



## A Turnkey Weld Inspection Solution Combining PAUT & TOFD

### INTRODUCTION

With the recent evolutions of the codes & standards, the replacement of conventional film radiography with advanced ultrasonic testing is drawing a lot of attention for the manufacturing and in-service inspection of welds. The benefits on the safety of the operators and co-workers compared to RT are obvious, but the increase in productivity and implementation of cost reductions are major drivers explaining the rapid adoption of the alternative ultrasonic techniques.

The state-of-the-art is indisputably the use of PAUT and TOFD. The complementarity of these techniques leads to a robust and reliable solution for weld inspection. Indeed, interrogating weldments with such a combination of techniques typically yields a high probability of detection and excellent sizing capabilities while remaining more flexible to handle practical difficulties often encountered in the field, like unexpected joint geometries or slight variations from the nominal geometry.

Even though the PAUT and TOFD inspections of a specific part could be done sequentially, the simultaneous application of these techniques offers so many benefits that it becomes counter-productive to do otherwise. It obviously allows increasing the productivity of the inspection crew simply by reducing the amount of scans and manipulations that need to be done. But it also has an impact on the quality of the acquired data. Indeed, when the two inspection techniques are applied sequentially, it is difficult to have exactly the same mechanical references (start position on the scan and offset from the weld center

line). This could lead to some imprecision on the positioning of the indications. Also, when two different scanners are used for the PAUT and TOFD techniques, the difference in the encoder calibration may lead to an imprecision on the length sizing of the indications.

However, in reality, the simultaneous application of PAUT and TOFD is easier said than done. In the next paragraphs, the many challenges to the efficient implementation of such an inspection will be explained and a recently developed turnkey solution will be presented.

## **CHALLENGES**

Despite the fact that both are ultrasonic techniques, PAUT and TOFD are very different in their application. This differentiation leads to hardware and software requirements specific to each technique. We find on the market many inspection systems dedicated to PAUT and others dedicated to TOFD, but very few offer excellent performances for both techniques simultaneously. Another challenging aspect of the technique differences is the training and experience of the operators. Indeed, an operator with a lot of experience with PAUT will not necessarily be able to calculate the proper probe-center separation (PCS) to use for a specific TOFD configuration or to properly interpret TOFD data. The same holds for an experienced TOFD operator; he might not be able to properly setup a sector or electronic scan. This often means that the inspection needs to be done by two specialized operators.

The scanning device required to support the simultaneous encoded application of PAUT and TOFD can become complex. As a minimum, the scanner needs to support 4 search units (2 PA probes and 1 TOFD pair). However, as the thickness becomes larger, the TOFD inspection needs to be done in different depth zones and therefore requires more TOFD probes and larger PCS to cover the full volume of interest. In order to maximize the efficiency of the inspection crew, which often has to inspect thin-wall and heavy-wall components in the same shift, the scanner should allow the flexibility to support a wide range of thicknesses.

Other accessories, like a splitter box for the probe connectors and an irrigation pump, can also make the on-site deployment of the inspection solution more cumbersome.

## **SOLUTION**

In an effort to overcome the challenges listed above, Zetec has put together a simple, efficient & evolutionary solution for weld inspection using PAUT and TOFD simultaneously. This solution is based

on an advanced portable PAUT and TOFD system, innovative embedded software and a modular scanner.

### *ADVANCED PORTABLE PAUT & TOFD SYSTEM*

From lessons learned over the years, Zetec has developed a new-generation portable instrument capable of combining PAUT and TOFD technologies with the highest standards of performance. The TOPAZ<sup>32</sup> (Figure 1) is an advanced, battery-operated system designed to tackle the most challenging applications.



**Figure 1:** TOPAZ<sup>32</sup> Portable PAUT & TOFD System

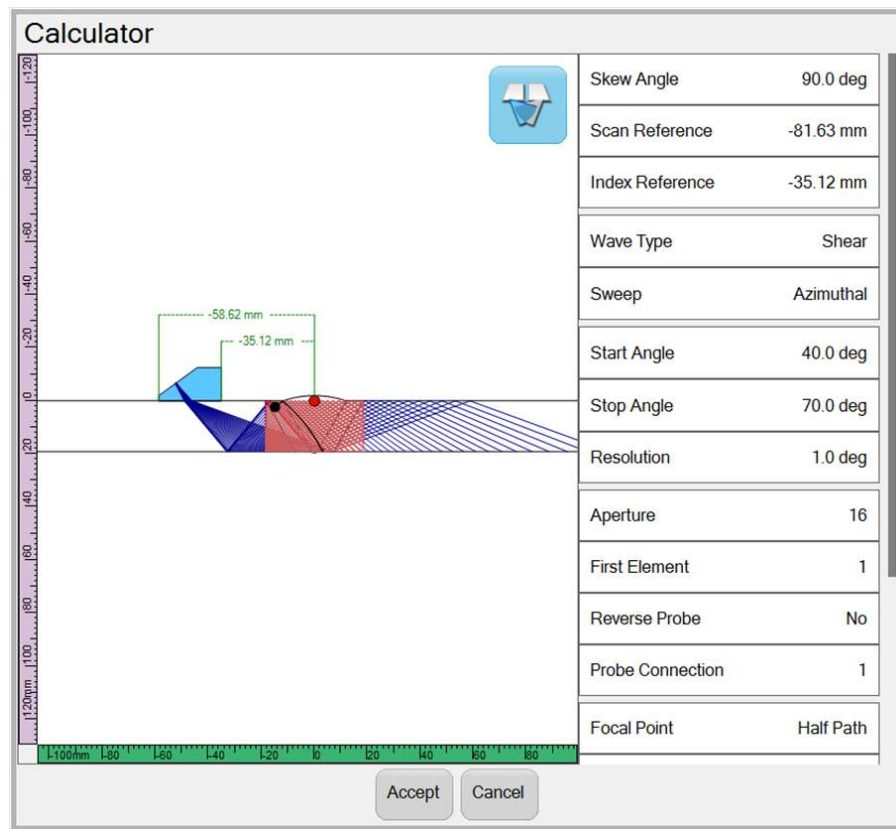
Its 32/128 configuration is ideal for two-sided PAUT weld inspection. Indeed, the active aperture up to 32 elements and the high-voltage pulsers allows the transmission of enough acoustic energy to adequately inspect weldments up to 6 inches thick, and the possibility to connect up to 128 elements (a 64-element probe on each side of the weld), allows an adequate coverage in all circumstances.

In addition to its PAUT capabilities, the TOPAZ<sup>32</sup> is also equipped with 2 dedicated conventional UT pulsers & receivers. Being able to pulse up to 200V and designed specifically to provide an optimum signal-to-noise ratio, these channels are ideal for TOFD inspections. Unlike first-generation portable systems, the dedicated UT channels can be used simultaneously with the 128 PAUT channels. Therefore, for configurations requiring 1 or 2 TOFD groups, there is no need to use pre-amplifiers to compensate for the fact that the low-energy TOFD signal is processed through the PAUT channels.

### *INNOVATIVE EMBEDDED SOFTWARE*

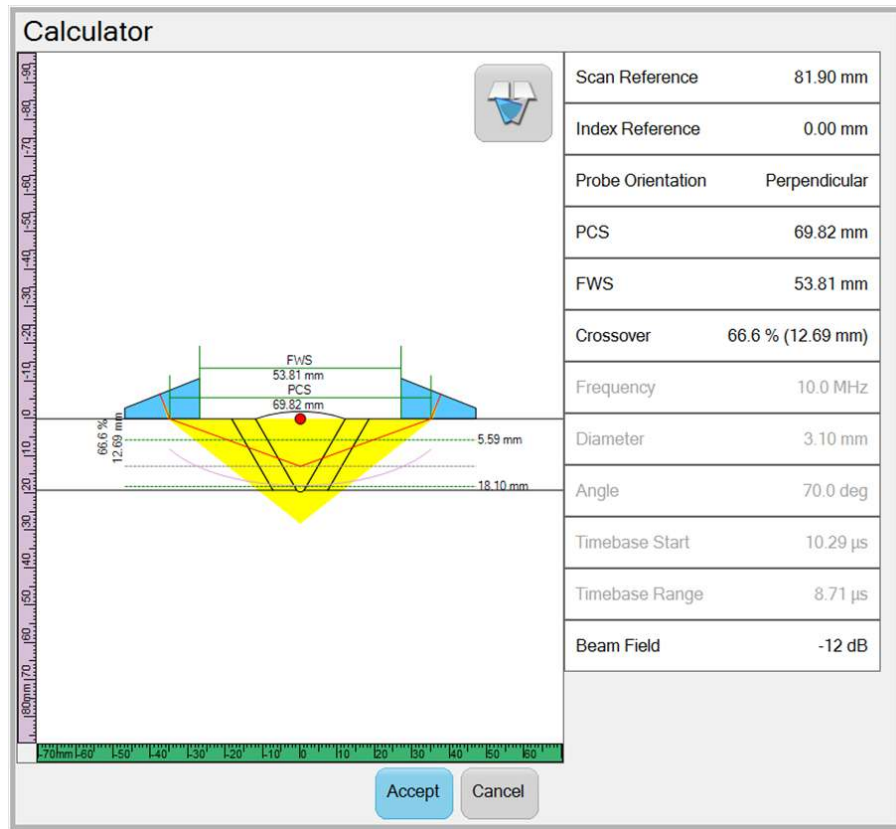
It is not all to have a system that offers superior hardware performances; it needs to be coupled with embedded software that allows the user to fully and easily exploit its potential. The up-to-date computing platform of the TOPAZ<sup>32</sup>, running under Windows 7 OS, allowed Zetec to embed all the power of its UltraVision 3 software behind a simplified user interface.

One of the main improvements of UltraVision Touch over the first-generation portable systems embedded software is the visual feedback provided in the creation of the setup (Figure 2). In particular, the onboard calculator allows the easy creation of an adequate scan plan and assessment of the volume coverage (including the heat-affected zone). When using first-generation systems, this step in the setup creation has to be done on PC-based software, and then be manually transposed to the embedded software. This obviously adds complexity to the task of the operator and makes the process more prone to errors.



**Figure 2:** UltraVision Touch Onboard PA Calculator with Visual Feedback

For non-experts, setting up a TOFD channel can be quite complicated. The visual feedback provided UltraVision Touch makes TOFD channel creation easy (Figure 3). By setting the required depth of the crossing point of the transmitter and receiver beams, the PCS is automatically calculated. The beam divergence (at -3, -6, -12 or -20 dB) of the TOFD configuration is calculated and displayed to adequately evaluate the coverage of the volume of interest. The theoretical values of time base start and range are automatically applied, simplifying even more the TOFD setup creation.



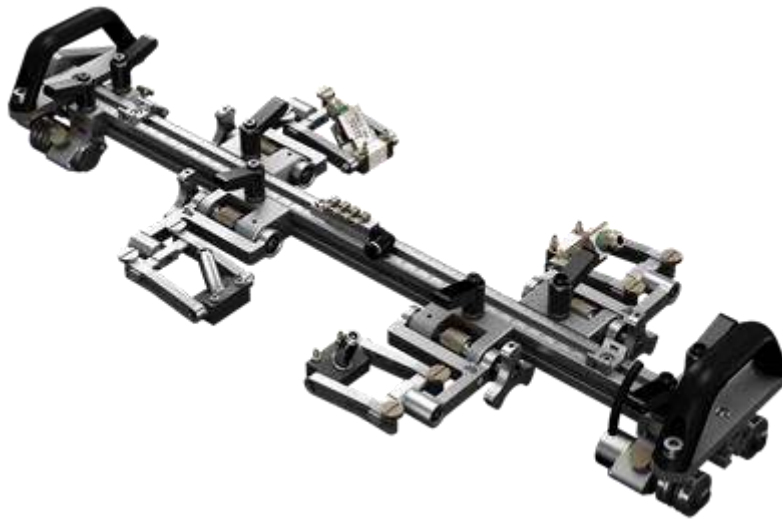
**Figure 3:** UltraVision Touch Onboard TOFD Calculator with Visual Feedback

UltraVision Touch also offers all the required analysis tools, directly from the TOPAZ<sup>32</sup> screen. Indeed, advanced tools like the volumetric merge, gate selectors, automatic amplitude-drop sizing and TOFD lateral wave synchronization & removal are accessible from the TOPAZ<sup>32</sup> user interface. With other systems, these tools are only available on PC-based analysis software, which adds complexity and slows-down the on-site data analysis process.

Even though it is not the most value-added part of the inspection process, reporting is nonetheless a key task. This important step usually cannot be done efficiently on first-generation portable systems. UltraVision Touch allows the easy and quick creation of an indication table and generation of ready-to-print customizable PDF reports. The data analyst can select the information he wants to display in the report, from hardware settings, scan plan to indication information, and can add a list of custom fields. By providing a meaningful report by the click of a button, the TOPAZ<sup>32</sup> helps keeping the post-inspection paperwork to the bare minimum.

## MODULAR SCANNER

During an inspection campaign, the size and geometry of the welds to be inspected can vary a lot. In order to maximize the efficiency of the inspection crew, the scanner used for the simultaneous use of PAUT and TOFD needs to adapt to as many inspection configurations as possible. It is in this perspective that Zetec has designed the WELD Crawler (Figure 4).



**Figure 4:** WELD Crawler

The basic scanner kit allows the two-sided inspection of circumferential welds from 2.5 NPS and up, and for thicknesses up to 2 inches. Its compact design allows the use of the WELD Crawler in clearances as low as 2¼ inches, which increases its range of application. The adjustable tensioning system of the 4 probe holders insures adequate coupling to the inspection surface in all conditions.

For thicknesses larger than 2 inches, the TOFD inspection is usually performed in more than one zone. Therefore, when used simultaneously with PAUT, more than 4 probe holders are required. Also, larger PCS values are required to cover the bottom of the volume of interest. Optional extension kits are available to extend the range of applicability of the WELD Crawler for thicknesses up to 6 inches.

When axial welds need to be inspected, the WELD Crawler can be converted in less than 90 seconds, using an optional mechanical part. In its axial configuration, the scanner allows the inspection of longitudinal seam welds for pipe of 6 NPS and up.

## COMPLETE INTEGRATION

The different components of Zetec's weld inspection solution are all exceptional on their own. However, the full potential of the solution resides in the way these individual components interact together.

In order to connect the 2 PAUT probes to the TOPAZ<sup>32</sup>, a splitter box is required (Figure 5). Instead of providing a cumbersome cable extension coupled with an adapter box, Zetec has designed an elegant splitter box which latches directly at the back of the TOPAZ<sup>32</sup>. When connected to the PA connector, the splitter box offers a multi-probe dialog; UltraVision Touch will recognize the two probes attached to the splitter box, including their serial number, and will automatically configure the probe parameters. Also, during the calibration process, the serial number of the probes will be saved with the calibration results and will be verified before the start of the inspection. For weld configurations requiring more than two TOFD groups, the splitter box allows connecting 4 extra conventional UT probes through the PA connector (on channels 63, 64, 127 & 128).



**Figure 5:** Splitter Box

When connected to the TOPAZ<sup>32</sup>, the WELD Crawler is also automatically recognized by UltraVision Touch. The resolution of the encoder is therefore automatically set to the right value. Moreover, when equipped with the optional battery-powered motorization & irrigation kit (Figure 6), the WELD Crawler can be fully controlled through UltraVision Touch: the inspection sequence can be started and stopped, and the scanner can be realigned to compensate a potential drift directly from the TOPAZ<sup>32</sup> screen.





**Figure 6:** Complete Weld Solution with Motorization & Irrigation Kit

The optional vision kit allows attaching USB cameras and a laser alignment guide to the WELD Crawler (Figure 7). The cameras can be used to monitor the coupling of the wedges on the inspected part and the drifting of the scanner from the weld center-line (WCL). The image of the cameras can be displayed on the TOPAZ<sup>32</sup> screen during the data acquisition and saved with the ultrasonic data. During data analysis, it is possible to look back at the probe position and to visually verify coupling conditions at any point of the scan.



**Figure 7:** WELD Crawler's Vision Kit

Finally, to further simplify the setup creation, a tool in UltraVision Touch allows an inspection supervisor to program a set of basic rules that will be used to propose a specific setup from a simple specimen definition. Depending on the specimen thickness, weld profile, heat-affected zone definition, sound

velocity in the material, etc., UltraVision Touch will propose the use of PAUT and TOFD search units, automatically calculate the position of these search units from the WCL to achieve the required volume coverage, set the time base of every groups and apply an appropriate display setup complying to the inspection supervisor rules by the click of a button. Using the integrated ruler on the WELD Crawler, the software will indicate the required position of the probe holders. This proposed setup can then be used by the operator as an appropriate starting point for the finalization of the inspection setup.

## CONCLUSIONS

From the work presented in this paper, the following conclusions can be drawn:

1. The simultaneous use of PAUT and TOFD is a very powerful inspection solution for welded joints, but several challenges need to be overcome:
  - a. The specifics of each technique require different hardware & software specifications;
  - b. Operators need a considerable amount of training for both techniques to be able to properly setup an inspection using PAUT and TOFD;
  - c. Scanners and accessories need to be flexible enough to be used on a wide range of pipe ODs and thicknesses.
2. In an effort to overcome these challenges, Zetec has put together a simple, efficient & evolutionary solution based on an advanced portable PAUT and TOFD system, innovative embedded software and a modular scanner.

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