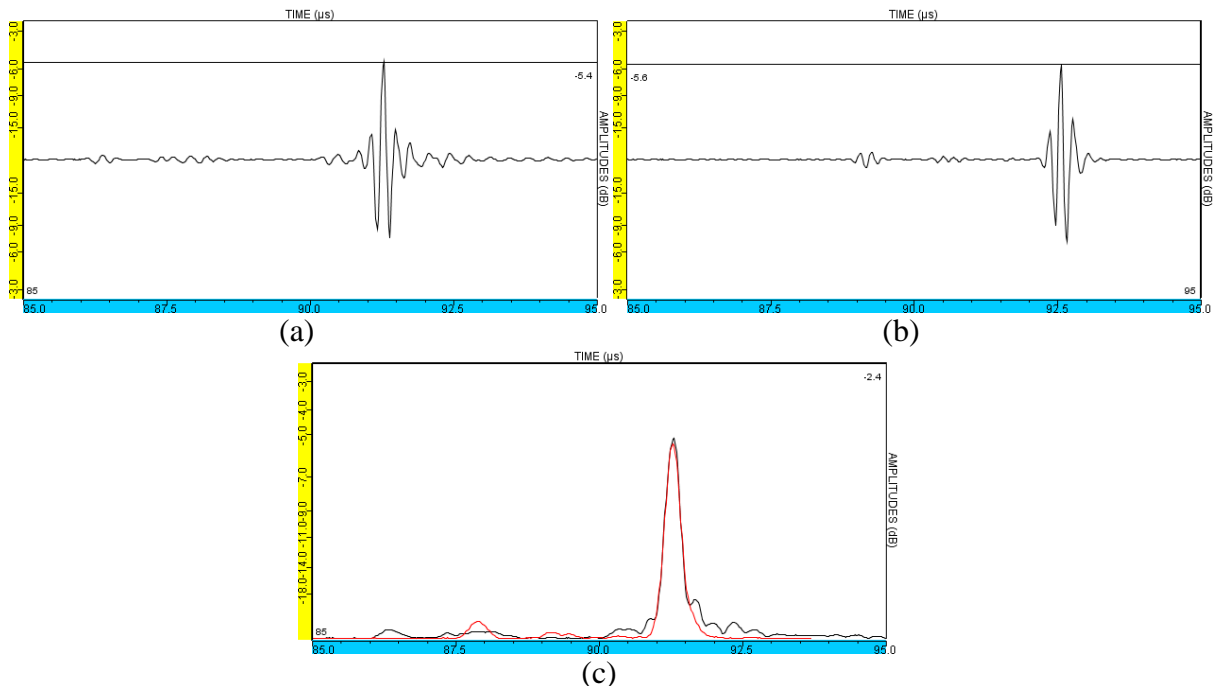


Figure 5 : Comparison of Ascans at the maximum of the experimental and simulated flaw – (a) experimental A-Scan, (b) simulated A-Scan, (c) Superimposition of the envelope of the simulated and experimental A-Scans.

A complete training teaches the student to face several and different cases. The developed tool allows achieving this by providing the possibility to add the response of any flaw in an acquisition. Thus now it is possible to change the flaw characteristics (shape, size, orientation, position,...) and present them for analysis to the trainee. On Figure 6, the simulated flaw added on the C-Scan is now tilted with an angle of 30° . As a consequence of this orientation, the amplitude of the flaw is lowered. This is an example of the influence of the tilt on the defect response.

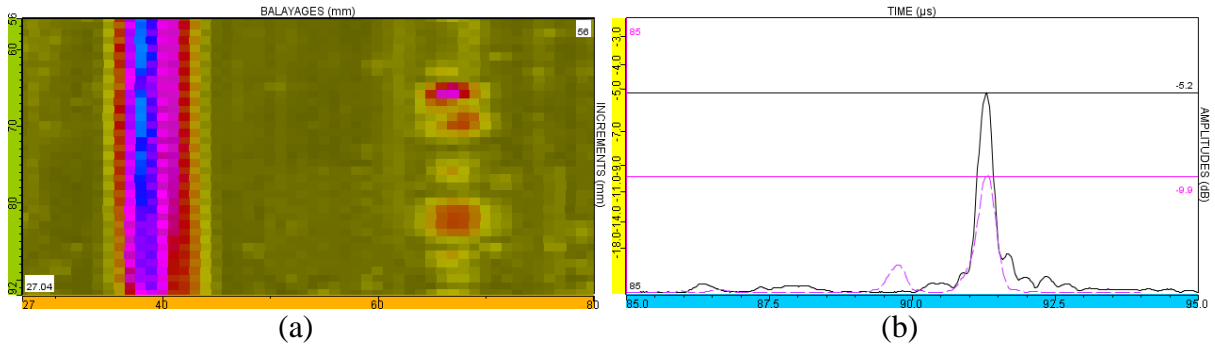
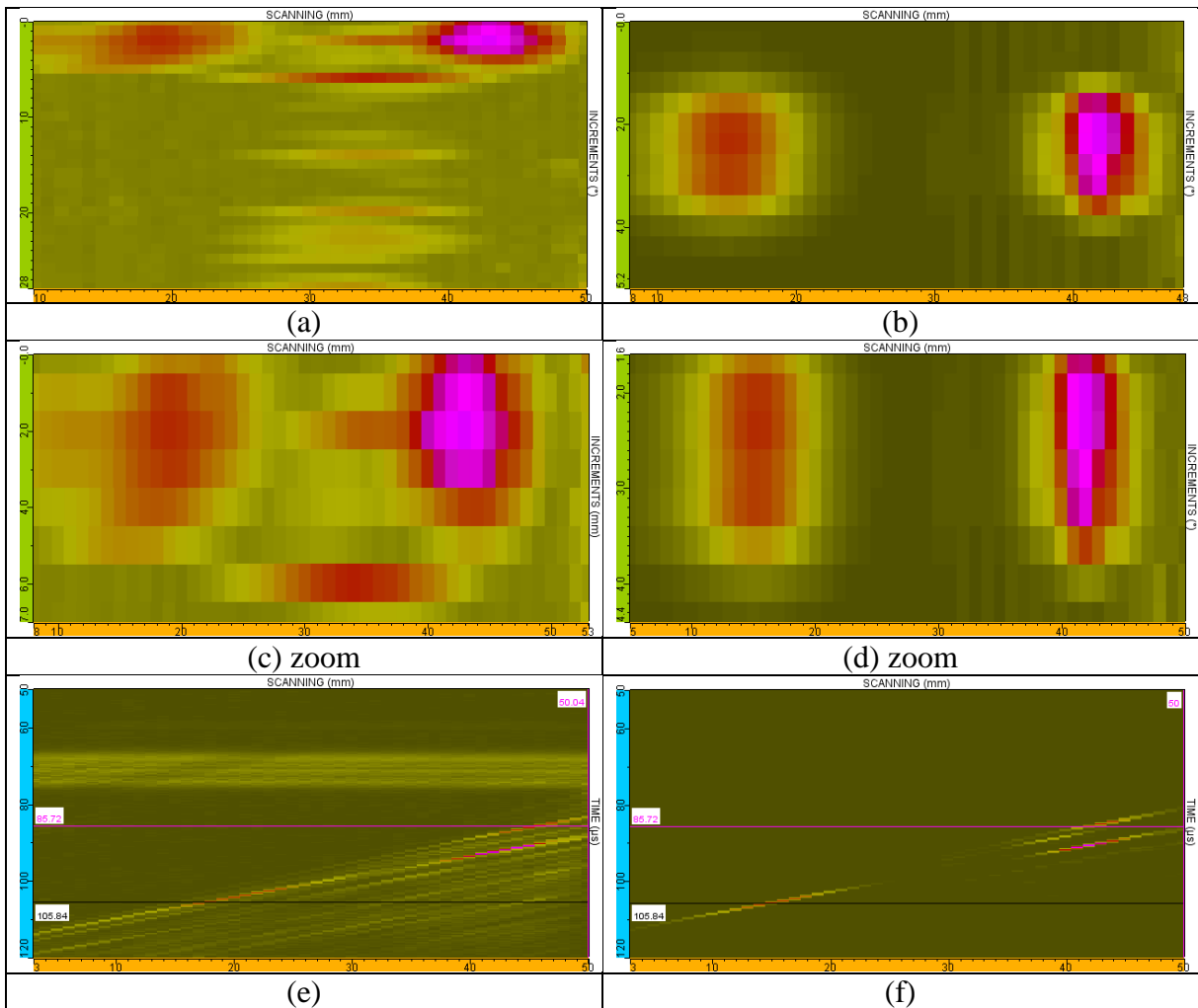


Figure 6 : (a) Experimental C-Scan augmented with the response of the tilted notch – (b) Comparison of the experimental and simulated A-Scans envelopes.

3.2. Application on the inspection of a lack of fusion: notch along a welding bevel

In this section we evaluate the addition of simulated echoes from a lack of fusion located along a welding bevel. Figure 7 (a) and (b) show respectively experimental and simulated C-Scan obtained with SW45° inspection. Figure 7 (c) and (d) display the experimental and simulated Bscans. The comparison of the different images allows noticing the similarity between simulation and real acquisition.



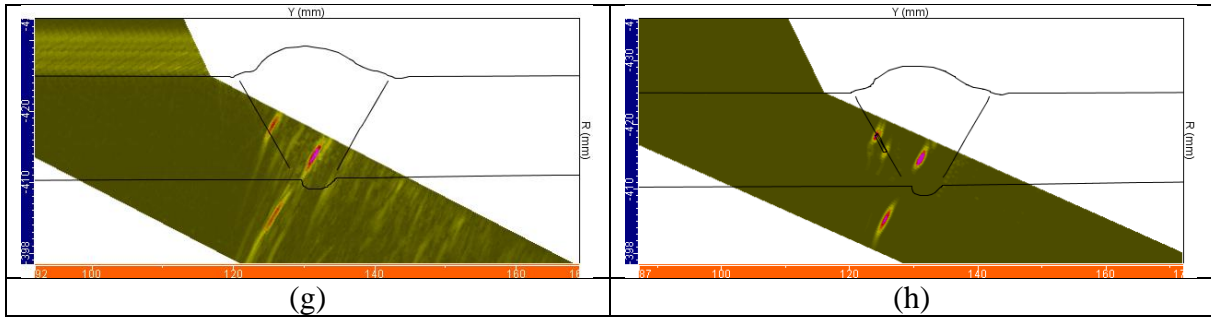


Figure 7 : Comparison of experimental and simulated Cscans : (a) experimental SW60° Cscan, (b) experimental SW60° Bscan, (c) zoom from experimental SW60° Cscan, (d) zoom from experimental SW60° Bscan, (e) simulated SW60° Bscan, (f) simulated SW60° Bscan, (g) simulated SW60° True-Bscan, (h) simulated SW60° True-Bscan

Figure 8 shows the Cscan resulting from the addition of the simulated data in the acquisition. As expected, the difference between experimental echoes and simulated ones is very small. The differences that can be observed are mainly associated with geometrical echoes (surface and backwall) that have not been calculated in order to save time computation. In the real mock-up, the geometry of the backwall (especially the weld bead) changes along the specimen extension. Contrary to real life, simulation does not consider variations in the specimen geometry along extension. Therefore, as in real life, two same defects may show echoes (Ascans and Bscans) slightly different due to backwall variation. Imprecise definition the simulated flaw can also cause some differences due to imprecise definition of the tilt, skew and/or position of the flaw. Sometimes these values are not known exactly and may be tricky to check. However, once the simulated data is included in the acquisition, the previously differences are smoothed: the augmented data keeps the geometrical echoes and RSB from the acquisition which makes the new file very realistic.

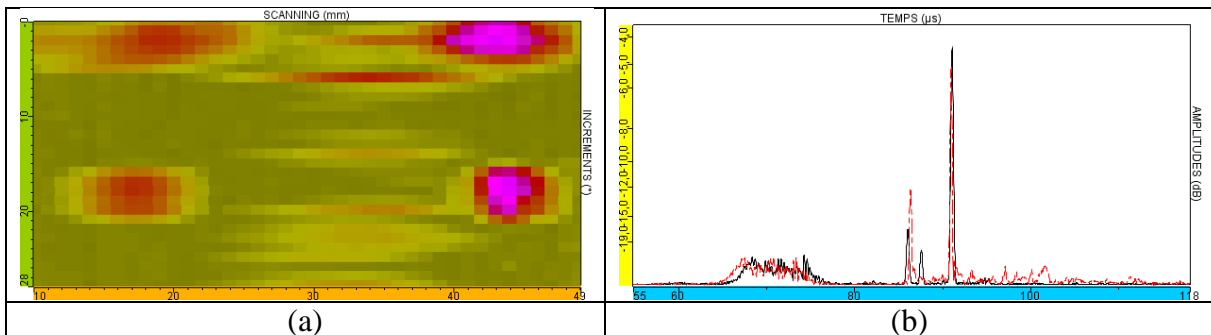


Figure 8 : (a)Augmented Cscan – The simulated echo of the same defect than experiment has been added to the acquisition data at another increment, (b) comparison of the experimental and added defect response

On Figure 9(a) is displayed the Cscan of the original experimental data augmented with simulation of a longer lack of fusion (l=30mm). Thus, the echoes associated to the new defect are larger. Figure 9(b) shows to the superimposition of the echodynamic increment curves extracted at the max of the larger defect from Figure 9(a) and Figure 8(a). The comparison of the 2 curves highlights the larger response from the larger defect. The possibility of adding flaws with different size and the analysis tools available in CIVA allows the student training to characterization.

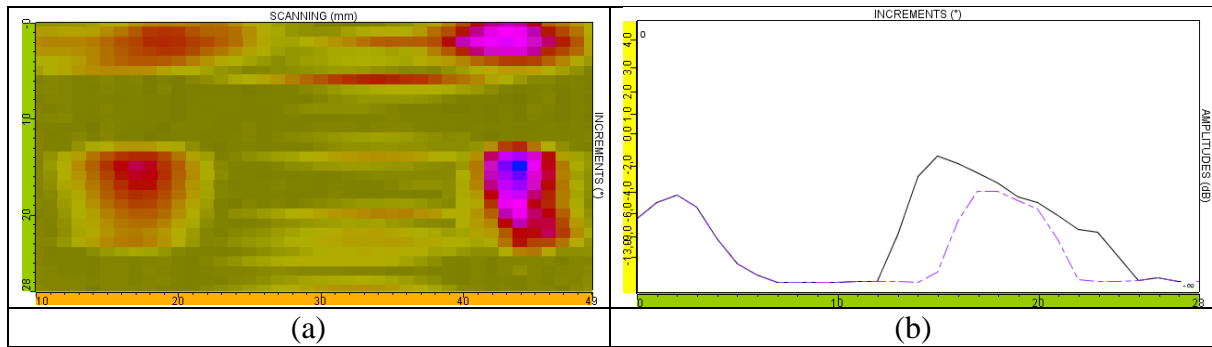


Figure 9 : (a) Experimental C-Scan augmented with the response of the longer notch, (b) superimposition of echodynamic curves from the C-Scan of Figure 8(a) and Figure 9(a)

4. Conclusion

The main objective of the “simulation on acquisition” tool developed by EXTENDE is to improve and to lower costs of NDT trainees by providing experimental files augmented by simulation. The tool has been evaluated on acquisition data typical from industrial application cases: inspection of a cylindrical welded specimen. We showed that it is possible now to create augmented files mixing both acquisition results and simulated echoes. The simulated responses from lack of fusion and surface breaking notch have been successfully included in acquisition files. The resulting augmented data is very realistic and makes it hard to distinguish between real and simulated flaws: echoes from geometry and from the material are preserved or very well simulated. Thanks to simulation and the tool, it is possible to change the flaw characteristics in order to train to characterization: size, positioning, orientation and type of flaw can be changed and included in an acquisition file. Thus students can face several cases and then run efficient and complete training while the training organization can save the manufacturing of several mocks-up and machining of artificial defects. The augmented files which have a *.civa extension can be opened and analyzed in CIVA or CIVA Analysis software which offer now efficient tools for analysis and understanding of the results. This tool opens then the way to a new and efficient type of training at low costs.

5. Acknowledgments

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